

# Systems Engineering - Creating a common base for the development organization to cope with current and future challenges

Nordic Systems Engineering Tour 2021 - Virtual event

Niels Jørgen Strøm

Chief Software Architect, GfSE Level B, CSEP, CSM

Product Development, Software

Grundfos Holding A/S

be  
think  
innovate

GRUNDFOS 

# Topics

- Grundfos - a value driven company
- Why Systems Engineering
- Pre-requisites and actions
- How to simplify and connect the process landscape with Systems Engineering
- Achievements and ongoing activities
  - Overview
  - Modular architectures

# Topics

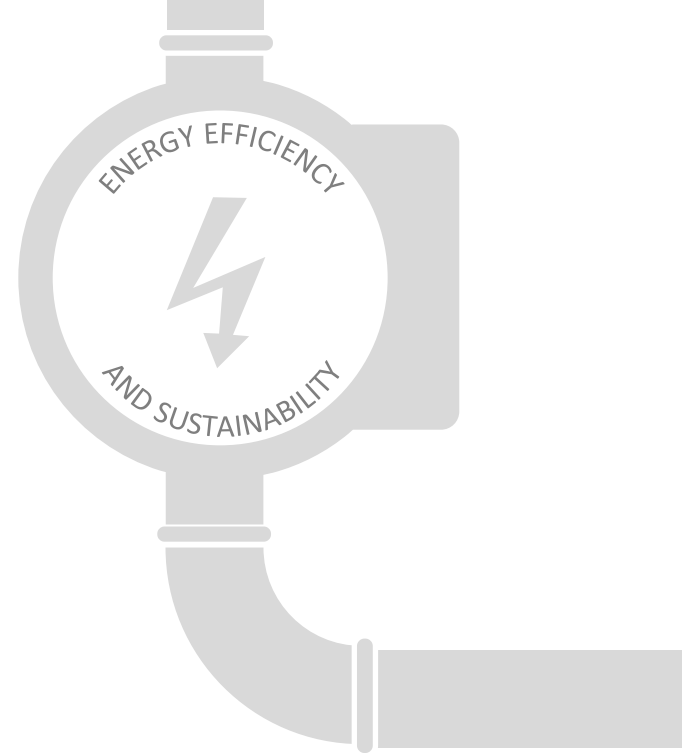
- **Grundfos - a value driven company**
- Why Systems Engineering
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  - Overview
  - Modular architectures



# PUMPS IN PERSPECTIVE

Grundfos is  
a World Leader







And with climate changes - now more than ever...

Pumps provide and remove water. This is essential to life on earth

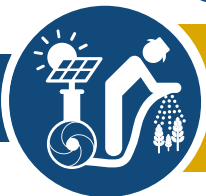


The infographic features a large blue pump on the left with a circular impeller. A thick blue pipe extends from the pump and splits into three horizontal branches. Each branch contains a circular icon and a corresponding text box. The top branch is blue with a water drop icon, the middle is yellow with a sun icon, and the bottom is red with a flame icon. The word 'Impact' is written inside the pump's impeller.

