Systems Engineering Concept®

OUTLINE

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Preface

System-oriented design is one of the best ways to achieve radical improvements in any company.

We believe that a system-oriented mindset is the key to effective high-quality design. This means that any technical design can be treated as a system and supported by well-known principles for systems engineering and management. Achieving this mindset is dependent on having a **common language** across management and technical disciplines; a language that creates an unambiguous understanding of the system design from idea to operation. This is what the Systems Engineering Concept (SEC) provides.

We know that the world is not ideal at all. SEC described in this manual is designed to handle non-perfect scenarios in any design discipline by three means: (1) Capturing of non-perfect requirements in system breakdown structures. (2) Incremental development loops in a spiral model to gradually mature the system design and integration, with continuous system integration, stakeholder validation and design review. (3) A stepwise and controlled accumulation of documentation based on incremental loops in the spiral model. This ensures that only documents which are currently suitable for a given system at a given time of development, needs to be made.

SEC is based on selected international systems engineering principles combined with methods from ISO & IEC standards and European norms of which we are recognized experts. This mix enables your organization to cooperate based on high-quality information throughout the system life cycle, making it possible to ensure on-time delivery of projects within the budget, and with quality under absolute control.

Legal statement

This document describes

Systems Engineering Concept®

which is developed by and a registered trademark of Systems Engineering A/S.

The Systems Engineering Concept is covered by legal rights as defined in the license agreement between the licensee and Systems Engineering A/S.

SEC consists of three elements, a process and two specific methods for working in this process and creating documentation as output. Furthermore, tools to be used in support of the methods are provided.

General systems engineering terms are adopted from the ISO/IEC/IEEE 15288:2015 standard and the INCOSE systems engineering handbook 4th edition 2015.

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1 Introduction

SEC is a concept for development of technical systems of any kind that ensures a gradual maturing of the system requirements and its design, with continuous stakeholder involvement and system integration checks.

SEC is based on four core beliefs:

- **Requirements:** Requirements are never perfect at the onset of a project and they must be matured just like the system design.
- **Stakeholders:** Stakeholders must be involved throughout the entire development process. Their input on requirements and system design are crucial for delivery of the right system design in an agile manner.
- **Documentation:** System documentation reflects the level of available design information for a system; it must therefore be gradually developed as the available design information increases.
- **System integration:** System integration starts at the beginning of a project, not at the end when systems are finally integrated. Successful system integration requires systematic focus throughout the development.

When applied correctly, SEC provides a **common language** among managers, technical engineers and designers in a wide range of industries. SEC process including the SEC methods are the mechanisms that provide full control of any complexity.

The result of using SEC is therefore a proven significant positive impact on time consumption, cost and quality.

Figure 1 – Positive impact on time, cost and quality

2 The Systems Engineering Concept in Short

SEC consist of three elements, which are used to make agile and safe incremental steps in the development of any system with continuous verification and validation of requirements and system design, see Figure 2. The three elements are:

- A method for systematic **requirement capture**
- A **development process** that ensures gradual maturing of requirements, system design and information
- A method for structuring and gradual development of **information**

Figure 2 - The three SEC elements

2.1 Requirements Capture

The basis for all system design is the requirements for the system. Simply put, the designers need to know what to build to be able to design and build it, which is what the requirements define.

Figure 3 – Illustration of requirements

In an ideal world, requirements would always be concrete, complete and consistent, however in the real world this is rarely the case, and designers struggle to handle immature requirements and deliver a successful design. In fact, it is more often the rule that requirements are *ambiguous, inconsistent, incomplete, multiple, unfeasible, unverifiable* etc. SEC therefore presumes that requirements are not perfect, and that development projects must be able to handle imperfect requirements.

To address this challenge, SEC is designed to capture these imperfect requirements and gradually mature these through design loops in the development process to be usable requirements, that makes sense to the designer of a system.

Note: SEC concept naturally also captures perfect and well specified requirements.
However, this it is not a necessity for using SEC.

Requirements are captured through a systematic search by the design team and allocated to appropriate elements of the system, using a system breakdown structure. In SEC this structure is also known as *the system structure*, which in fact consists of up to four different structures, and it is a key element in the description of the system architecture. The system structure can be thought of as a fishing net to capture the requirements, see Figure 4.

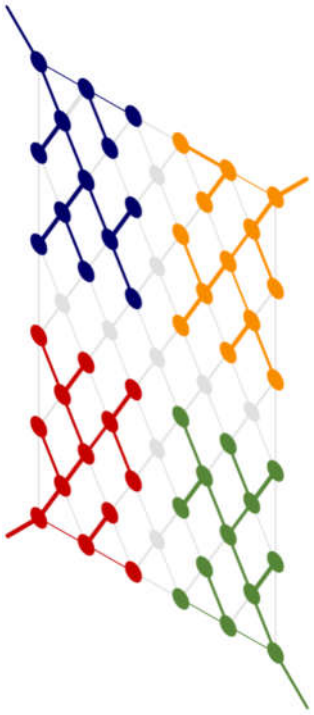


Figure 4 – Illustration of the system structure net

The system structure is a vital part of the description of the system architecture and reflects different aspects of the system design in accordance with ISO/IEC 81346-1. The four fundamental aspects of any system design are:

- The Functional aspect (functional view)
- The Module aspect (physical view)
- The Type aspect (type / family view)
- The Location aspect (spatial view)

Within each structure, systems and their elements are arranged by compositional relations in hierarchical structures, which is how complex system design can be controlled.

