Embedding Systems Thinking

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Science and Operations Director

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ESI at a glance

Mission: *Embedding leading edge methodologies into the Dutch high-tech systems industry to cope with the ever increasing complexity of their products.*

Synopsis

- ❑ **Foundation ESI started in 2002**
- ❑ **ESI acquired by TNO per January 2013**
- ❑ **~55 staff members, many with extensive industrial experience**
- ❑ **5 Part-time Professors**
- ❑ **Working at industry locations**
- ❑ **From embedded systems innovation to embedding innovation**

Focus

Managing complexity of high-tech systems

through
- **system architecting,**
- **system reasoning and**
- **model-driven engineering**

delivering
- **methodologies validated in cutting-edge industrial practice**

Partner Board

ASML · ThermoFisher SCIENTIFIC · PHILIPS · nexperia · THALES · Canon · TNO · UNIVERSITY OF AMSTERDAM · TUDelft Delft University of Technology · Radboud University Nijmegen · UNIVERSITY OF TWENTE. · TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

An initiative of industry, academia and TNO

Mentimeter question 1

Engineering of complex systems has been done for ages

... and the Dutch were good at it ...

Anno 1612

Inpoldering van de Beemster
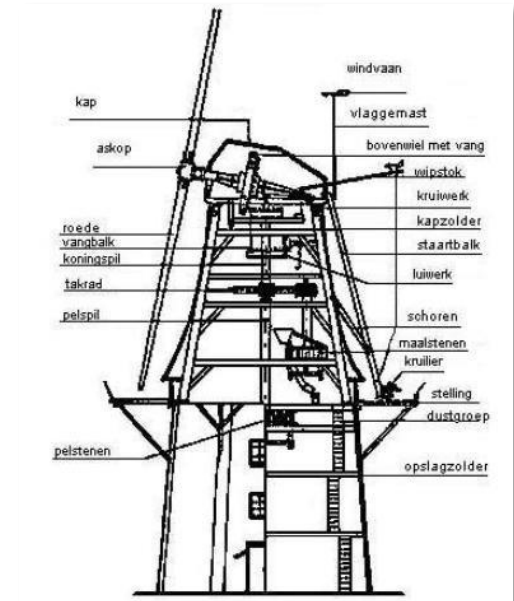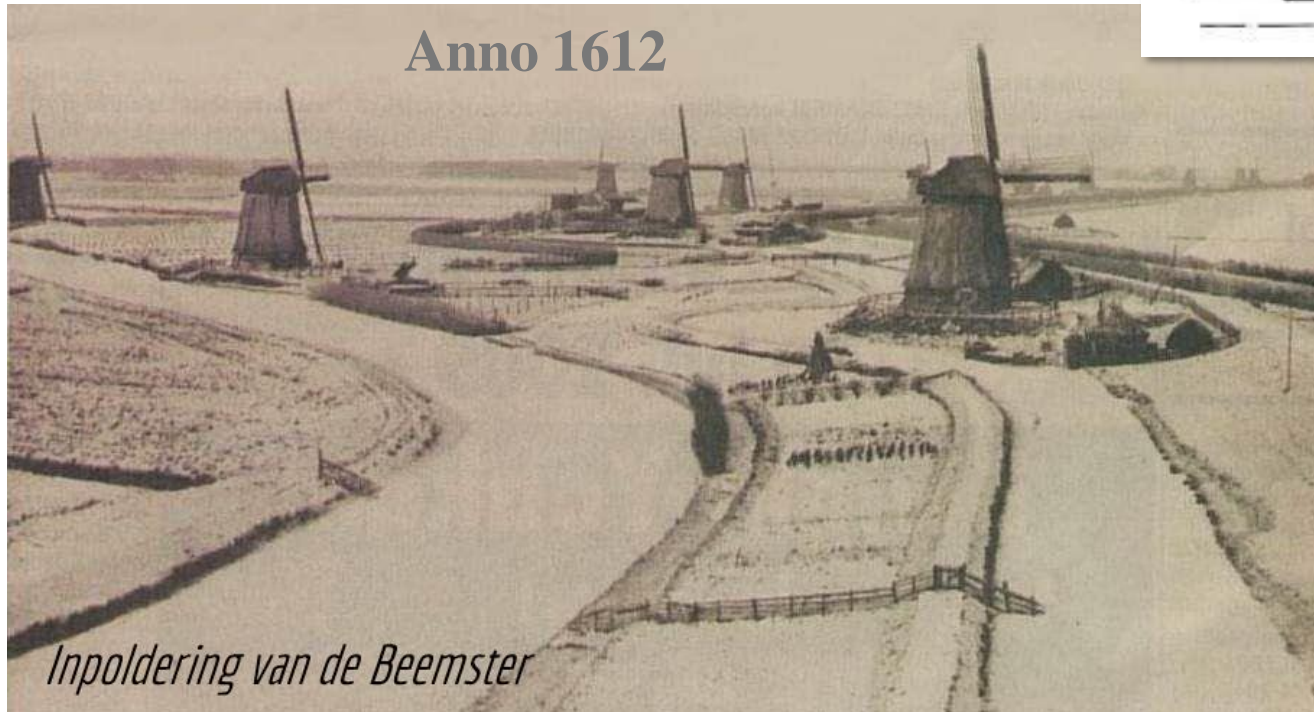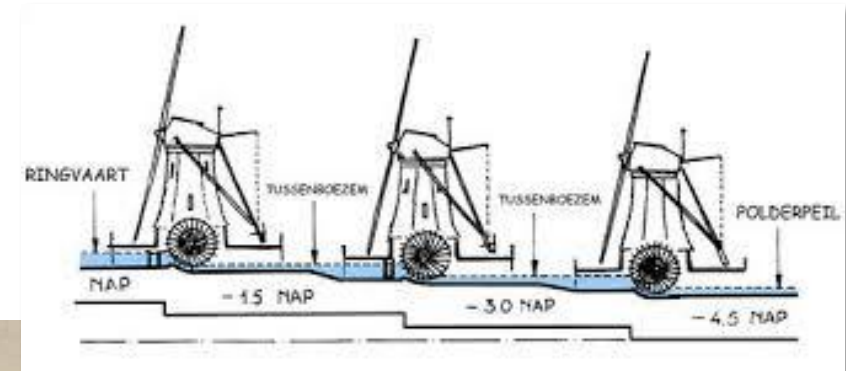
And still are …

Water works

Complex systems

And still are …

Agro food

Complex systems

And still are …

High Tech industry

Complex systems

#1

#1

#1

#1

#1

#1

ESI

Complex

the relationship between cause and effect can only be perceived in retrospect

robe – sense - respon

rgent pra

chaotic

Cynefin framework by Dave Snowden

Complicated

the relationship between cause and effect requires analysis or some other form of investigation and/or the application of expert knowledge

sense – analyze - respond

good practice

best practice

the relationship between cause and effect is obvious to all

sense – categorize - respond

Simple

Why The Netherlands?
SERC Helix studies compared cultures

Leadership: egalitarian vs hierarchial

Denmark	Israel	Canada	US		France	Poland	Saudi Arabia	Japan
Netherlands		Finland	UK	Germany	Italy		Russia	India	Korea
Sweden	Australia				Brazil	Spain	Mexico	Peru	China	Nigeria

Egalitarian ←——————————————————————→ Hierarchical

Knowledge is power

Limit stratification

Expect to be challenged

Federation of brilliant people who influence each other for the common good

Process fits the project

Collaboration includes consensus

I talk with people for a living

Influence Without Authority

Constructive Debate

Yes, and…

Power comes from order: role, function, organization

Projects fit the process
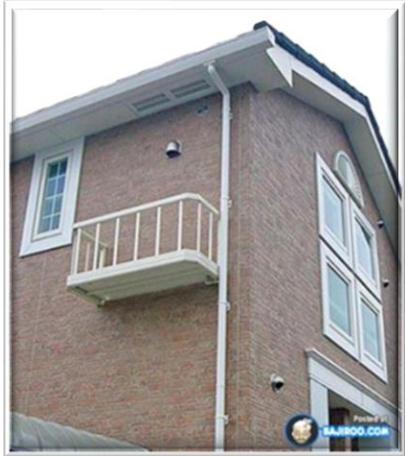
Do we recognize ourselves?