Impact



**500 million people** get clean groundwater  
from Grundfos submersible pumps



**200,000 solar-driven** Grundfos pumps provide  
water - especially in developing countries



**400 million people** get heating  
from Grundfos circulation pumps

HOME

ABOUT

THE WATER CRISIS

IMPACT CAMPAIGN

HOST A SCREENING

NEWS

PRESS



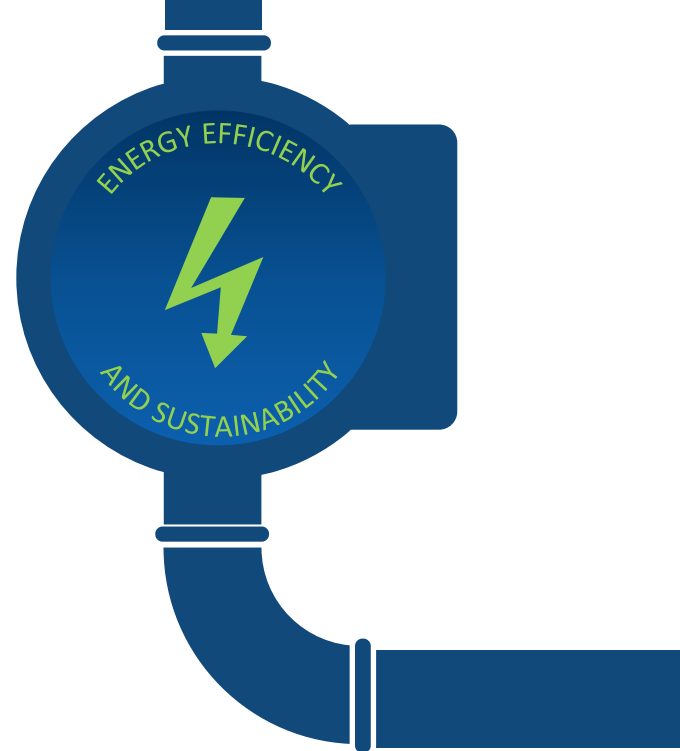
# INTODUST

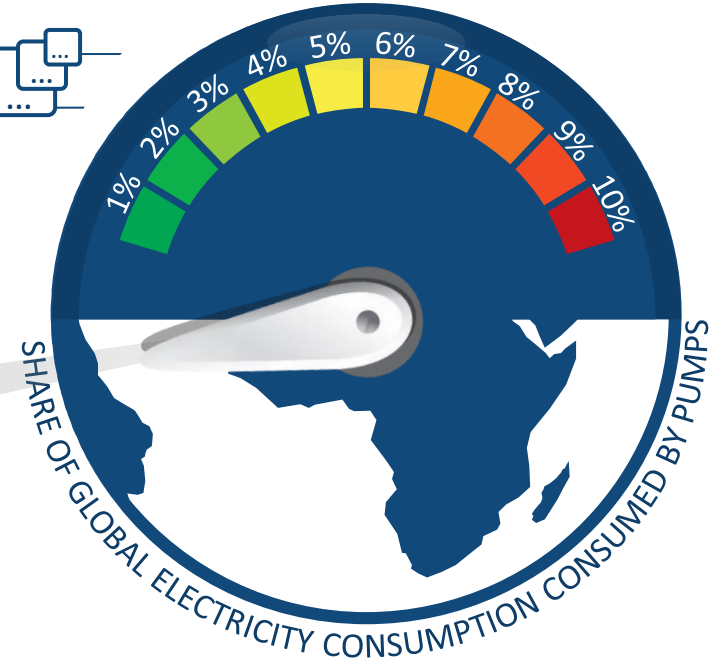
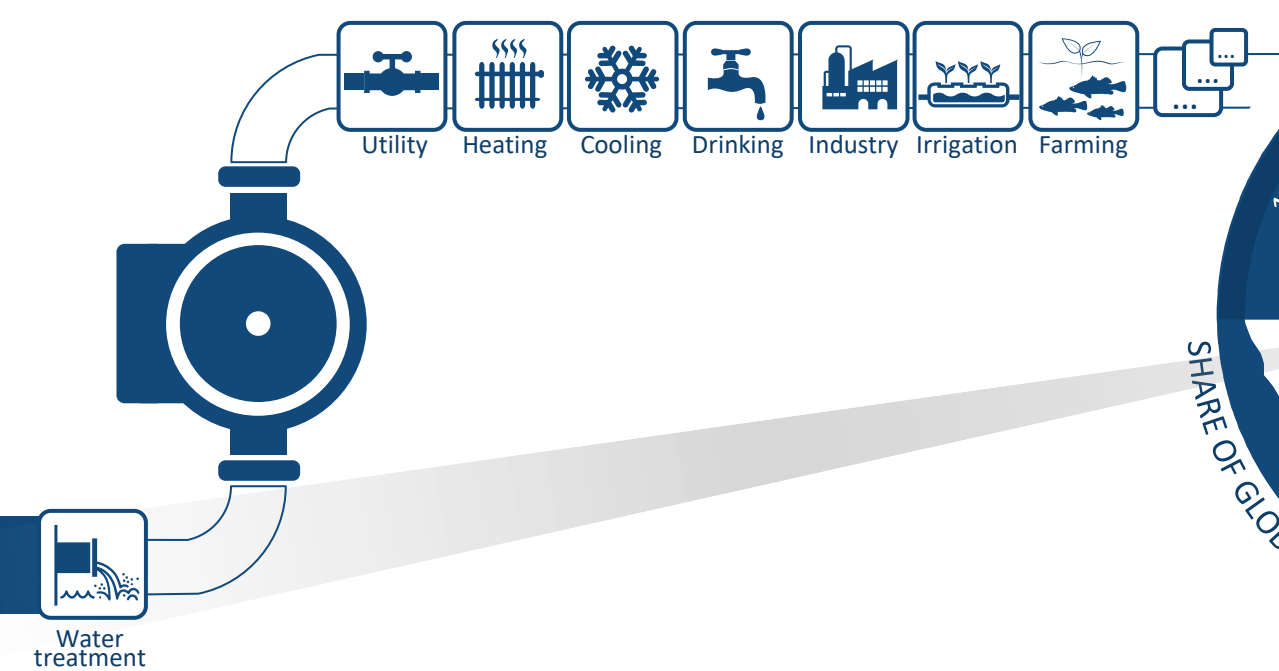
AVAILABLE NOW

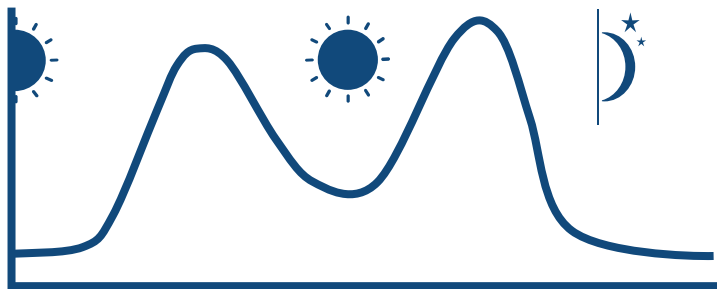


[Into Dust – From Grain Media \(intodustmovie.com\)](http://intodustmovie.com)

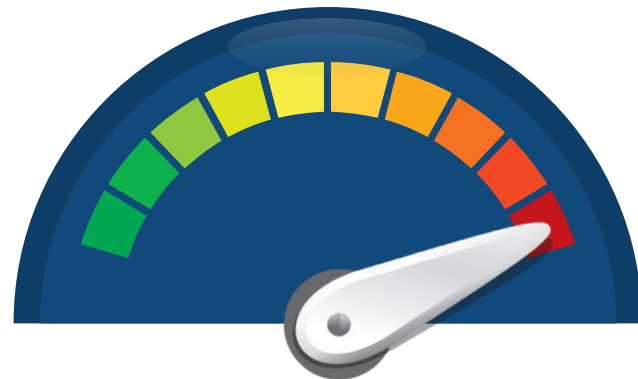








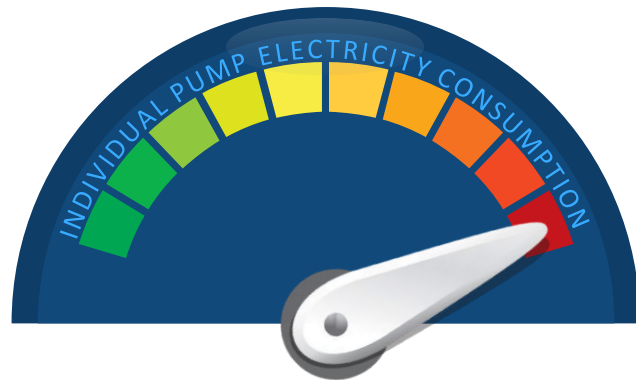
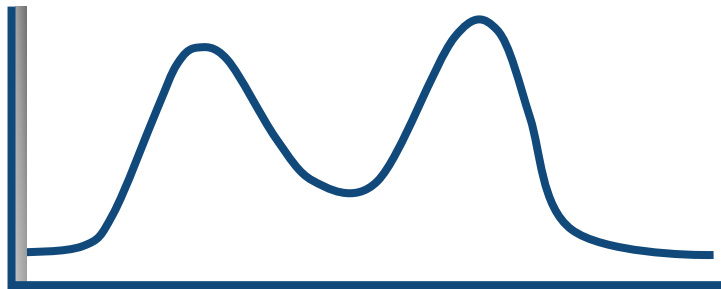
THE FLOW DEMAND VARIES



