Theory and Practice of Systems Engineering in Kongsberg Projects

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Abstract
The Systems Engineering Body of Knowledge provides many means to create products and to run project creating systems. We discuss the theory and reflect on experiences from practice, focusing on Kongsberg industry.
Figure Of Contents™

- SE theory in a nutshell
- some examples from Kongsberg
- SE revisited
  - CAFCR+
  - more examples from Kongsberg
- size considerations
- one more example from Kongsberg
- SE conclusions in a nutshell
- questions from Kongsberg?

start

finish
**Systems Engineering theory**

Follow phase model

needs > requirements > concepts > detailed design

SMART Requirements

Evaluate multiple concepts

Think "Functional", What versus How

**typical buzzwords**

stakeholders, concerns, life cycle,

risks, reviews, V-model
Phase Model for Development

0. feasibility
1. definition
2. system design
3. engineering
4. integration & test
5. field monitoring

reviews

tender execution deployment

requirement specification

working system
V-Model

needs

specification

system design

subsystem design

component design

component realization

validation

verification

system test

subsystem test

component test
The SMART acronym

<table>
<thead>
<tr>
<th>Specific</th>
<th>quantified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurable</td>
<td>verifiable</td>
</tr>
</tbody>
</table>

Assignable (Achievable, Attainable, Action oriented, Acceptable, Agreed-upon, Accountable)

Realistic (Relevant, Result-Oriented)

Time-related (Timely, Time-bound, Tangible, Traceable)

*variation of meaning*
### Concept Selection “Pugh” Matrix

<table>
<thead>
<tr>
<th></th>
<th>fuel cell</th>
<th>battery</th>
<th>generator</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>peak power</strong></td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td><strong>efficiency</strong></td>
<td>2</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td><strong>weight</strong></td>
<td>1</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td><strong>pollution</strong></td>
<td>5</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td><strong>infra structure needs</strong></td>
<td>1</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

- 12
- 18
- 17

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- March 6, 2013
- version: 0.1
- TPSEPconceptSelection
“Functional” Thinking; What and How

What

- sense position
- sense orientation
- sense speed

How

- GPS
- gyro
- DL2128V

- CAN master
- ARM CPU
- 8 12 bit DA

- 256MB DDR III
- 256MB NAND Flash

- control setpoints
- engine
- rudders

- determine trajectory

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TPSEPwhatAndHow
Examples from Kongsberg

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start

finish
Typical Tendering with Navy

- **Requirements from Customer**
- **Order**
- **Tender**
- **Project Execution**
- **Installation, Operation, and Maintenance**

**Bid Spec**
- **Must**
  - yes
  - yes
  - yes

- **Want**
  - yes
  - no
  - yes
  - no

**Updated Spec**
- **Spec Changes**
  - yes
  - yes'
  - no
  - no

- **Real Discussion after Order**
  - no
  - no
  - yes"
  - no

- **New Insights**
  - yes
  - yes'

- **Customer Understanding Required**

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KDAWSBidSpec
Rigor may Back Fire

Change proposal caused that multiple alarms could be visible at console for single signal

Change was introduced in the field.
Field change was required later to repair.
Latency of Introduction, Detection and Repair

how much customer credit has been lost?

change request
fine-grain prioritization

release

time

change request to repair
fine-grain prioritization

release repair

change request
fine-grain prioritization

release
SE revisited; CAFCR+ model

Start

SE theory in a nutshell

SE revisited CAFCR+

Some examples from Kongsberg

More examples from Kongsberg

Size considerations

One more example from Kongsberg

SE conclusions in a nutshell

Questions from Kongsberg?

Finish
CAFCR+ model

What does Customer need in Product and Why?