Tensions that when managed well support stellar innovation as described by Gary Pisano in "The hard truth about innovative cultures"

1. Tolerance for failure but no tolerance for incompetence

2. Willingness to experiment but highly disciplined

3. Psychologically safe but brutally honest

4. Collaboration but with individual accountability

5. Flat but strong leadership

Pisano, G. (2019). The hard truth about innovative cultures. *Harvard Business Review*, January-February 2019, pp 62-71. Reprint# R1901C

And yet ...

Door sterke toename zonneprojecten
Stroomnet vol in bijna heel Brabant

Nog vóór Brabant deze zomer definitieve plannen voor zon-

de Volkskrant

Cumns & Opinie Uitgelicht Wetenschap Mensen

CIJFERS BIJ HET NIEUWS
Nederland loopt achterstand bij vaccineren nog niet in

DAGBLAD VAN HET NOORDEN

VOORPAGINA NET BINNEN MIJN NIEUWS GRONINGEN DRENTHE VIDEO SPORT CULTUUR ECON

Nieuwe Zuidelijke Ringweg kost provincie 94 miljoen extra; tevergeefs verzoek om informatie over verdeelsom

Opnieuw dreigt vertraging voor de Noord/Zuidlijn

NOS Nieuws Sport Uitzendingen

NOS NIEUWS • BINNENLAND • POLITIEK • 02-03-2020, 19:25

Extra experts ingezet om problemen met C2000-systeem op te lossen

Het ministerie wist in 2011 al dat de stint niet deugde — minister Van Nieuwenhuizen zou dat hebben verzwegen voor de Kamer
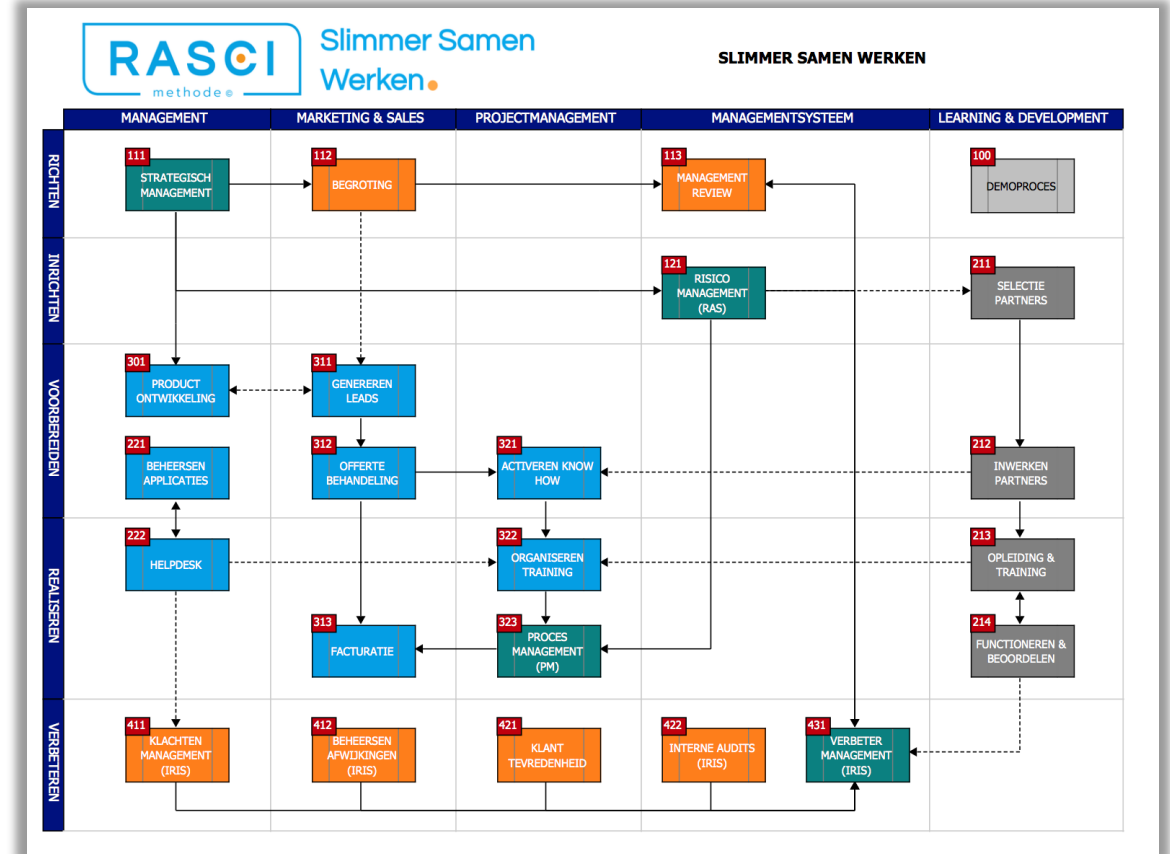
ANP
25 sep 2019

de Volkskrant

Cumns & Opinie Uitgelicht Wetenschap Mensen Beter Leven

NIEUWS TOESLAGENAFFAIRE
Minister Wiebes betreurt falen rechtsstaat bij toeslagenaffaire: 'het belang van de ouders en hun kinderen voorop'

Standard project management practices
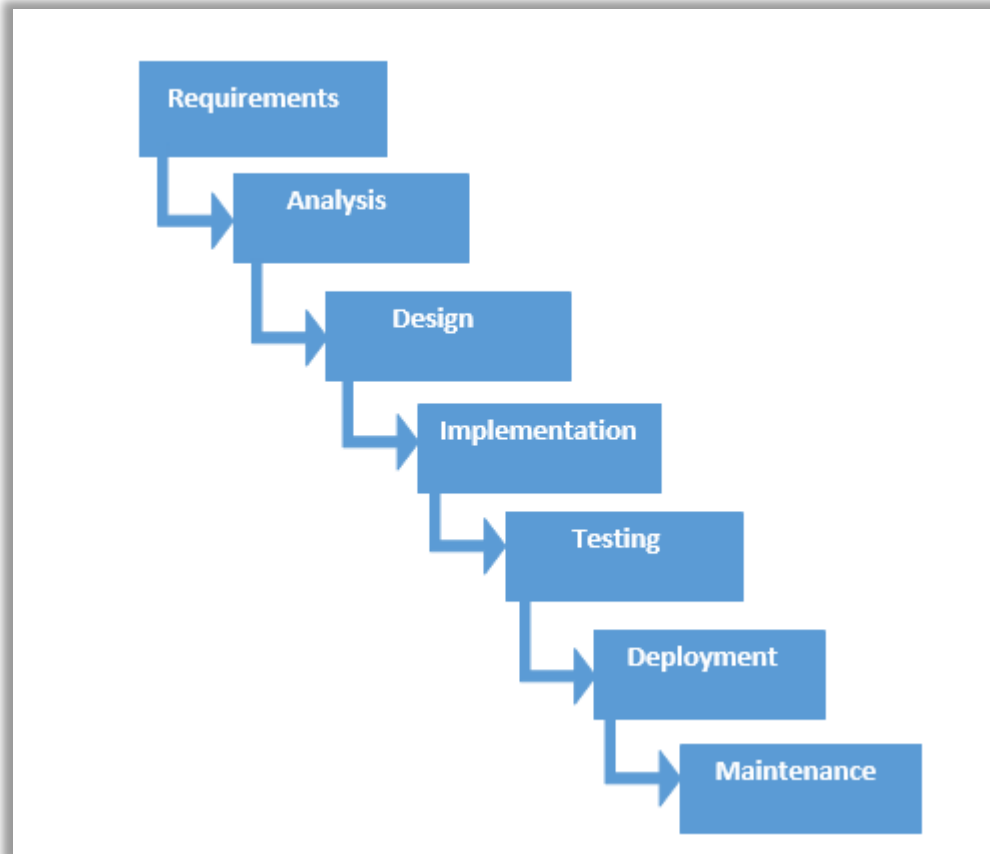
Missing: dealing with uncertainties

Missing: overall system responsibility

Systems Engineering

Incose

Systems Engineering is a __transdisciplinary__ and __integrative__ approach to enable the successful realization, use, and retirement of __engineered systems__, using __systems principles and concepts,__ and scientific, technological, and management methods.