- YET MOST PUMPS RUN FULL SPEED 24/7

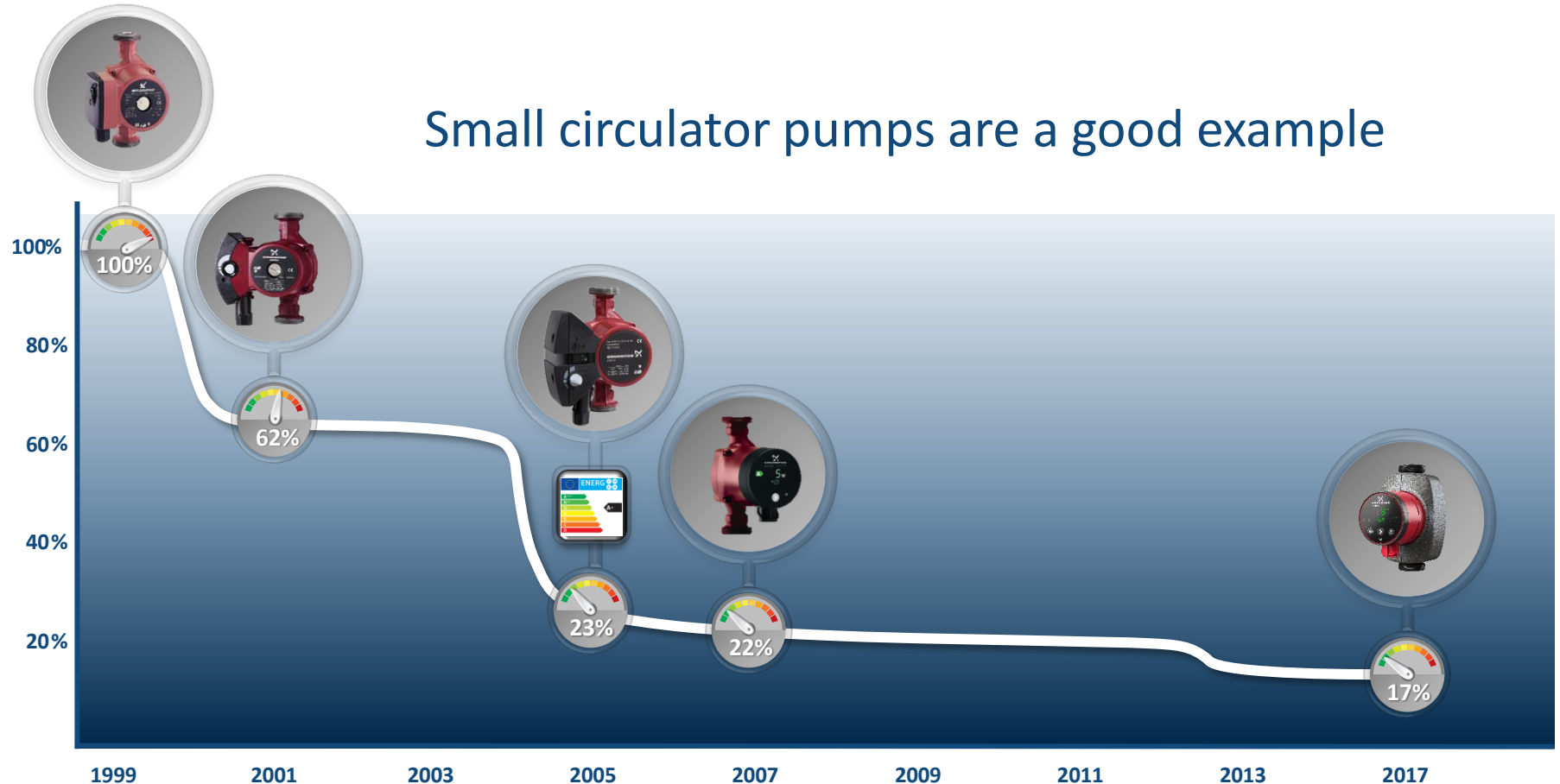
9 out of 10 pumps are running full speed

- Even when there is no need



Solution: auto adaptable pumps and motors  
- that can potentially save 5% of global electricity

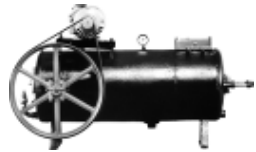
## Small circulator pumps are a good example