Customer
What

Customer
How

Product
What

Product
How

C - Customer objectives

A - Application

F - Functional

C - Conceptual

R - Realization

Life cycle
SE activities in CAFCR

Customer objectives

Application

Functional

Conceptual

Realization

value drivers

applications

functions

qualities

subsystems and components

multi-disciplinary engineering
Theory and Practice of Systems Engineering in Kongsberg Projects

SE revisited

understand customer and business (value) help to transform into specification multi-disciplinary design ensuring functionality and qualities

Customer objectives Application Functional Conceptual Realization

value drivers applications functions

qualities

subsystems and components

multi-disciplinary engineering

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TPSEPdefinitionSE
Continuous Iteration

**Customer objectives**
- ask needs
- reconstruct needs
- validate

**Application**
- why
- explore use cases
- use proto

**Functional**
- why
- draft spec
- spec
- verify

**Conceptual**
- why
- draft design
- design
- integrate

**Realization**
- get solution as answer
- explore solutions
- build proto
- build

and iterate and evolve further....
More Examples from Kongsberg

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start

finish
Dynamic Positioning

Independent DP joystick

Thruster control

Machinery automation and cargo control

Chart radar and conning display

Bridge auxiliaries

Designed for efficiency and safety

source:
http://www.km.kongsberg.com/ks/web/nokbg0240.nsf/AllWeb/F6D8ACE8F32AE306C12575C500323661?OpenDocument
Integration of Existing Products

Anchor Handling ship

K master

Anchor Handling

Dynamic Positioning
Automation
Navigation

training
documentation
Software Stack

projects

products

technology

Anchor Handling

Handling ship

systems

Anchor Handling

applications

DP

services

AIM

qualified and configured OS

computing hardware

AK

real-time control

Rbus

I/O
Understanding Stakeholder Needs

Work flow

Example of anchor placement

Geographical example of anchor placement
Example of System Quality: Configurability

emerging configurability:
multiple configuration utilities configuring similar data in different ways
Concept Selection Examples from Subsea

Workover Stack

- EDP
- LRP
- XT

concept for connection

two sided connectors

connectors in hub

connectors in hub with roll-off

wireless connection
Quality and Understanding Improves by Iteration

we learn by evaluating concepts; multiple iterations are needed
Size considerations

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Diagram:

- Start
- SE theory in a nutshell
- SE revisited
- CAFCR+
- Size considerations
- SE conclusions in a nutshell
- Questions from Kongsberg?
- Finish
Level of Abstraction Single System

- Static system definition
- Multidisciplinary design
- System requirements
- Monodisciplinary
From system to Product Family or Portfolio

system  →  portfolio

- system
- multidisciplinary
- monodisciplinary
- increase
- systems
- multidisciplinary
- monodisciplinary

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DRALpyramidGrowth
Product Family in Context

- $10^9$: enterprise context
- $10^6$: enterprise
- $10^3$: stakeholders
- $10^0$: systems
- $10^{-3}$: multidisciplinary design
- $10^{-6}$: parts, connections, lines of code

number of details
Frequently observed gaps

- Enterprise context gap
- Marketing gap
- Context gap
- Multi-disciplinary gap
- Systems
- Multidisciplinary
- Monodisciplinary
- Stakeholders
- Enterprise
- Number of details
Highly Successful Remote Weapon Station

Extreme fast growing business: Remote Weapon Station

* PROTECTOR Hellfire
* PROTECTOR Javelin
* PROTECTOR Lite
* PROTECTOR NM221
* Sea PROTECTOR
* PROTECTOR M151
* PROTECTOR CROWS
* PROTECTOR Training Systems

source:
Growth in many directions

- profit
- turnover
- customers
- systems in the field
Consequences of Growth

- employees
- configurations
- sites
- nationalities
- platforms
- weapons
- sensors
Conclusions Systems Engineering

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7. One more example from Kongsberg
8. SE conclusions in a nutshell
9. Questions from Kongsberg?
What I Hope that you will Remember

Know your stakeholders and their needs and concerns.

The specification must fit the needs.

Concepts and technology must be appropriate.

The system must fulfill all qualities.

And all of this has to happen in time.  

no analysis paralysis
This presentation is partially based on the master project work of:

Ola Gustav Kalager

Håvard Ruden

under supervision of Thor Hukkelås

and on research work within the Kongsberg Group

where many employees contributed thorough interviews or work shops.

One example is based on the master project of Dag Jostein Klever (FMC)
Questions from Kongsberg

SE theory in a nutshell

some examples from Kongsberg

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start

It is your turn!

finish