We use the terms "engineering" and "engineered" in their __widest sense__: "the action of working artfully to bring something about". "__Engineered systems__" may be composed of any or all of people, products, services, information, processes, and natural elements.
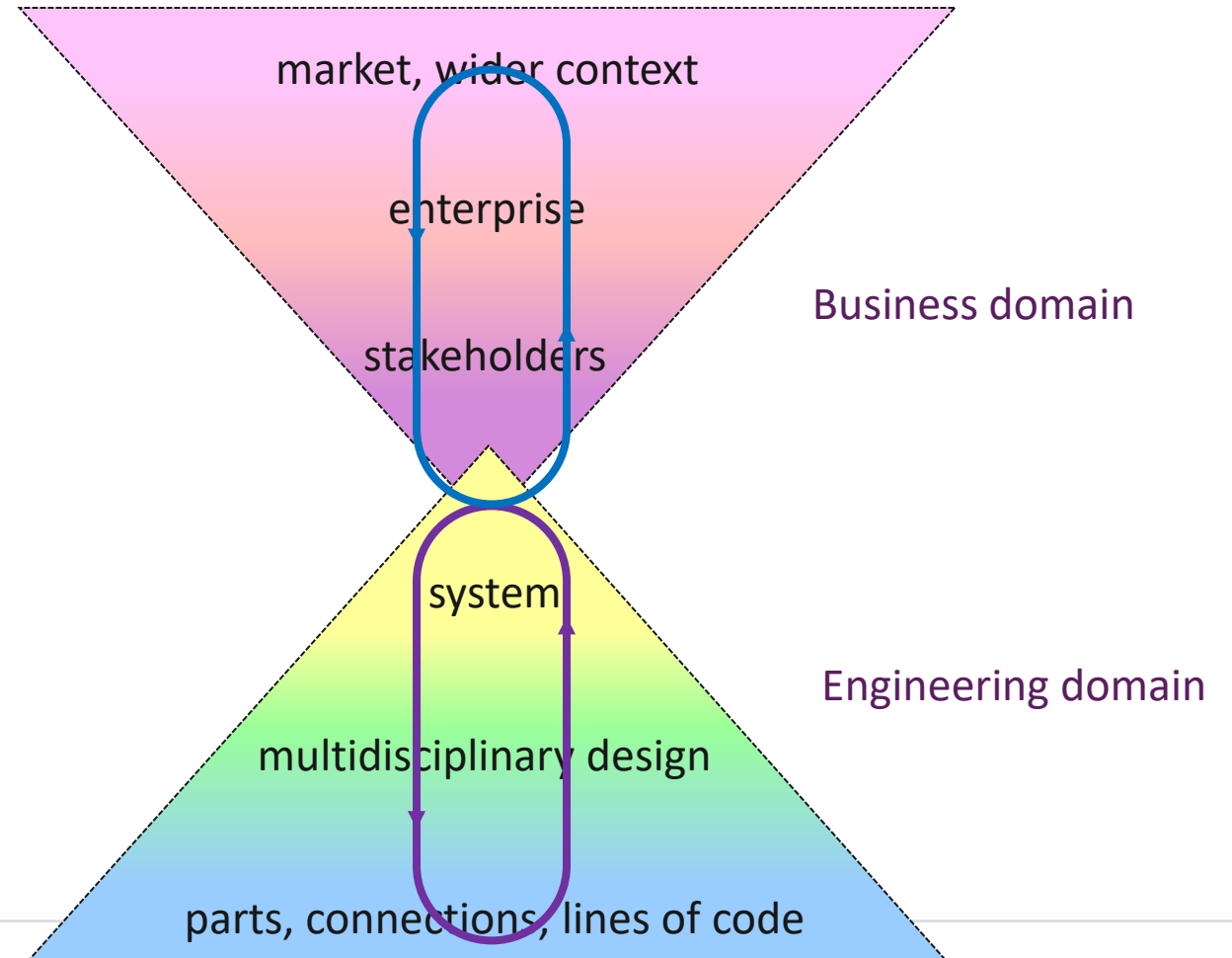
Traditional SE practice: focus on the engineering aspects

- **Requirements driven**
- **Decompose system**
- **KPI budgets allocation**
- **Manage integration**
- **Project de-risking**

Engineering domain

system

multidisciplinary design

parts, connections, lines of code
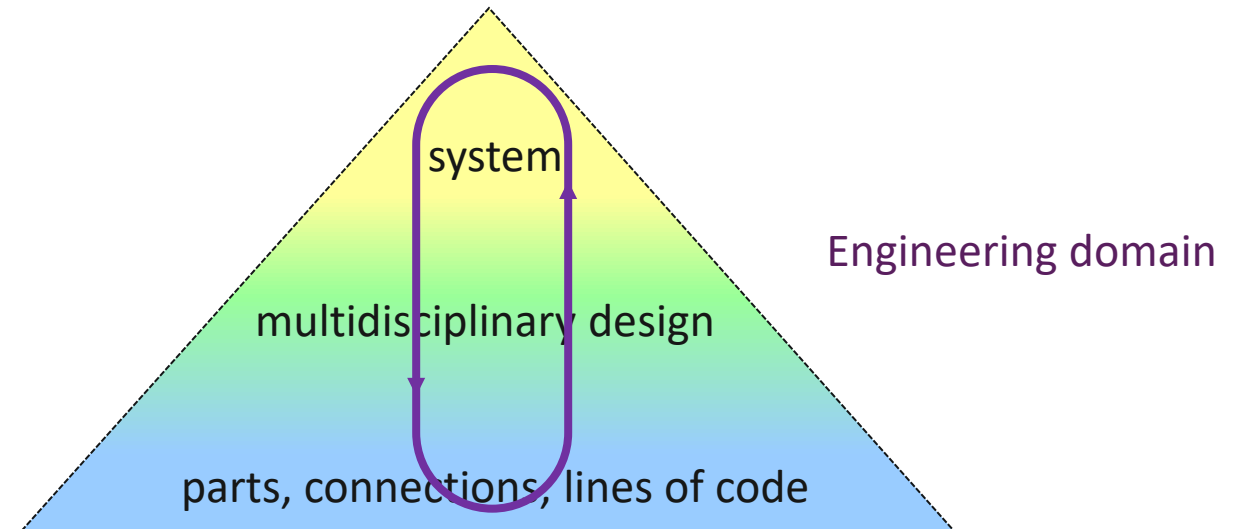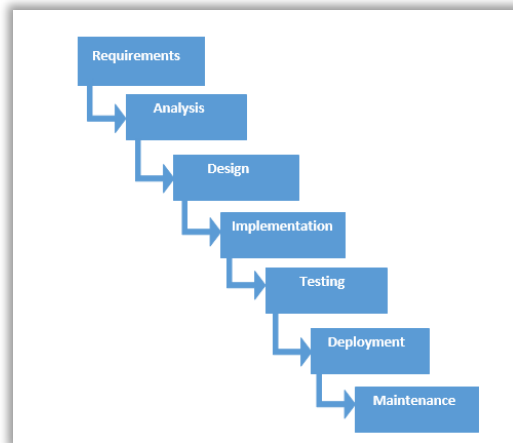
The system extends beyond the engineering domain