# Topics

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# Growth waves



WAVE 1  
1945-1960



+ MOTOR

WAVE 2  
1960-1990



+ MOTOR  
+ ELECTRONICS

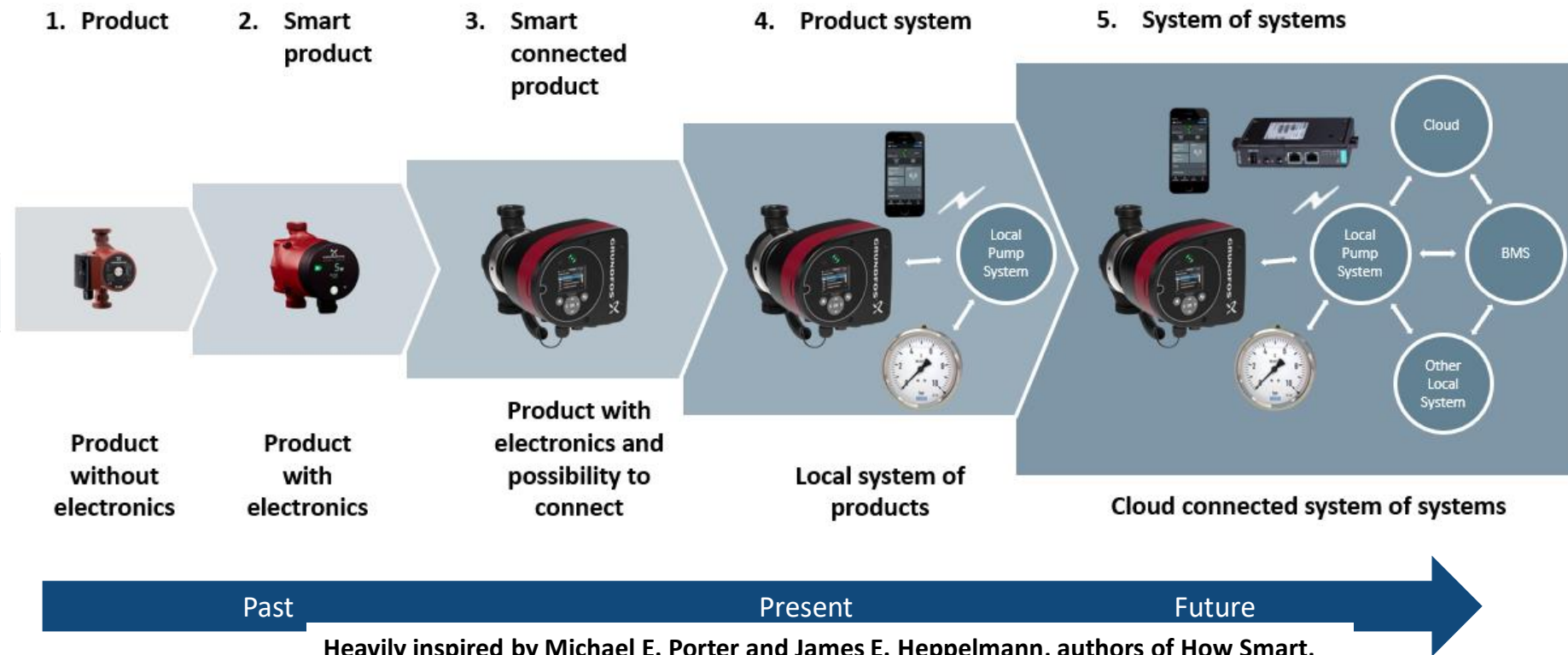
WAVE 3  
1990-2006



+ MOTOR  
+ ELECTRONICS  
+ CONNECTIVITY  
+ VALUE ADDED SERVICES  
+ SOFTWARE PRODUCTS  
+ NEW BUSINESS MODELS  
+ NEW SALES CHANNELS

WAVE 4  
2006-FUTURE

# Expanding the Core – Changing Focus



Heavily inspired by Michael E. Porter and James E. Heppelmann, authors of *How Smart, Connected Products Are Transforming Competition*, HBR, 2014

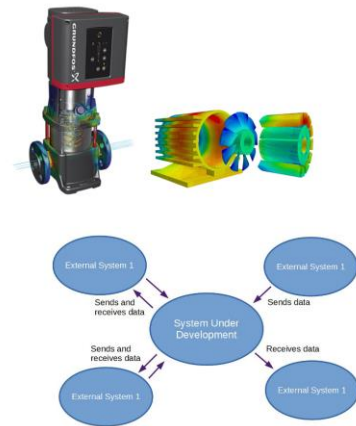


**In need of a common language  
And a common way of thinking - Systems Thinking**



## Systems Engineering is ...

- Modelling
- Reflection
- Context
- Dividing
- Alternatives?
- Distinguish



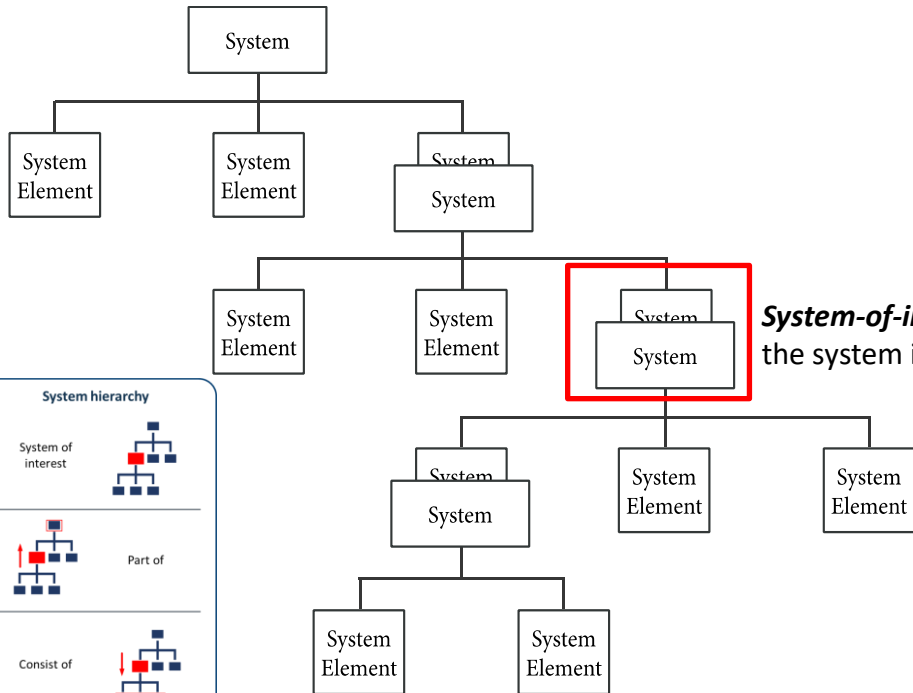
## System Levels and System Hierarchy

**A system hierarchy** is the breakdown of a system into its system elements.

A system consists of system elements

A system element is part of (belongs to) a system

A system hierarchy is not the same as a system architecture – it is a **breakdown view**



**System-of-interest (SOI)** is the system in focus.



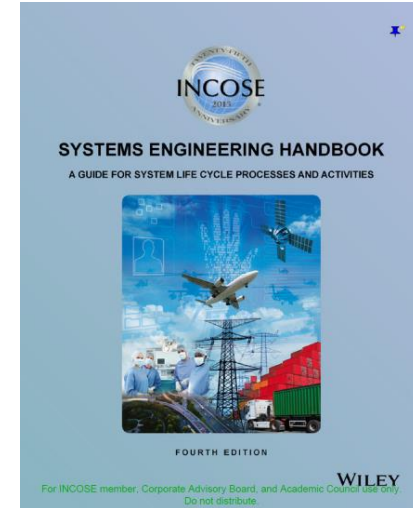
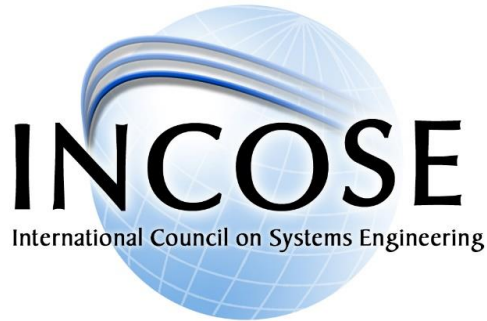
"Whatever you make today will plug into a bigger system tomorrow"

