



WHITE PAPER

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The Systems Engineering Concept[®] provides practical hands-on methods and tools, that enable companies to meet today's global business challenges through a systematic approach to development of system design.

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Systems Engineering A/S

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1 Executive summary

Most companies today face classic challenges like growing competition, growth in complexity, short time to respond to market needs, lack of necessary and competent resources, requests for cost reduction and a constant search for optimizations etc.

This white paper introduces systems engineering as defined in ISO 15288 as a possible response to these challenges.

The benefits of using systems engineering in general is documented by means of a survey conducted by Carnegie Mellon University, which demonstrates that projects with high systems engineering capabilities are much more likely to be high performing in terms of satisfying the time schedule, budget and technical requirements of the project.

This improvement in project performance does not mean that systems engineering fixes all problems, but tailored correctly to the needs, it has proven to have a positive impact on the requested improvements.

Systems engineering includes a range of different processes defined by ISO 15288, which you can run depending on the requested needs. But ISO 15288 does not provide specific instructions for the execution of these, and very often systems engineering will be performed by specialists responsible for systems engineering activities as an add-on to other project activities, rather as an integral part of the daily life of designers and engineers.

This white paper introduces a concept for systems engineering, The Systems Engineering Concept® (SEC), which can be used by all project participants and not just

specialists. The SEC is a practical and hands-on concept based on systems engineering principles, but put together in a unique way and combined with practical know-how and other relevant processes.

The SEC is focused on handling requirements in a non-perfect world, developing the system maturity in seven well defined steps, systematic stakeholder involvement and system integration between the design of hardware and/or software in an agile manner. The SEC also ensures that the amount of documentation is aligned with the system maturity level at any given time, to ensure that only the necessary documentation is available at all times and no unnecessary documentation or information is produced.

The output from the SEC process is a system design that is guaranteed to meet the stakeholder requirements with the necessary quality.

By following the SEC, companies can achieve significant improvements in their project performance as demonstrated by a client example from Systems Engineering A/S. The SEC not only drastically reduces expended project hours, but also ensures that projects are always guaranteed to be delivered on time.

Implementing the SEC is something that ultimately impacts the entire organisation. Therefore, it will require a senior management decision to implement SEC in an organization, as it will respond to strategic goals of the organization. A certain level of change management will be a natural part of the implementation, which should start with a pilot project, as projects often are the means to accomplish strategic goals.

2 Business Challenges

Most companies today are faced with growing competition, increased market demands, and a dynamic drive for change in their products, organisations and ways of working.

It has never been easier for customers to take their business elsewhere, and so to remain competitive, companies must be able to consistently deliver high quality products on time and on budget or risk permanently alienating customers.

This puts pressure on companies to navigate a set of challenges when developing products and systems, that are only growing in complexity and size.

Organisational changes

Today, many business organisations are distributed around the world and continually undergoing change, in the form of mergers, re-organisations and outsourcing.

The effects of this are felt especially in development organisations which are increasingly working in unknown territory without a fundamental common approach to system development that is shared by all stakeholders involved and not disturbed by the everchanging organisation.

Resource performance

Development organisations must contend with limited resources because of both financial restrictions and competition for qualified employees. The challenge in this case is how to get consistent, high quality work out of all employees in the development organisation, and respond to the business challenges with the available resources.

Technical excellence

The complexity of products typically grows with each new generation, making it increasingly difficult to manage the development process and ensure that the final design does indeed comply with the requirements and needs of the customer.

Development projects must often deal with requirements that are unclear, unknown and dynamic, which leads to a demand for agility in the development process of both hardware, software and the integration between these.

The lack of system integration is a consistent source of errors and quality problems, that plague projects where system integration is neglected or left until the end of development. This challenge only grows as the system complexity increases.

Documentation can end up taking precedence over getting the system design right, or is left until the end of the development project, where it requires a frantic effort to complete before the project is finished.

Response to challenges

What is needed to address these challenges is first and foremost a shared foundation for the development and control of the technical design that all parties involved are familiar with. Like a common language spoken by the organization that allows them to work together efficiently and respond to any challenge.

This common language is fundamental to collaboration among all stakeholders and communication across technical disciplines.



3 Enterprise Governance

Collaboration in any company is dependent on good enterprise governance which lays the foundation for all the activities of the company.

Enterprise governance is *“the set of responsibilities and practices exercised by the board and executive management with the goal of providing strategic direction, ensuring that objectives are achieved, ascertaining that risks are managed appropriately and verifying that the organisation’s resources are used responsibly”* (Information Systems Audit and Control Foundation, 2001).