- **Value driven**

- **Changing contexts**

- **Emergent properties**

- **Incomplete requirements**

- **Integration uncertainties**

market, wider context

enterprise

Business domain

stakeholders

system

Engineering domain

multidisciplinary design

parts, connections, lines of code

The Top 10 Illusions of Systems Engineering

1. **Absolute**: there is a "right" or optimal answer.
2. **Unambiguous**: it is possible to specify unambiguous requirements using human
3. **Sequential**: a fundamentally sequential approach to development.
4. **Rational Actors**: Engineers and managers are rational decision makers that have access to complete and perfect information
5. **Reductionistic**: the ability to divide and conquer
6. **Centrally Controlled**: Control of the development organization(s) is centralized and absolute.
7. **Static**: In essence, the system need and the system context never change.
8. **Mechanistic**: blind to the human element, including culture and history
9. **Deterministic**: system behavior is deterministic
10. **Context Free**: Best practices are universal and do not vary depending on the context.

Case: economic uptime of equipment

Customer need: **maximize economic use of equipment**

Translated into requirement: **maximize mean-time-between-failures (MTBF)**

Initial approach: **Design for robustness - problem: exploding cost diminishing returns**

Trade-off with alternatives needed:

- **Design for diagnosability: decrease downtime upon failure**
- **Design for prognostics: scheduled vs. unscheduled maitenance**

Stakeholders:
- **Design engineers**
  - Competence shift
  - Architecture
- **Manufacturing**
- **Product management**
- **Marketing & sales**
  - Different value proposition
- **Customers**
- **Field services**
  - Way of working
- **Suppliers**

Concerns the whole organisation
Requires Systems Thinking

Disruption!
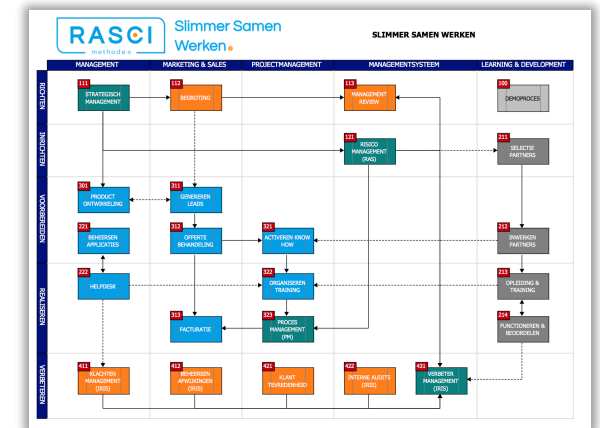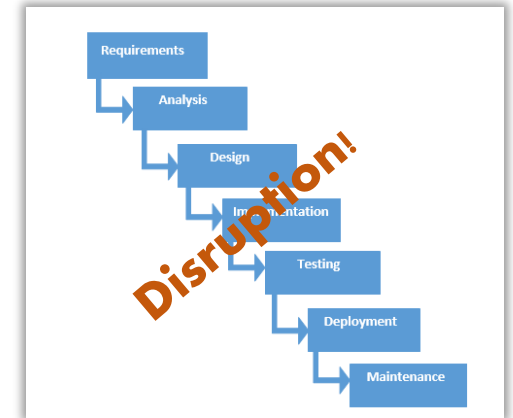
Cuts across roles

What is Systems Thinking?

The insight that systems cannot be understood by analysis- the properties of the parts can only be understood within the larger context of the whole.

For engineered systems, how about:

Systems ~~Engineering~~ thinking is a transdisciplinary and integrative approach to enable the successful realization, use, and retirement of engineered systems, using systems principles and concepts, and scientific, technological, and management methods.
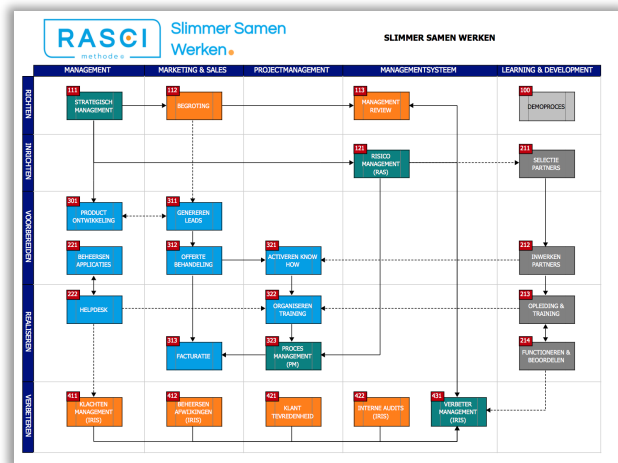
Tensions

	To be managed	
Analysis		Synthesis
Divide & Conquer		Integral & shared system awareness
Projectleader		System Architect
Multi-disciplinary	TENSION	Cross-disciplinary
Requirements-based		Value-based
RASCI		CAFCR
Linear		Iterative
Risk-averse		Risk-hungry

System thinking managers

- **Break through the silo's - Cut across disciplines**

- **Awareness of system-level concerns**

- **Ability to switch between analysis and synthesis views**

- **Support the System Architect and Project Manager**

- **Right incentives: e.g. integral costs versus material costs**
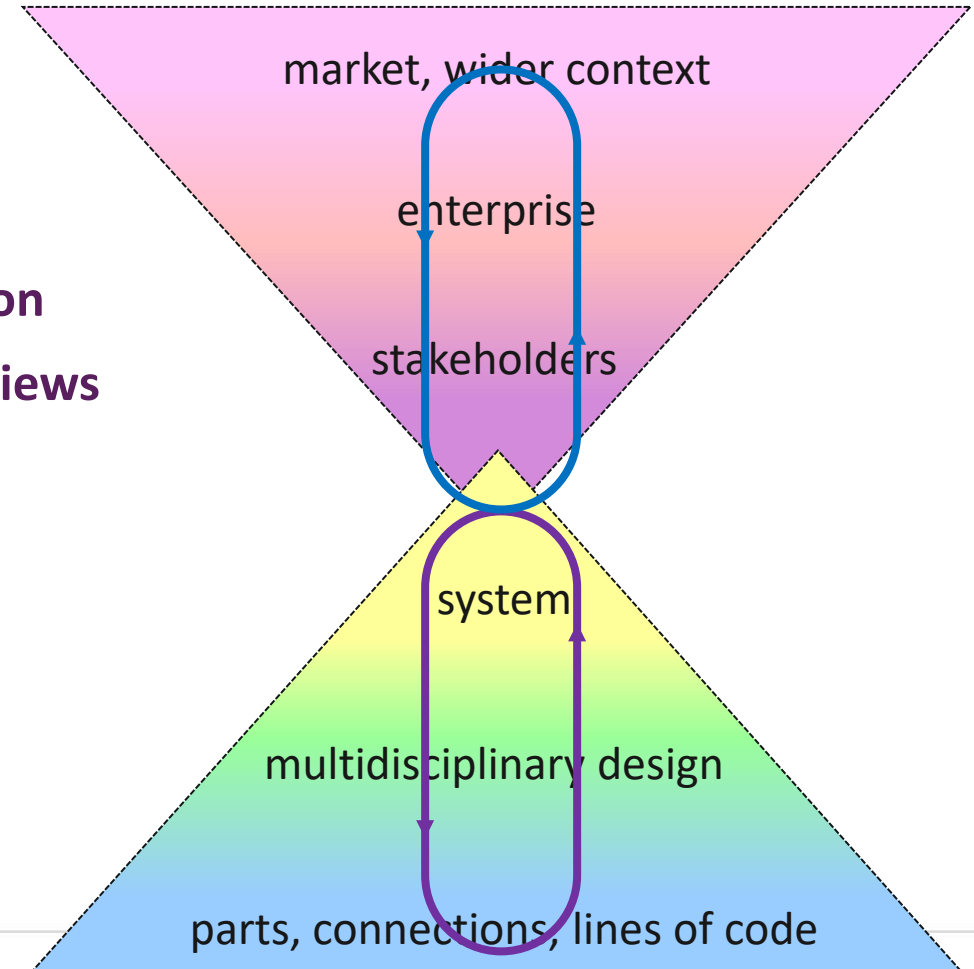
- **Appreciate the top 10 illusions**