*Based on the Systems Engineering terms*

# Systems Engineering as foundation

## Definition:

**Systems Engineering** is an **interdisciplinary approach** and means to enable the realization of successful systems.



# Topics

- Grundfos - a value driven company
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- **Prerequisites and training**
- How to simplify and connect the process landscape with Systems Engineering
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# Prerequisites



# Certified and formally trained Systems Engineers

- Approx. 30 Systems Engineers certified at level B
- Approx. 100 Systems Engineers basic training (level C)
- Another approx. 40 engineers signed up for education



# SE-ZERT© Level B Schedule

SE-ZERT® Level B			
Module 1	Module 2	Module 3	Module 4
<b>Day 1</b> <ul style="list-style-type: none"> <li>• Introduction</li> <li>• Systems Engineering (SE) Overview (Scope of SE, Recap handbook and important topics)</li> <li>• Exercises</li> </ul>	<b>Day 4</b> <ul style="list-style-type: none"> <li>• Requirement Analysis</li> <li>• RAMS (Reliability, Availability, Maintainability, Safety)</li> <li>• Measurement</li> <li>• Decision Mgt.</li> <li>• V&amp;V planning</li> <li>• Exercises</li> </ul>	<b>Day 7</b> <ul style="list-style-type: none"> <li>• Configuration Management</li> <li>• Implementation &amp; Integration (implementation strategies)</li> <li>• QM &amp; Product Assurance (DIN EN ISO 14000)</li> <li>• Exercises</li> </ul>	<b>Day 10</b> <ul style="list-style-type: none"> <li>• Company interfaces</li> <li>• Overlapping processes</li> <li>• Quality Management (Lessons Learned)</li> <li>• Exercises</li> </ul>
<b>Day 2</b> <ul style="list-style-type: none"> <li>• Teamwork</li> <li>• Characters in teams</li> <li>• Team development</li> <li>• Exercises</li> </ul>	<b>Day 5</b> <ul style="list-style-type: none"> <li>• System architecture</li> <li>• Modeling languages SysML</li> <li>• Interface Management</li> <li>• Design</li> <li>• Exercises</li> </ul>	<b>Day 8</b> <ul style="list-style-type: none"> <li>• Cross-functional enablers (maintenance, logistic support)</li> <li>• Cost Analysis (Design for cost, life cycle costing)</li> <li>• Exercises</li> </ul>	<b>Day 11</b> <ul style="list-style-type: none"> <li>• Competition audit (configuration, assembly, performance audit)</li> <li>• Information Management</li> <li>• Tailoring</li> <li>• Exercises</li> </ul>
<b>Day 3</b> <ul style="list-style-type: none"> <li>• PM &amp; SE Mgt.</li> <li>• SE Management (Tailoring, PDM)</li> <li>• Risk Management (Use Case Analysis)</li> <li>• Stakeholder Requirements</li> <li>• Exercises</li> </ul>	<b>Day 6</b> <ul style="list-style-type: none"> <li>• MBSE &amp; other model based approaches</li> <li>• Project evaluation &amp; Control (Reviews, Milestones, Monitoring)</li> <li>• Exercises</li> </ul>	<b>Day 9</b> <ul style="list-style-type: none"> <li>• Integration</li> <li>• Integration proof and validation (feasibility study, verification &amp; test plan)</li> <li>• Project closure</li> <li>• Exercises</li> </ul>	<b>Day 12</b> <ul style="list-style-type: none"> <li>• Leadership, Communication</li> <li>• Summary of ...                             <ul style="list-style-type: none"> <li>• Conflict Management</li> <li>• SE Basics</li> <li>• SE &amp; Organization</li> <li>• SE Management</li> </ul> </li> </ul>

# Basic Training with UNITYacademy Certificate

Basic Training with UNITYacademy certificate	
Module 1	Module 2
<b>Day 1</b> <ul style="list-style-type: none"> <li>• Systems Engineering (SE) Overview</li> <li>• SE processes</li> <li>• Training concept</li> <li>• Business and Mission Analysis</li> </ul>	<b>Day 4</b> <ul style="list-style-type: none"> <li>• Project Management</li> <li>• Measurement</li> <li>• Decision Mgt.</li> <li>• Risk Mgt.</li> </ul>
<b>Day 2</b> <ul style="list-style-type: none"> <li>• Requirements Management</li> <li>• Verification and Validation</li> <li>• Architecture definition</li> </ul>	<b>Day 5</b> <ul style="list-style-type: none"> <li>• SE Management</li> <li>• Tailoring</li> <li>• Cross-cutting methods and processes</li> </ul>
<b>Day 3</b> <ul style="list-style-type: none"> <li>• System Design / Analysis</li> <li>• Implementation, Integration</li> <li>• Configuration Management</li> </ul>	<b>Day 6</b> <ul style="list-style-type: none"> <li>• Enterprise interfaces</li> <li>• Organizational Processes</li> <li>• Quality Management</li> <li>• Summary</li> </ul>

Example





# Systems Engineer network/community



EDIT LINKS

## Systems Engineer community

Home

Notebook

Documents

Pages

Pages

Site contents

Recycle Bin

EDIT LINKS

Documents [2]

New Upload Sync Share More

✓	Name	Modified	Modified By
	Architecture	...	
	ED Committee	...	
	Job and role descriptions	...	
	MD Committee	...	
	Misc System Eng material	...	
	SE Events	...	
	Systems Engineering training	...	

Secondary Contact

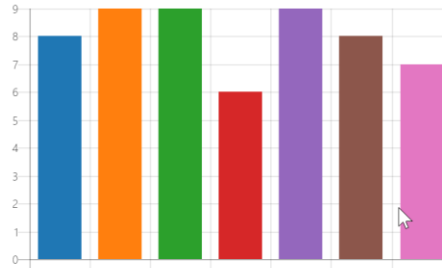
Ch...

