“We are too small for (MB)SE!?”

Systems engineering in comparison between corporate groups and SMEs

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INTIS

What INTIS does

- Charging technology for electro mobility and micro-mobility
  - Contactless charging technology (inductive)
  - Conductive charging technology (DC fast charging)
  - For public and industrial applications
- Modular integrated energy solutions
  - With battery storage system and energy management
  - Grid-operated or stand-alone grids (decentralized energy supply)
  - Control energy, peak shaving, power factor correction, etc.
  - Battery storage-supported charging of electric vehicles

Driving inductive charging innovation INTIS

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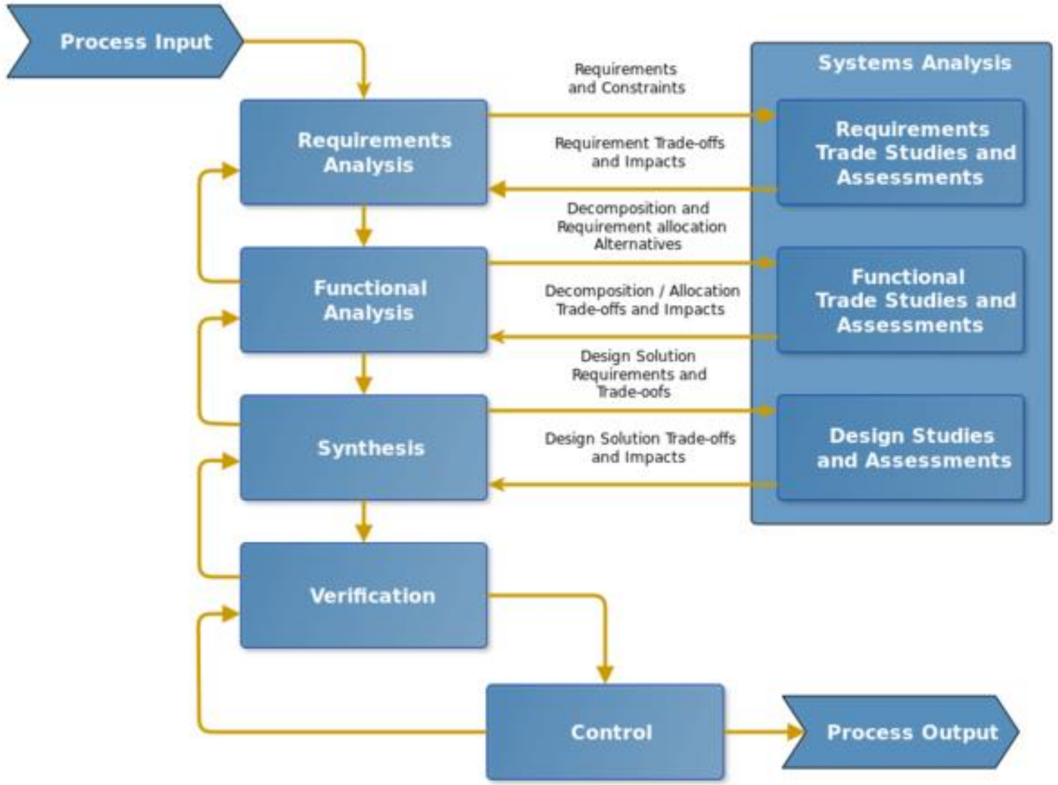
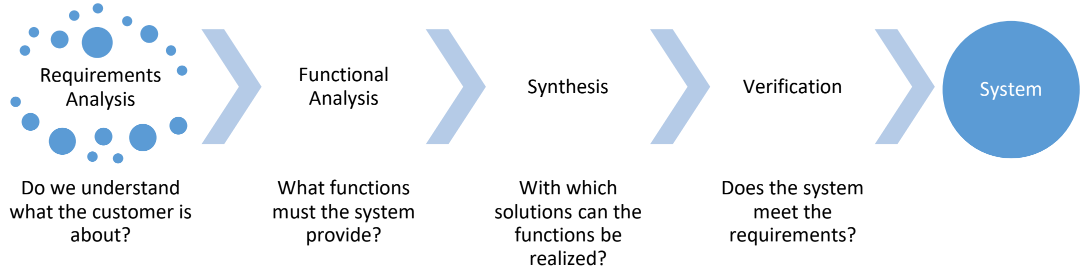
Back to the roots or what Systems Engineering is all about

IEEE-1220 Process Model



or in simple words



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We are too small for (MB)SE!?