At least one structure, covering one design aspect, is needed for requirements capture, however multiple structures based on the four different aspects may be used depending on the project specific needs and kind of design to be developed.

By allocating requirements to elements of the structures, the design team achieves complete overview and control of the design requirements for the system they are developing.

2.2 Development process

In SEC, the system development follows an incremental process based on a spiral model, that supports gradual development with continuous integration checks and stakeholder feedback, see Figure 5. In each loop of the spiral the methods in SEC enables the designers to make an agile and controlled development of the design, as both the requirements and design are matured.

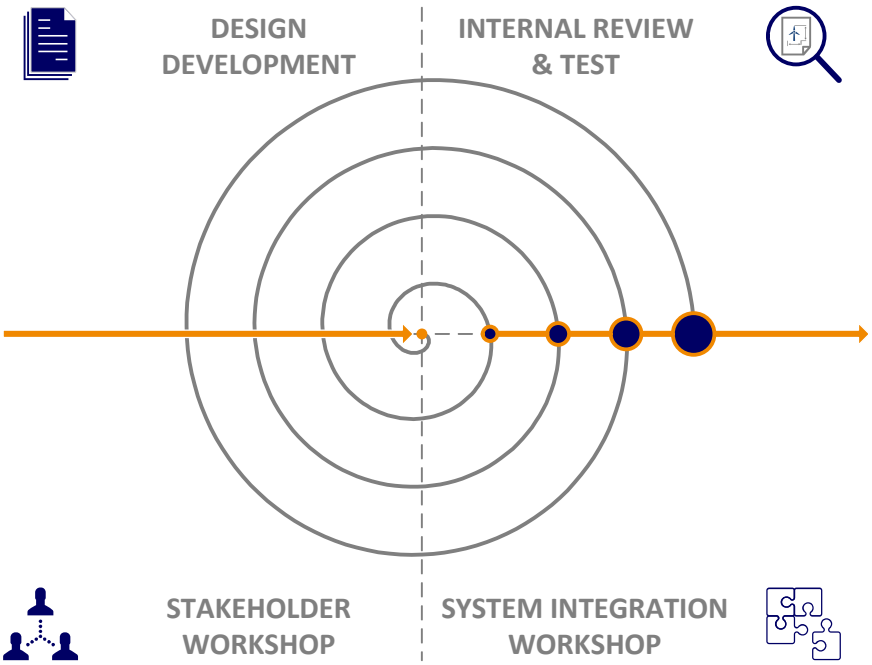


Figure 5 – The spiral model used to incremental development of designs

With each loop in the spiral the maturity of the system design is raised to a new level, and subsequently the design information is also increased. The level of design maturity is defined by the type and amount of available design information and is therefore known as the *Level of Information (LOI)*.

SEC defines seven such levels and specifies the kind of documentation that shall exist at each level. This means that up to seven loops can be performed, which will take a system design from initial idea to a design ready for production. It should be noted that most development projects start with a system design at LOI 3 and ends at LOI 6 or LOI 7, since it is rare for projects to start from a blank slate.

The development process is initiated with an initial capture of requirements and early description of the system architecture, indicated by the arrow to the centre of the spiral. Both the requirements and the architecture are then matured through the four activities of the development process.

The four activities are:

Activity 1: The system integration workshop(s).

Activity 2: The stakeholder workshop(s).

Activity 3: The design development to the next LOI.

Activity 4: The Internal review(s) and test(s) before release of next LOI.

From each loop and execution of the activities, an update of existing documents plus new documents forms the new set of documents, which is produced for the corresponding LOI, indicated by the arrow exiting the spiral. This set of documents then becomes the baseline for the next loop in the spiral.

2.3 Information

Information, for example in the form of documentation, follows in SEC a very structured development path, which ensures that unnecessary information is not produced too early, and that the task of documenting the system design is accomplished gradually when information is produced and needed.

SEC also specifies the use of structuring principles for documentation that follows the system structure in accordance with IEC 62023. Among other things, this allows for easier documentation update and minimizes the effect on documentation from design changes.

In SEC, each incremental loop in the spiral model results in a certain amount of documentation being produced corresponding to the LOI of any given subsystem, see Figure 6.

Figure 6 – Information / documentation as per Level of Information (LOI)

Documentation of relevant system designs are very limited in the early loops. At the final loop, the documentation is complete and therefore also often quite voluminous.