Chri 1. Which of the below Systems Engineering topics would you like to WORK ACTIVELY with?

[More Details](#)

- Product Line Engineering and ... 8
- Architecture - process and pra... 9
- Verification and Validation - pr... 9
- Agile Systems Engineering 6
- Simulation Driven Development 9
- MBSE (Model Based Systems E... 8
- Platforms and projects - the ri... 7

Drag files here to upload



Jira Grundfos A/S Jira BD Dashboards Projects Issues Boards Portfolio

### System Engineering

Requirements Management S... Kanban board Releases Reports Issues Components

QUICK FILTERS: Active Archived

Component name Lead (option)

Component	Status
Anchoring	ACTIVE
CM	ACTIVE
Requirements	ACTIVE
Validation and Verification	ACTIVE

PROJECT SHORTCUTS

Add a link to useful information for your whole team to see.

+ Add link

Requirements Management SE improvement

### Kanban board

Collaboration workflow and agile thinking 3 issues

SE-122

Analysis of requirements visible in more modules

Collaboration workflow and agile thinking

SE-123

Requirements workflow must be feature centric instead of single requirement centric

Collaboration workflow and agile thinking

SE-118

A0 poster for requirements

Collaboration workflow and agile thinking

# Systems Engineering Learning portal



Systems Engineering ★  
*This is an open community*



Notifications ON

Leave community

Welcome to the Systems Engineering community at Grundfos.

Here you can learn about Systems Engineering as defined by the International Council on Systems Engineering (INCOSE) and take part in the discussion.

## Agile Systems Engineering



INCOSE Website

Get to know INCOSE

## Learning plans



### 1D Statistical Tolerance Chains

0%



### Systems Engineering

100%



### Architecture Definition Process

50%



### Verification Process

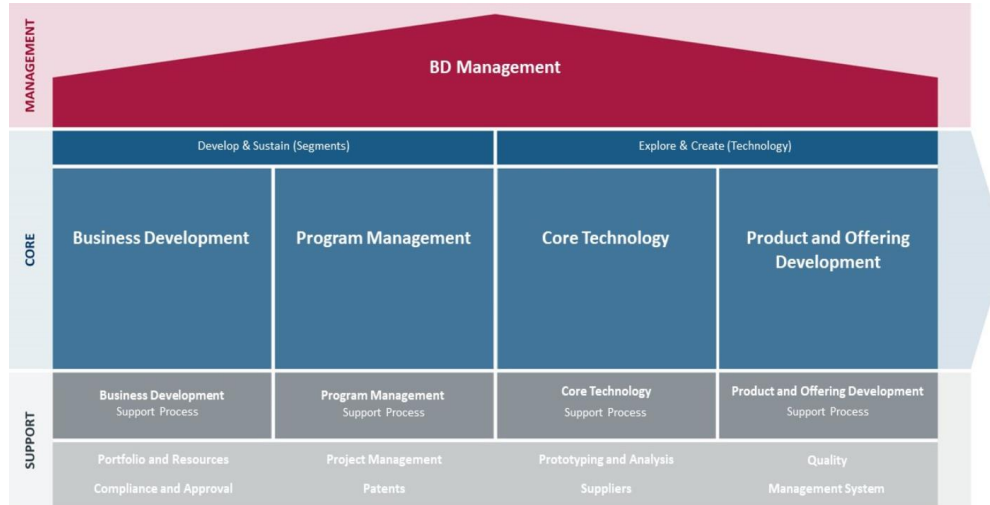
69%

# Topics

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# Process oriented

ISO 9001 Internal  
Audit Program



# ISO 15288 alignment, why and what?

## Our starting point

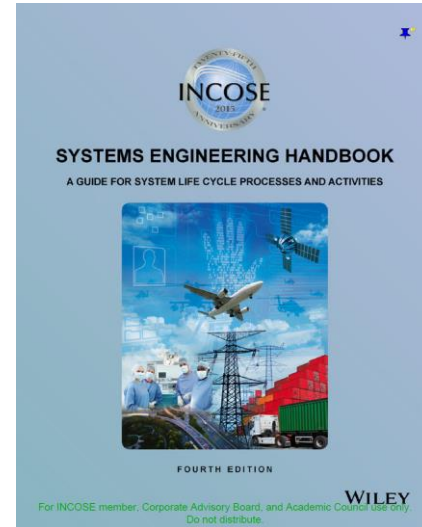
- From software processes
- **to individual sets of processes** within both SW, HW, MECH, and System based on ISO15504/33000

## ISO15288 has provided us with

- a common organizational language/vocabulary
- a holistic view on processes and their interaction

## Which we use to

- simplify and streamline our processes
- create **one set of processes** covering all levels and disciplines



# IDEA-TO-MARKET

## GRUNDFOS IDEA TO MARKET 2.0



### 0 GROUP STRATEGY SETTING



### 1 OPPORTUNITY SCOPING



PRODUCT & SOLUTION  
INNOVATION

Proposals  
for DP

TECHNOLOGY & CAPABILITY INNOVATION

BUSINESS IMPROVEMENT

TECHNOLOGY

ARCHITECTURE

### 2 PORTFOLIO MANAGEMENT



Portfolio Setting  
(Products & Solutions)

Portfolio Setting  
(Technology & Capability)

### 3 EXECUTION



PRODUCT & SOLUTION DEVELOPMENT

MATURING

DEVELOPING

COMMERCIALISE

DECISION POINT MODEL  
(3 DP-Archetypes)