The Top 10 Illusions of Systems Engineering

STEVENS
INSTITUTE of TECHNOLOGY

1. **Absolute**: there is a "right" or optimal answer.
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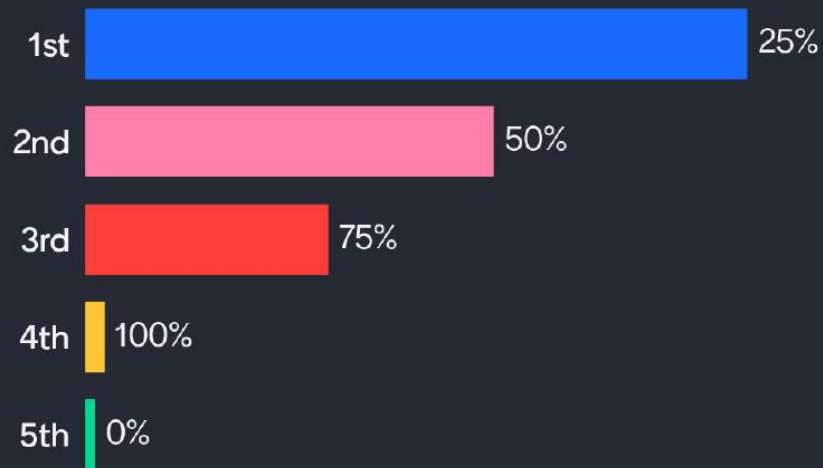
The system thinking architect

- **Understand silo's, mono-disciplinary concerns**
- **Awareness of all stakeholder's concerns**
- **Be the system conscious of project and organization**
- **Ability to switch between analysis and synthesis views**
- **Support management**

market, wider context

enterprise

stakeholders

system

multidisciplinary design

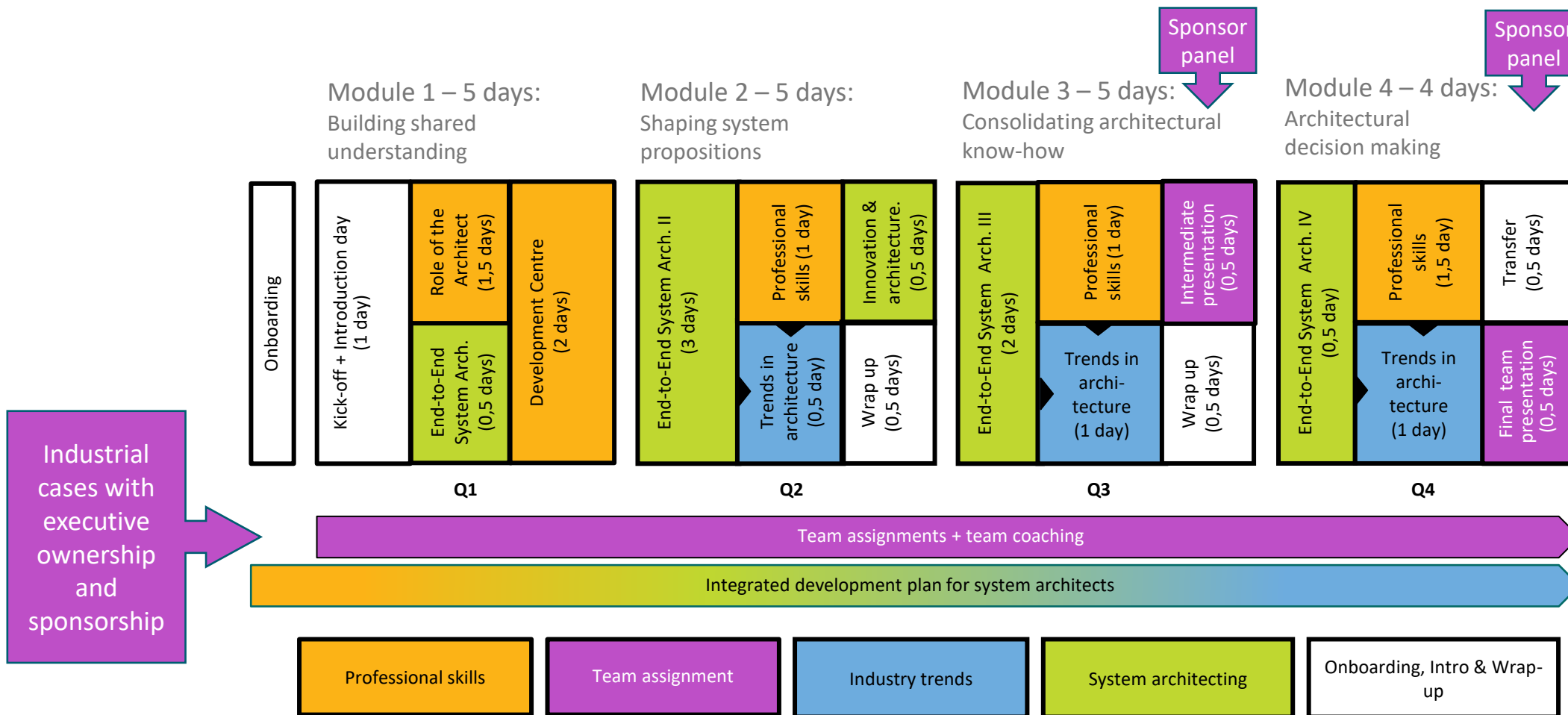parts, connections, lines of code

Mentimeter question 2

# How to get management on board in System Thinking?

1. **Involve top management in training of SA's and SE's**

2. **Qualitatively: Apply CAFCR (for real!)**

3. **Quantitatively: Daarius methodology**

1. Executive sponsorship key element in our training programs

Module 1 – 5 days:
Building shared understanding

Module 2 – 5 days:
Shaping system propositions

Module 3 – 5 days:
Consolidating architectural know-how

Module 4 – 4 days:
Architectural decision making

Sponsor panel

Sponsor panel

Onboarding

Kick-off + Introduction day (1 day)

Role of the Architect (1,5 days)

End-to-End System Arch. (0,5 days)

Development Centre (2 days)

End-to-End System Arch. II (3 days)

Professional skills (1 day)

Trends in architecture (0,5 day)

Innovation & architecture. (0,5 days)

Wrap up (0,5 days)

End-to-End System Arch. III (2 days)

Professional skills (1 day)

Trends in archi-tecture (1 day)

Intermediate presentation (0,5 days)

Wrap up (0,5 days)

End-to-End System Arch. IV (0,5 day)

Professional skills (1,5 day)

Trends in archi-tecture (1 day)

Transfer (0,5 days)

Final team presentation (0,5 days)

Q1 **Q2** **Q3** **Q4**

Industrial cases with executive ownership and sponsorship

Team assignments + team coaching

Integrated development plan for system architects

| Professional skills | Team assignment | Industry trends | System architecting | Onboarding, Intro & Wrap-up |