Working with enterprise governance is ultimately a balancing act between conformance and performance, and it is up to the company’s management to institute processes that support both.

Conformance processes, or “corporate governance”, deals with how the company is controlled and directed. It is important in the operation of the company and is key in ensuring accountability, but it does not in itself lead to success.

The performance dimension is ultimately what leads to value creation, and yet it is often conformance that gains the most attention. This is perhaps because the performance dimension is more difficult to deal with. In this, you are often very dependent on the skill of employees, and there are not always sufficient tools and

methods in place to support the value adding activities of the organisation. If the organisation was a racing team, you could say that they may be following the rules and making it across the finish line, but the team isn’t winning any races and the car breaks down too often.

In regards to the development of systems, management often tries to ensure good performance by instituting formal project management processes, in the perception that this will lead to high performing projects.

But, while good project management may solve many challenges in project execution, it is no guarantee for good technical results. Procedures for planning, budgeting and reporting may be in place, but achieving good results in development projects is ultimately dependent on how well the project team can manage the technical task of developing a system.

To achieve high performance projects, something must be added to traditional project management processes to ensure that the technical task of developing a system is performed to a high level of excellence, and with much greater chance of success.

Systems engineering is a discipline that can do exactly that. It deals with the technical aspect of system development and provides a fundamental approach to system development that goes hand in hand with project management.



4 Systems Engineering (SE) – A Common Language

Traditional project management disciplines exemplified by IPMA, PMI, PRINCE2® and ISO 21500, are good at organising and coordinating the execution of projects. However, they fall short as far as the technical design is concerned. This is because they deal with the mechanism of executing a project, and not with the technical tasks related to system development.

What is needed for successful development of systems is an approach that can supplement traditional project management with principles for engineering of technical systems. Systems engineering, defined in ISO 15288, is an internationally recognised approach and discipline that offers exactly that.

Systems Engineering

Systems engineering is an interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, and then proceeding with design synthesis and system validation while considering the full system life cycle.

Systems engineering integrates all the disciplines and specialty groups into a team effort forming a structured development process that proceeds from concept to production to operation. Systems engineering considers both the business and the technical needs of all customers with the goal of providing a quality product that meets customer needs [1].

Systems engineering offers greater control and awareness of the project requirements, interfaces, and issues and the consequences of any changes.

Key aspects

Systems engineering can be described as “big picture thinking and the application of common sense to projects.” through “a structured and auditable approach to identifying requirements, managing interfaces and controlling risks throughout the project lifecycle” [2].

There are two main objectives of the systems engineering processes. 1) To build the right system, and 2) to build the system right.

This means that systems engineering both addresses the task of designing the system as specified and ensuring that the system truly fulfils the customer needs.

To do this, systems engineering employs a range of different processes you can run, which are defined in ISO 15288. These processes are tailored to the specific need of the company and the environment in which they are run.

Applying Systems Engineering

To successfully apply systems engineering in an organisation, an easy understandable hands-on approach to systems engineering is needed.

This approach must be based on a fundamental systems engineering model that supplements traditional project management disciplines with hands-on instructions for execution. Systems Engineering A/S has developed a concept for this approach to systems engineering, that can form a common language for development spoken by all relevant stakeholders.

*Build the system right
&
Build the right system*

5 Systems Engineering Effectiveness

Systems engineering is no miracle cure for all that ails an organisation, but it offers significant positive impact to many areas of the organisation's work when developing new systems.

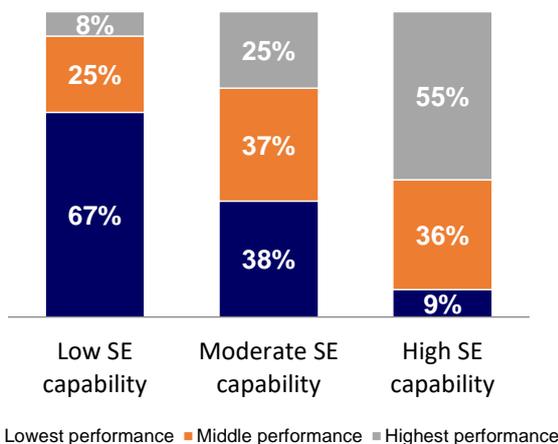
A study of projects across multiple companies conducted by Carnegie Mellon University [3] has shown conclusively that projects whose participants have good systems engineering capabilities, are much more likely to also deliver high performance.