Statements

I. Systems Engineering is a process model for PLC (Physically Large and Complex) projects.

II. The application of systems engineering leads to a strong formalization of development and is opposed to an agile approach.

III. Parallel to the formalization, systems engineering leads to a significant increase in project documentation.

Questions

- But is that really the case?
- Under what conditions is systems engineering applied in a corporate group and what does the implementation mean for a small or medium size company?

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Large versus small Projects

Large project

- Type: Naval Vessel
- Project volume : > 1 Billion Euro
- Runtime: 6 years
- 150 team members from 9 nations at 11 locations spread over 3 continents
- Input information :
  - Requirements : > 10.000
  - Performance description (scope of work) for the offer
- Scope of delivery
  - 3 vessels
  - In-Service Support (worldwide)

Small project

- Type: Inductive charging for Taxi lanes
- Project volume : < 1 Million Euro
- Runtime : 2 years
- 7 team members spread over two locations in Germany
- Input information:
  - Requirements: < 200
  - No performance description (scope of work) for the offer
- Scope of delivery
  - 1 Inductive Charging System
  - 1 Locations

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Requirement Analysis in Comparison

Large project

- Analysis of customer requirements
  - 30 team members / 3 weeks
- Risk assessment
  - 5 team members / ongoing
- Refine system requirements
  - 20 team members / 2 months
  - Focus on: Breaking down complex requirements and by responsibilities
- Documentation
  - Analysis of requirements in a Systems Engineering tool
  - Report with 320 pages reporting evaluation result of each requirement

Small project

- Analysis of customer requirements
  - 2 team members / 1 day
- Stakeholder / use case identification
  - 4 team members / 4 days
- Definition of system requirements
  - 2 team members / 1 month
  - Focus on: Certification
- Documentation
  - Analysis of the requirements in the systems engineering tool
  - 1 Specification

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Speaking of Requirements – a Real World Example

Customer requirement

- If a hot water tap is opened on board the vessel,
  hot water shall flow after eight (8) seconds.

Question

- Is the requirement technically feasible?
- Does this requirement meet the quality characteristics demanded of it?

Functional analysis in Comparison

Large project

- Functional modeling of mission critical systems, e.g., the platform management system.
- Individual functional models can contain more than 10,000 functions and 15,000 signals per system
- Different responsibilities
  - (Prime contractor/Subcontractor) within the model
- Basis for reliability, quality of service and functional safety analyses
- Documentation (for one system)
  - 48 Customer documents
  - 74 Supplier documents

Small project

- Modeling of the entire system
- Functional model with ~200 functions
- No different responsibilities
- Basis for functional safety and security analyses
- Documentation
  - 1 System description

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Synthesis in Comparison

Large project

- System architecture with more than 600 system elements
- 70% of the system elements are third-party supplies
- Custom architecture models
- Interface management divided into
  - system to system and
  - system-ship
- 80 formal design reviews (PDR/CDR)
- Documentation
  - 30 system descriptions
  - ~ 400 interface specifications
  - ~600 review documents
  - …

Small project

- System architecture with 50 system elements
- 10% of the system elements are third-party deliveries
- No specifications for architecture models
- Interface management
- No formal design reviews
- Documentation
  - 1 system description
  - 2 interface specifications
  - …