2. CAFCR-Analysis

- **Goal:**
    - Explore the system in its context
    - Understand the problem space
    - Chart the solution space
    - Combine full range of stakeholder views
- **Form:**
    - Interviews with key stakeholders
    - 3-day workshop, professionally facillitated
- **Who?**
    - Customers
    - Marketing
    - Services
    - Engineering
    - Product management
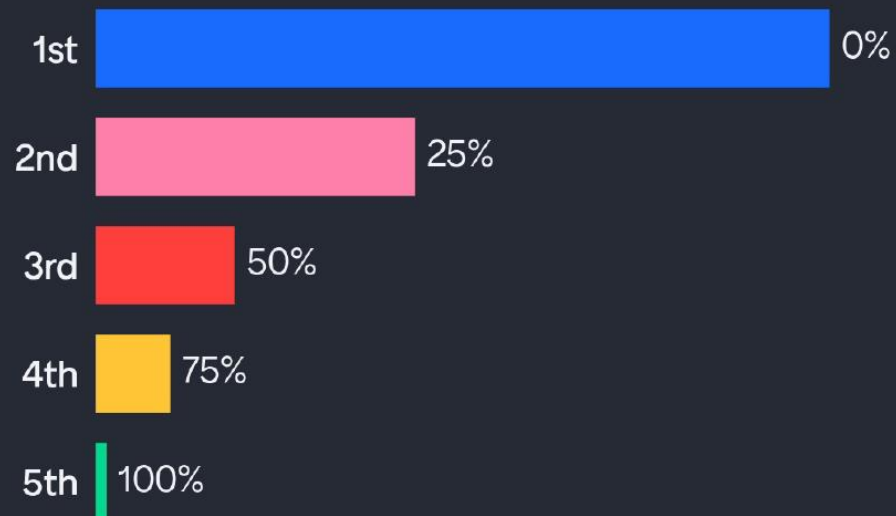   - Business management
    - System Architect
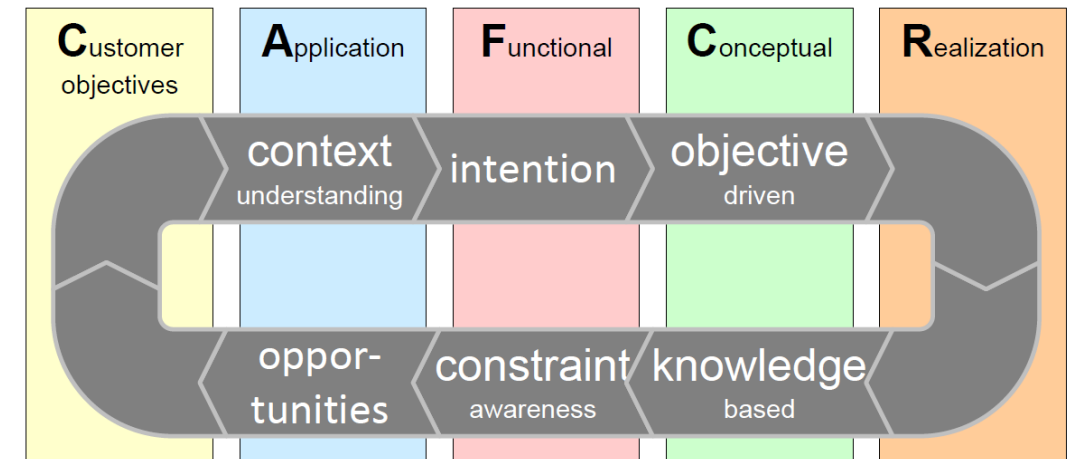
Must all attend and commit!
Shared responsibility and ownership

Mentimeter question 3

3. Daarius methodology

<u>Daarius</u> is a structured, scalable, and team-based system design methodology providing traceable underpinning for key design decisions and leveraging the abundance of simple executable models in systems engineering.

- Team-architecting (replacing super-hero architect)
- Dilemma handling
- Trade-off handling
- Communication across organization

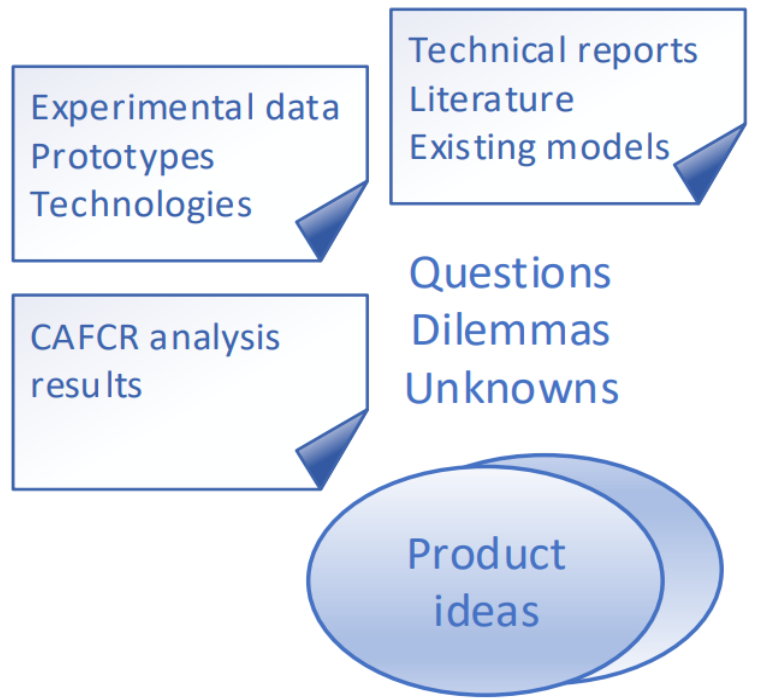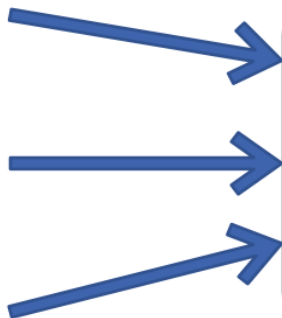**CAFCR based solution space analysis**