The projects were divided into three tiers based on their level of systems engineering capability within the following core systems engineering subjects:

- Requirements development and management
- Project planning
- Product architecture
- Trade studies
- Product integration
- Verification
- Validation
- Project monitoring and control
- Risk management
- Configuration management
- Integrated product team based capability

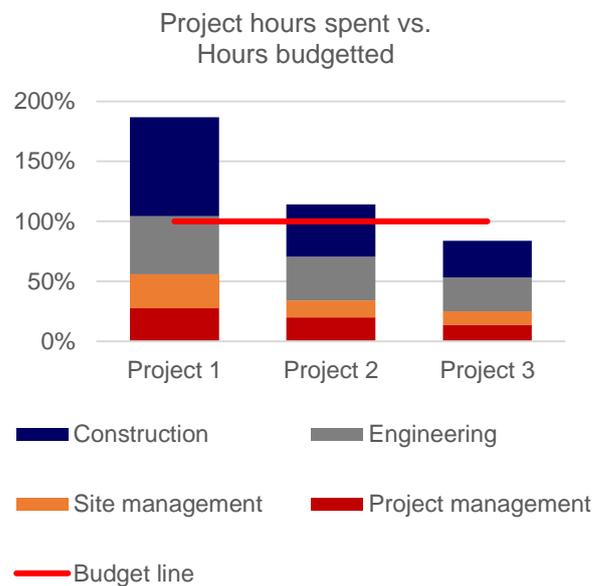
Within each tier the projects were then scored on Budget satisfaction, Schedule satisfaction and Technical requirement satisfaction, to see if they achieved low, moderate or high performance.

As can be seen from the statistics below, the percentage of projects with *High SE capability* that achieve the highest project performance is 55% compared to just 8% for projects with *Low SE capability*. This means that projects that show a high SE capability are much more likely to yield good performance, and much less likely to fail.



This effect can be seen in the performance metrics from real life projects. The figure below is from a company which is active in Engineering, Procurement and Commissioning (EPC) of large scale multimillion Euro projects, and the effect is drastic. From the initial introduction of systems engineering in Project 1, where the organisation's SE capabilities were limited, project performance was unsatisfactory.

As seen in the figure, the first project using SE showed an overrun of project hours of 87%. Two projects later after a rapid improvement in the organisations SE capabilities, the overrun had been transformed into a saving in project hours of 16%.



The effectiveness of using systems engineering on the total project portfolio can be drastic, but it is dependent on having a strong concept for applying systems engineering within the company across the organisation.

The Systems Engineering Concept® (SEC) developed by Systems Engineering A/S is a hands-on approach that can be learned by all project participants.

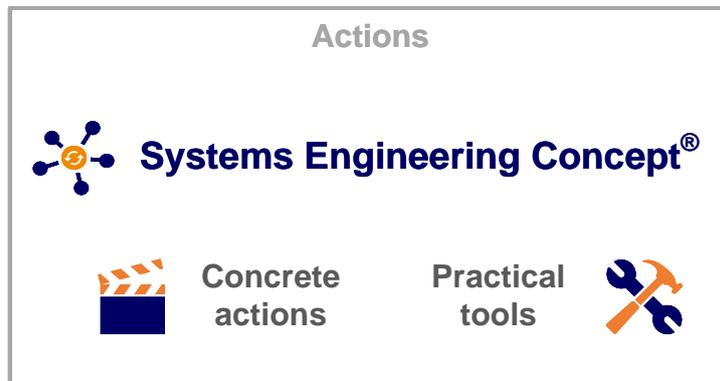
6 The Systems Engineering Concept® (SEC)

The systems engineering processes defined in ISO 15288 do not include practical instructions on how to execute the SE processes in real life. Based on daily needs, The Systems Engineering Concept® (SEC) combines practical experience and technical know-how with a systematic and practical approach to make the systems engineering discipline an integral part of the day to day work of the organisation.

The SEC is a concept which in details describes the systematic methods for development of technical

systems of any kind. It ensures a gradual maturing of the system requirements and system design, with continuous stakeholder involvement and system integration checks. The output is a thoroughly verified and validated system design that is documented in a stepwise manner as the design progresses.

With the SEC, an organisation obtains both concrete actions and practical tools that enable any company to handle the complex business challenges of today.