Certain documents are born at an early LOI, and are reviewed and maintained throughout all loops, whereas other documents are added successively as they make sense as the detailing level increases. A few documents are used at one LOI only, and then withdrawn.

In SEC the documents, their content, their structure and their classification are based on ISO and IEC standards. Therefore, at each LOI, a well-defined list of documents can be provided to serve as a part of a legal agreement among the parties of a project.

3 Tailoring SEC

The main purpose of tailoring SEC is to adapt SEC to the organisation and not vice versa.

SEC is designed so that is can be tailored to meet and support existing processes within the licensee company. SEC will support and strengthen existing project management processes and organisational arrangements with practical hand-on methods in execution of design development, without conflicting instructions.

The tailoring can take place at two levels:

Organisational level
At the organisational level, the tailoring adapts SEC to the organisational processes to meet the needs of the organisation and to fit SEC to the organisational context in which it will be applied.

Project level
At the project level, the tailoring adapts the organisational processes to the unique needs of a project. The need for tailoring to individual projects should be considered at the beginning of the projects but is not a requirement.

The tailoring will be based on an initial analyse and/or input from the organisation regarding the needs that SEC will address and the existing organisational processes. This may include:

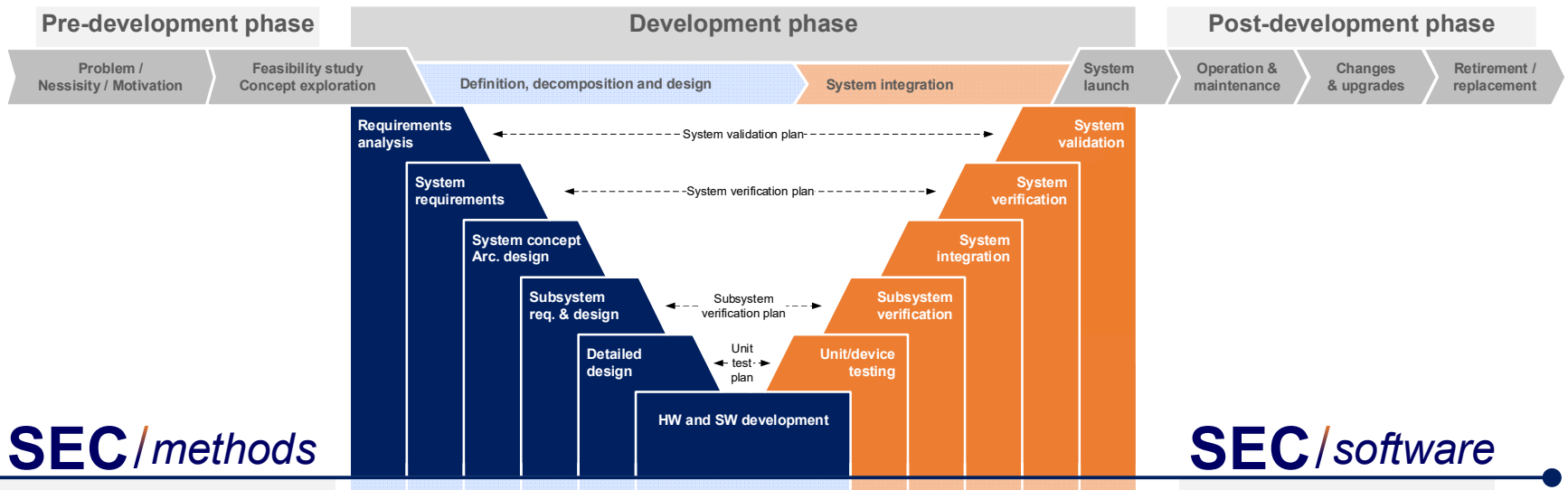
- Organisational strategic plans
- System life cycle models
- Project management models (e.g. PRINCE2®, PMI, IPMA, ISO 21500)
- Stakeholder interviews & surveys

4 SEC and the V-model

The V-model is essential basis for all disciplines of systems engineering. The V-model is generally accepted and recognised and a model for executing systems engineering. However, the general training of systems engineers does not provide practical instructions of how and what to do in real life.

SEC is a practical response to that question. On the next page we show how all elements of the SEC/*methods* corresponds with the general V-model as well as how the SEC/*software* supports this.

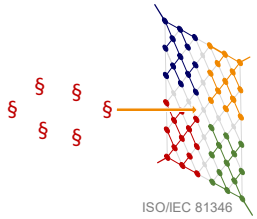
V-model & SEC – Systems Engineering Concept



SEC/methods

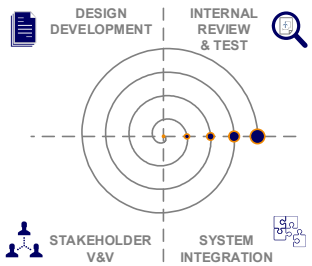
SEC/software

Requirements capture



- Requirements capture
- System libraries
- System descriptions

Development process



- System integration
- Stakeholder V&V
- Design development
- Internal review and tests

Information

- Level of information
- System information