Allows to stepwise fill and track solution space

- First: criticals
- Then: essentials
- Finally: others
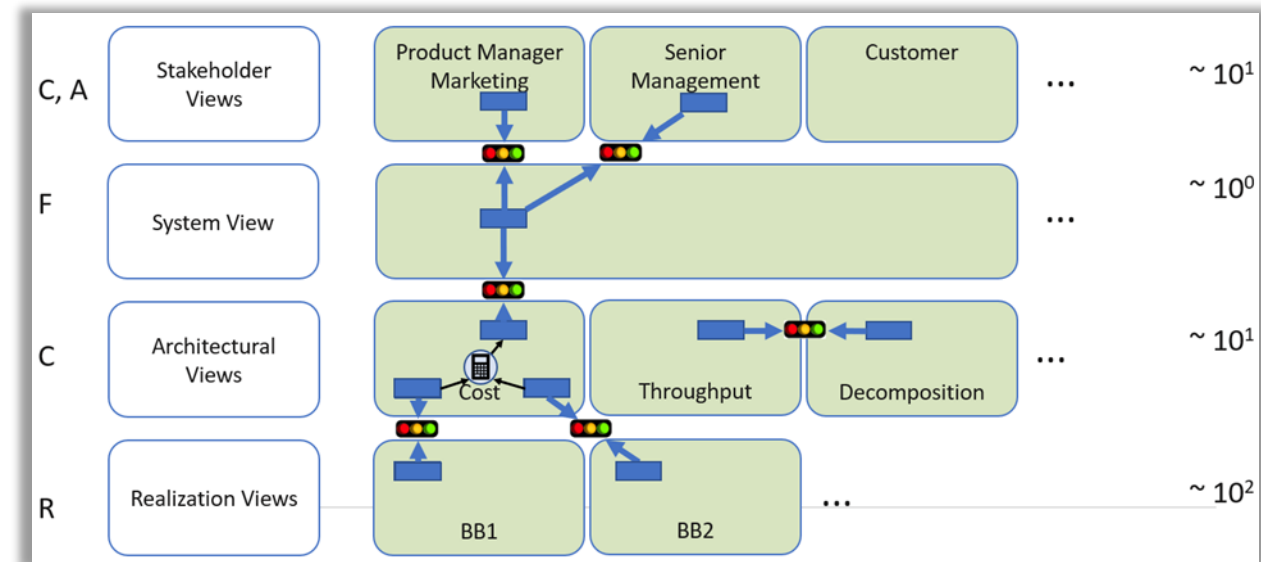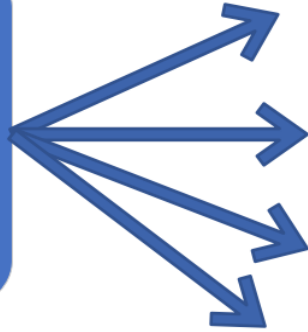
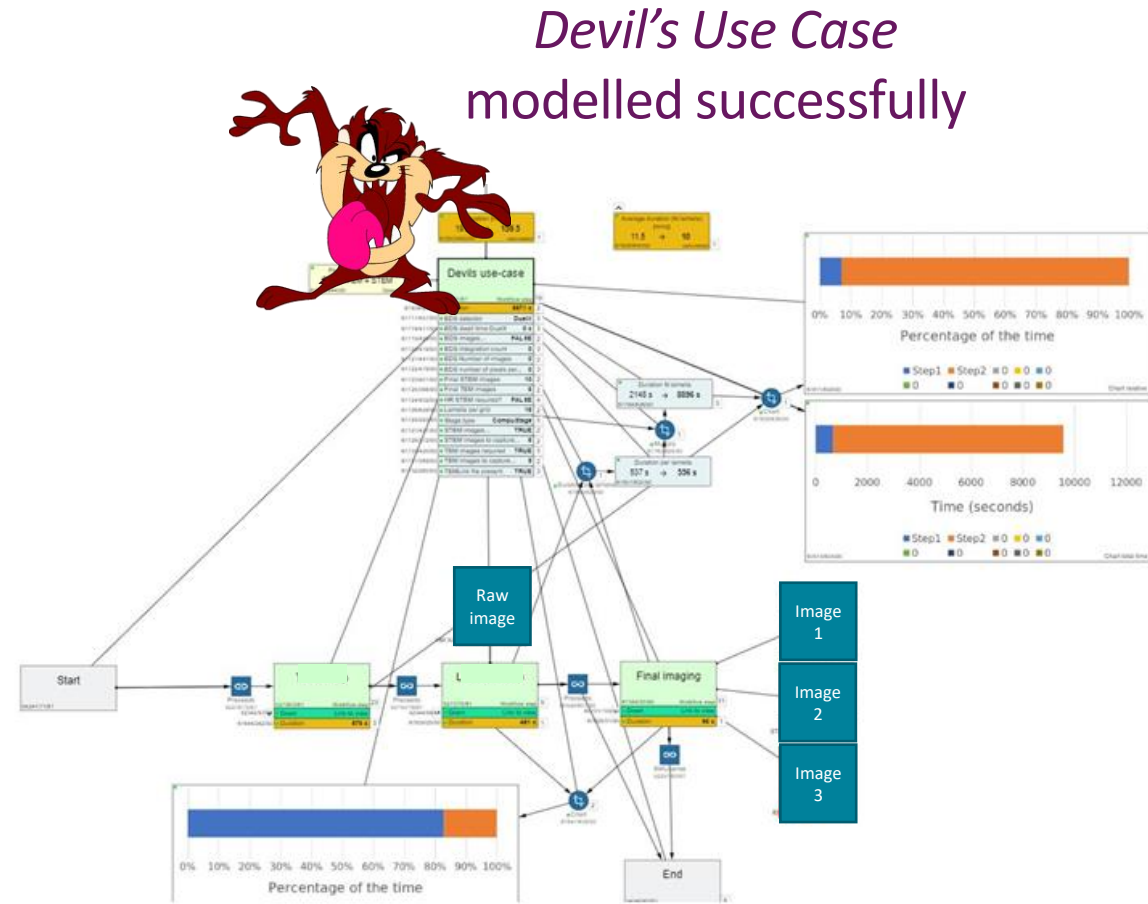# Exploiting available models for clear communcation between stakeholders, system architect and engineers
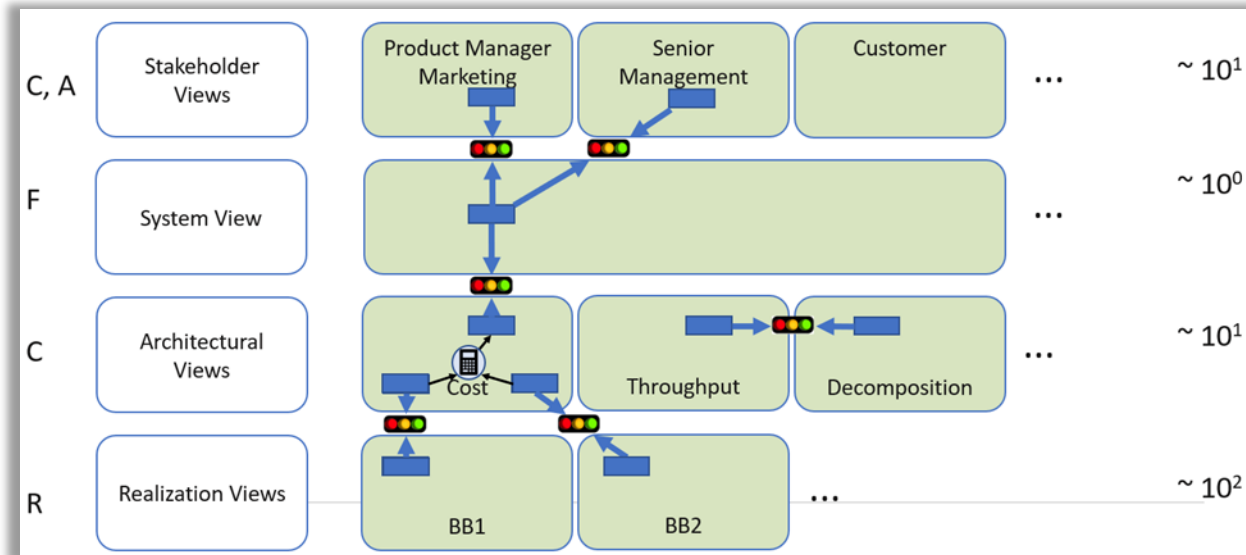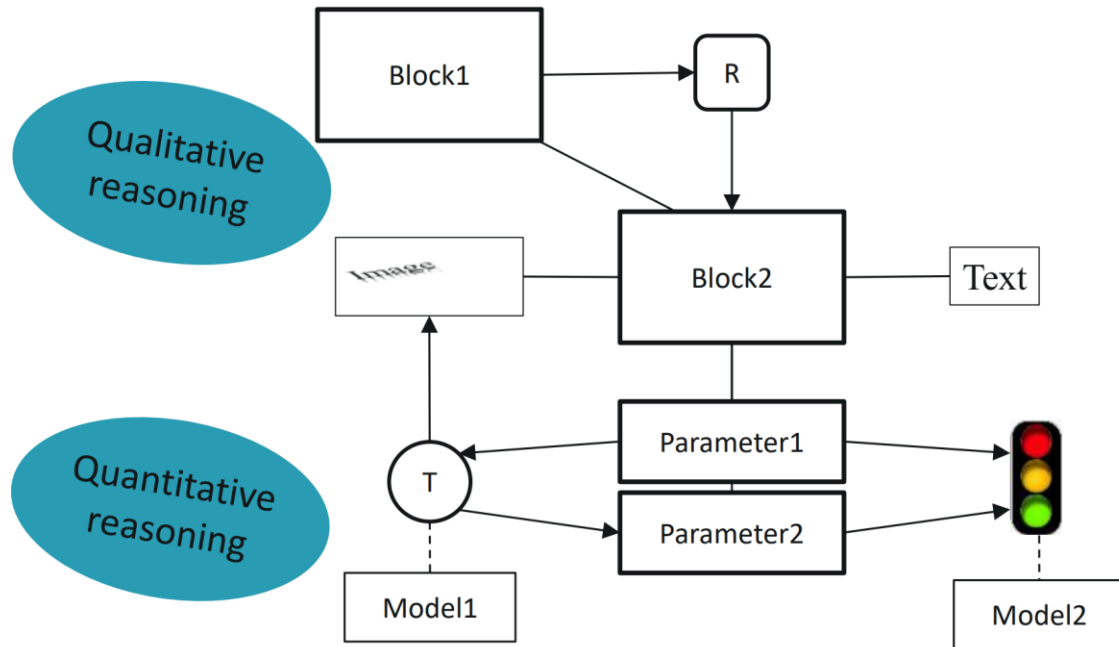
Value-based architecting