Business challenge	How the SEC addresses those needs
Requirements management	<p>The SEC is based on a fundamental presumption that requirements are rarely perfect, and that development projects must be able to mature the requirements, just as they would with the system design.</p> <p>The SEC captures requirements of any kind, e.g. hidden, unspoken, poorly defined, well defined and perfectly written, in a systematic maturing process where they are verified and validated. This ensures that all requirements are properly handled and allocated, and that they are fit for purpose.</p> <p>System designers use this element of SEC as the basis for their work, and project managers use it to monitor the performance of the design team, change management and perform the QA system delivery verification.</p>

Business challenge	How the SEC addresses those needs
System integration	<p>In the SEC system integration begins at the start of a project and continues throughout the entire development. A systematic series of system integration workshops during the development phase ensures smooth integration of the design in the production phase.</p> <p>This contrasts with other methods that either leave system integration to the end of the project, when the system is assembled, or lets individual engineers determine the level of system integration effort throughout the development project, with potential catastrophic results.</p> <p>System designers uses this element of SEC to clarify dependencies to other systems (inputs and outputs) and project managers use it to monitor the progress of integration and communication within the design team and external stakeholders.</p>

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Business challenge	How the SEC addresses those needs
Stakeholder involvement	<p>The SEC sees stakeholder involvement as crucial to a successful project outcome and efficient execution of the project itself. For this reason the SEC follows a stepwise maturing of the system and involves stakeholders throughout the project.</p> <p>Through a series of project loops, both requirements and system design are subjected to stakeholder review. Each loop in the SEC spiral takes the system design to a new level of design maturity, known as a Level of Information.</p> <p>By following a gradual design and involving the stakeholders in each loop, the project team can more easily pick up requests for changes and/or opportunities for optimising the system design, thereby giving the project a whole new level of agility.</p>

Business challenge	How the SEC addresses those needs
Resource performance	<p>The SEC is a concept, i.e. it is the common model for the general principles of how to perform the design work. As the concept is designed to be hands-on and very practical for daily use, the project team and project managers will establish a common language that is easy to understand and use.</p> <p>When employees are trained in the concept, typically after one project, they “speak the common language” and can be moved in and out of other projects conducted by the SEC as requested.</p> <p>In general systems engineering brings the best out of most engineers, and the SEC accelerates this by means of detailed and practical methods designed for daily use for all designers and project managers.</p>

Business challenge	How the SEC addresses those needs
Documentation	<p>The SEC sees documentation as something that is produced to communicate with stakeholders. It must therefore be produced only when needed, and address parts of a system that is of interest to a stakeholder.</p> <p>The SEC structures documentation to fit the system design following international standards, and it ensures that documents are only produced when needed for a particular design stage following the Levels of Information, that represent design maturity.</p> <p>The approach to documentation that is implemented by the SEC eliminates the classic problem of unnecessary and poorly structured documentation. It also reduces the effort needed to finalise the system documentation at the end of the project, by gradually developing the system documentation as needed.</p>

7 Getting Started

The decision to implement systems engineering as a discipline in an organization should always be a strategic management decision, as the implementation of SEC will provide the practical means of achieving strategic goals.

With support from the management, the SEC will quickly become the common language that unites designers and engineers.

The full implementation of SEC will typically follow a classic learning curve, i.e. a period of 1-2 years before it is fully implemented. To keep track of the progress it is important to identify key performance indicators which should be used to monitor the improvement.

Organisational change

Most engineers find the content of the SEC easy to adapt to their daily way of working, as it responds to classical challenges and supports existing project management models with practical ways of working. However, implementation of SEC will still require some kind of change in the organisation.

Depending on the culture in the organization, there may be a need for a slight push towards new ways of thinking, that are much more focused on the system as the driver for the work rather than a strict adherence to existing protocols and processes. This may vary from minor adjustments to radical changes. In both cases

management support and a clear strategic vision is recommended.

Pilot project

The best way to start of the implementation of The Systems Engineering Concept® is through a real development project, that can serve to test and demonstrate the SEC's effectiveness under real world conditions. This will also serve as the basis for integrating the SEC into the company's processes, and making any necessary adjustments of SEC to existing company culture.

It is recommended that this project should be sufficiently complex to fully demonstrate the full potential of the SEC, and that it should involve collaboration between several stakeholders in the organisation to show how systems engineering can serve as the common language for the entire organisation.

By following this advice, the organisation gets to immediately see the strength of the concept, and it quickly goes from strategic plans to reality.



8 About Systems Engineering A/S

ABOUT US

Systems Engineering A/S is an independent consulting firm that specializes in the implementation and application of Systems Engineering for private and public clients handling complex systems.

OUR MISSION

We believe that a common language across technical disciplines is necessary; a language that creates an unambiguous understanding of the system design from idea to operation among all stakeholders.

OUR CONCEPT

We create this common language by use of the accepted principles of systems engineering in accordance with international standards and European norms. In our Systems Engineering Concept® (SEC), all disciplines involved with the technical design rely on a shared system-oriented mindset.



It's all about creating a common language™ is a registered trade mark of System Engineering A/S

9 Bibliography

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