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Verification in Comparison

Large project

- Multi-stage verification process
  - Factory-> Harbor-> Sea)
- System by approval by government agencies
- 600 Factory Acceptance Test
  - Partly with customer involvement, i.e., approval of the test specification by the customer -> lead time 10 months
- Multilingual test specifications
  - German, English, customer language
- Documentation
  - More than 600 test specifications and test reports
  - Verification matrix with more than 30,000-line items

Small project

- Internal QS
- CE-Certification (self-declaration)
- Safety assessment as part of the CE-Certification
  - Recertification of the vehicles at the TÜV
- Commissioning and instruction protocol
- Documentation
  - 1 Test reports

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Summary - We are too small for (MB)SE!?

Statement I

- Systems Engineering is a process model for physically large and complex (PLC) projects.

Lessons learned

- In many cases, physical size is equated with complexity.
- However, one of the main characteristics of these projects is the complexity of the interacting system elements, or the risks that arise from uncontrollable interactions or interactions that are difficult to predict.
- Compared to the naval project, the inductive charging project is a very small project, but with many stakeholders and uncertainties that determine its success or failure.
- If not with systems engineering, with which holistic approach and process model do you want to face the challenges in the projects.

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Summary - We are too small for (MB)SE!?

Statement II

- The application of systems engineering leads to a strong formalization of development and is opposed to an agile approach.

Lessons Learned

- Contractual obligations, such as payment milestones or insufficient financial resources for changes, are aggravating factors for an agile approach.
- Systems engineering requires formalization in terms of decision points (quality gates) based information at the expected level of maturity.
- Agility is mainly constrained by the interdependency of the development processes of the individual system elements rather than by the process itself.
- Contractual framework conditions, such as payment milestones or insufficient financial resources for changes, are aggravating factors.

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Summary - We are too small for (MB)SE!?

Statement III

- Parallel to the formalization, systems engineering leads to a significant increase in project documentation.

Lessons Learned

- The systems engineering process specifies only a few details regarding the depth of documentation and documentation content.
- The documentation effort is essentially driven by requirements in the contract and/or the approval regulations.
- Not to be neglected are the needs of the customer in complex procurement projects.
  - Here, the procurer is legally responsible for the correct technical implementation of the requirements.
  - The scope and content of the documentation must ensure such an evaluation by customers out of mutual interest.

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And what about our water tap?

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And what about our water tap?

Is the requirement a "true requirement"?

- No - The customer has specified a design solution!

What is the customer’s “true“ requirement?

- Where does hot water come from on board and where does it go?

  Fresh water generator ➞ Fresh water tank ➞ Boiler ➞ Water tap ➞ Wastewater tank ➞ Wastewater treatment

What is the real problem?

- The inadequately designed hot water system resulted in increased operating costs for electrical power generation on the existing units.
- The customer's goal, and thus the actual content of the requirement, was to reduce operating costs.

Summary - We are too small for (MB)SE!?

- Systems Engineering aims at high-quality products and services, with the correct people and performance features, at an affordable price, and on time and it is the responsibility of the organization to what extent it restricts, allows, or even requires customization to meet project requirements.

  *The enterprise… shall **plan, conduct, and manage a fully integrated technical effort** necessary to satisfy the general requirements of this document, as **tailored for the specific project**; IEEE-1220 4. General requirements*

- It is not the size of the company or project that is critical, but rather an understanding of the challenges posed by the system, system/project environment, or procurement regulations.
- The process is intended to steer the team members' thinking in the right direction, whereby the corporate culture must both support and demand this.

  Freely adopted from Socrates: *I know that I know a lot, but I also know nothing.*
  Genuine knowledge consists in the knowledge of knowing nothing.

- The organization, or to put it plainly, the **Team Members** shall **understand Systems Engineering as a Philosophy and Toolbox** and less as a process.

Thank you for your attention

The biggest advantage of not doing systems engineering is that failures will continue to take us completely by surprise and we won't have to worry about them months in advance.

UK Ministry of Defense 2009 Systems Engineering Handbook

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