- **Customer value:**
  - optimize customer workflow

- **Initial requirement:**
  - minimize timing

- **After understanding CV:**
  - Further reduce timing did not affect workflow
  - Instead: optimize at application level

Architect of ESI industry partner:
"I can talk to SW engineers, System engineers, Application specialists, Managers. They can all understand me. Brilliant!"

Typical use: large structures
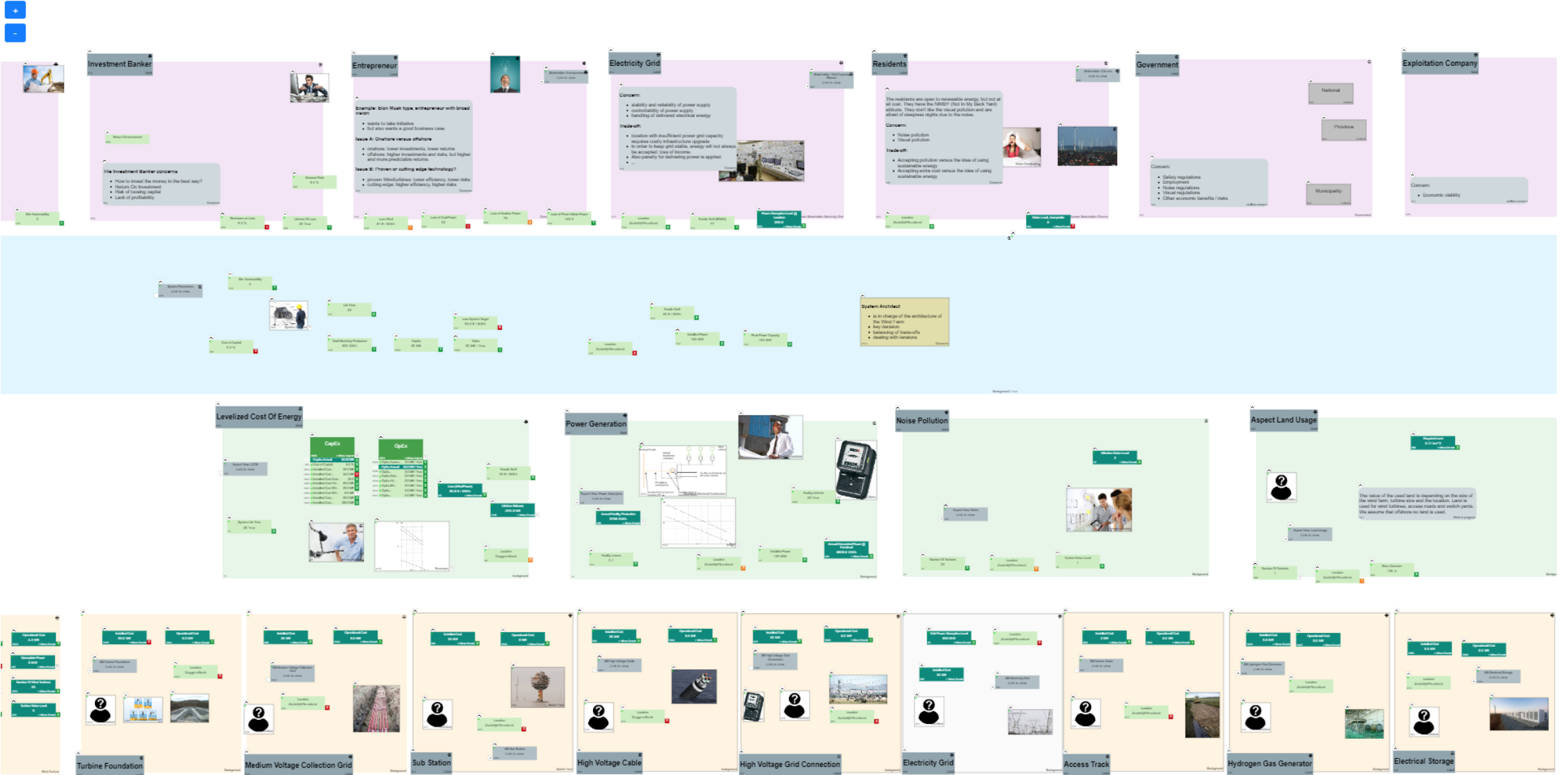
How to get management on board in System Thinking?

1. Involve top management in training of SA's and SE's

2. Qualitatively: apply CAFCR (for real!)

3. Quantitatively: DAARIUS

4. Systems thinking training of managers?

Mentimeter question 4

Introduce one topic that should not be missing in a System Thinking training for managers.

mindset
fail early
flexibility
business analysis
strength of modeling   risk management
benefits of collaboration
listen summarize question   why
stakeholders   single source of truth
technology evolution   simplicity
communication   system awareness
technical debt
cafcr   scalability uncertainty

Summary and outlook

Embed Systems Thinking throughout organization

- **Engineers, project management, general managers, marketing&sales**

- **If possible extend to customers and suppliers**

- **Continuous effort**

- **Own it and lead it**

- **Methods like CAFCR and Daarius are just methods; true awareness is essential**

Start now, since complexity only increases: AI/ML, Cloud, Systems-of-systems, Sustainability

- Explainability
- Security
- Continuous upgrade
- Configuration explosion
- Decommisioning and recycling

International Digital Enablement Week 2021

Date: April 13-20, 2021
Venue: online
Registration →

We cordially invite you to the International Digital Enablement Week '21.

Throughout this week you can attend online events on hot topics from the world of complex high-tech systems. All events will feature speakers from industry and universities that introduce the problem and explore solutions, followed by discussions with all participants. A detailed program introducing the lectures will be published on the website along with the confirmation and information that you will receive after registration.

We look forward to meeting you!

INTERNATIONAL DIGITAL ENABLEMENT WEEK 2021

ESI
Managing your legacy
Date: April 13, 2021
Time: 14h30 - 17h30 CET

About this event →

ESI & HIGH TECH NL
Hoe volg ik mijn klant?!
Partner: High Tech NL
Date: April 14, 2021
Time: 14h30 - 17h30 CET

About this event →

ESI & OFFIS
Verification, validation, configuration
Partner: Offis/DLR
Date: April 15, 2021
Time: 14h30 - 17h30 CET

About this event →

ESI & SERC
MBSE applied
Partner: SERC
Date: April 17, 2021
Time: 14h30 - 17h30 CET

About this event →

ESI & TNO
Data sharing, AI, and digital twinning
Partner: TNO ICT Unit
Date: April 19, 2021
Time: 14h30 - 17h30 CET

About this event →

ESI
Reference architecting
Date: April 20, 2021
Time: 14h00 - 17h30 CET

About this event →

Thank you!

www.esi.nl

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