TECHNOLOGY & CAPABILITY DEVELOPMENT

BUSINESS IMPROVEMENT PROJECTS

TECHNOLOGY PROJECTS

ARCHITECTURE PROJECTS

### 4 COMMERCIALISING



MAINTENANCE

### 5 PHASING OUT



PHASE OUT

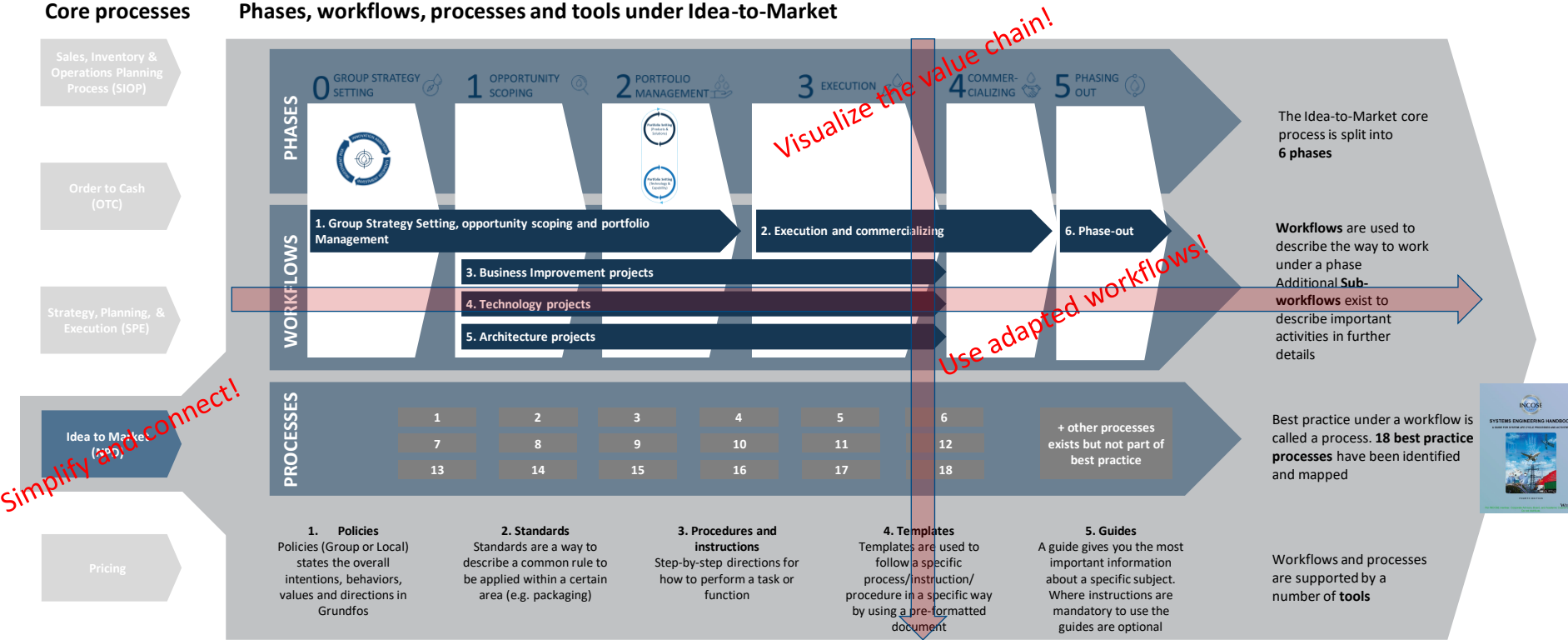
Visualize the value chain!  
Simplify and connect!

Source: Global PMO & Excellence

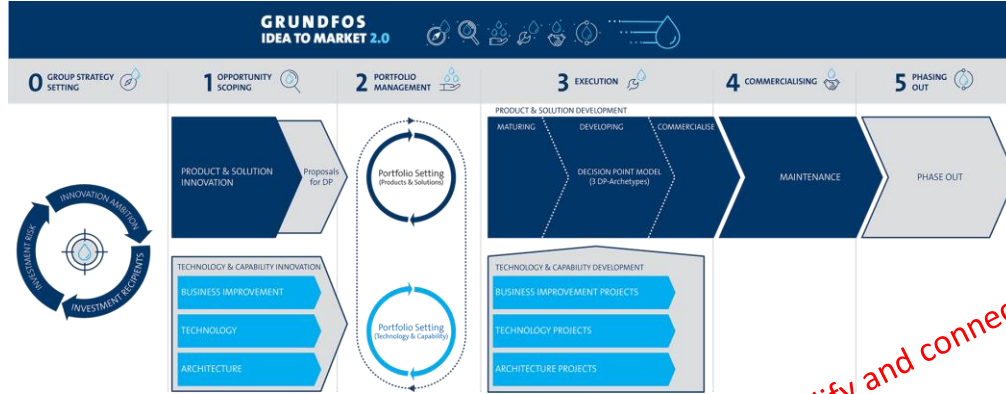
# The Idea-to-Market is described in workflows and best practice processes

Core processes

Phases, workflows, processes and tools under Idea-to-Market



# Using ISO 15288 to remove redundant processes, using these processes for multiple workflows, unifying the "language", and integrating the disciplines



*Simplify and connect!*

Define process roles, independent of job roles - dependent on competences only

*Use process roles!*

## Processes in QMS

Hardware Design Process  
Mechanical Design Process  
Product Design Process  
Software Design Process

Hardware Integration Process  
Mechanical Integration Process  
Product Integration Process

Mechanical Realisation Process  
Hardware Implementation Process  
Product Realisation Process

Mechanical Test & Verification Process  
Hardware Verification Process  
Product Test & Verification Process  
Verification Process  
Software Verification Process

Mechanical Req. Specification Process  
Hardware Req. Specification Process  
Product Req. Specification Process  
System Element Req. Process  
System Req. Definition Process

## Processes in ISO 15288

Design definition process

Integration processes

Implementation process

Verification process

System requirement definition process



# Topics

- Grundfos
- Why Systems Engineering
- Pre-requisites and actions
- How to simplify and connect the process landscape with Systems Engineering
- **Achievements and ongoing activities**
  - **Overview**
  - **Example: Modular architectures**

+ New

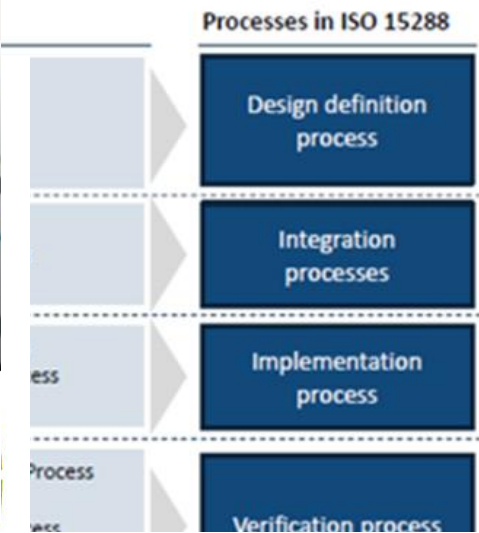
Send by email

Page details

PLAYBOOK FOR

Communities of Practice

Published 5/25/2020



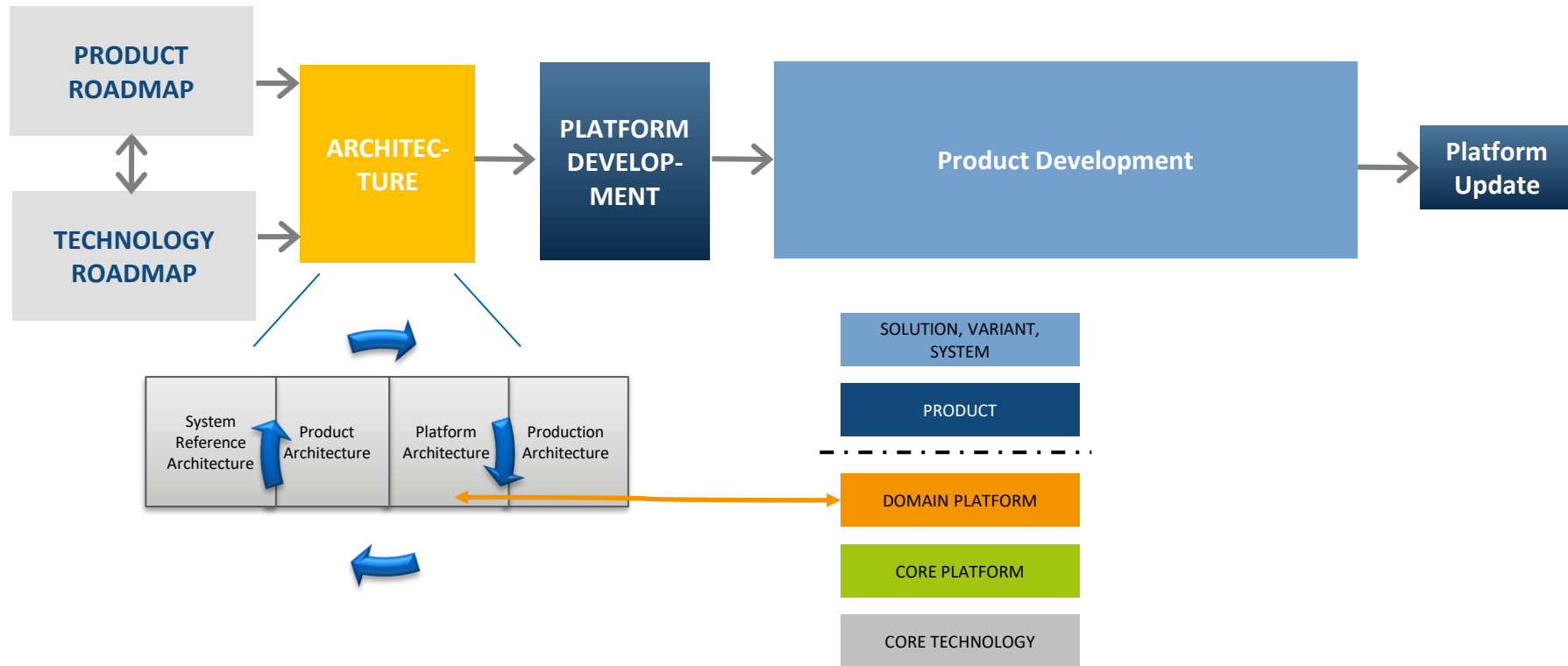
# PLAYBOOK - Communities of Practice (CoP)

Systems Engineering Community



Systems Engineer community

# Identifying and continuing development of platforms



# Identifying and continuing development of platforms


 Power Apps | Grundfos Design Library



  
Product Elements

  
Manufacturing Elements

  
Document Search


  


## Grundfos Design Library

... agreed and documented design foundation

The Grundfos Design Library contains the foundation for designing future product and manufacturing solutions in Grundfos.


The purpose of the library is to store agreed and documented design foundation, and to make it easily accessible to relevant developers in Grundfos.

 Introduction to Grundfos Design Library

 How to search for elements

 How to search for documents

 How to read the one-pager

 How to read the relations page

Request Access

General Feedback

About


Terms of use

CONFIDENTIAL


*\*Internet Explorer is not supported*

# Identifying and continuing development of platforms

Power Apps | Grundfos Design Library



Grundfos Design Library  
— agreed and documented design foundation


Relations 

Product Search

Manufacturing Search

Document Search

Open relations in new

System levels 

Port folio


Families

Products


Assemblies



Sub-assemblies



Parts



Part of 



Control Box Dosing



Consist of 



  HMI PCBA


  Main PCBA



  Heatsink



  PCB Connector


  Display

  TIM (Thermal Interface Material)


Relation to 

  Line - PreAssembly [Mechatronic Assembly]

  Line - Controls [Mechatronic Assembly]

Where Used 

Smart Digital

External Contacts 

Name	Region	Country	Primary Contact Person	Contact Type	Priority
We didn't find any data to show at this time					

# Identifying and continuing development of platforms

Power Apps | Grundfos Design Library

Grundfos Design Library  
... agreed and documented design foundation

One-Pager

Product Search | Manufacturing Search | Document Search | Open element in ne

### Control Box Dosing

**Specifications:**

Power: XX W  
Weight: XX Kg  
Max dimensions (x,y,z): XX x XX x XX mm  
Ambient temp.: XX to XX C  
HMI: XX  
Accessibility: XX  
I/O: XX  
Ready for add-on modules: XX

### Characteristics

Element ID: 115

**Affiliation**  
Organization: POD:ED  
Accountable:   
Responsible:

**Relations**  
Part of: 0  
Consists of: 14  
Relation to: 2  
Where used: 1  
External Contacts: 0

**Classification**  
System Level: Product: 4 - Assemblies  
Group: Control box complete  
Domain: Control Box Dosing.

Version 30.0

### Documents

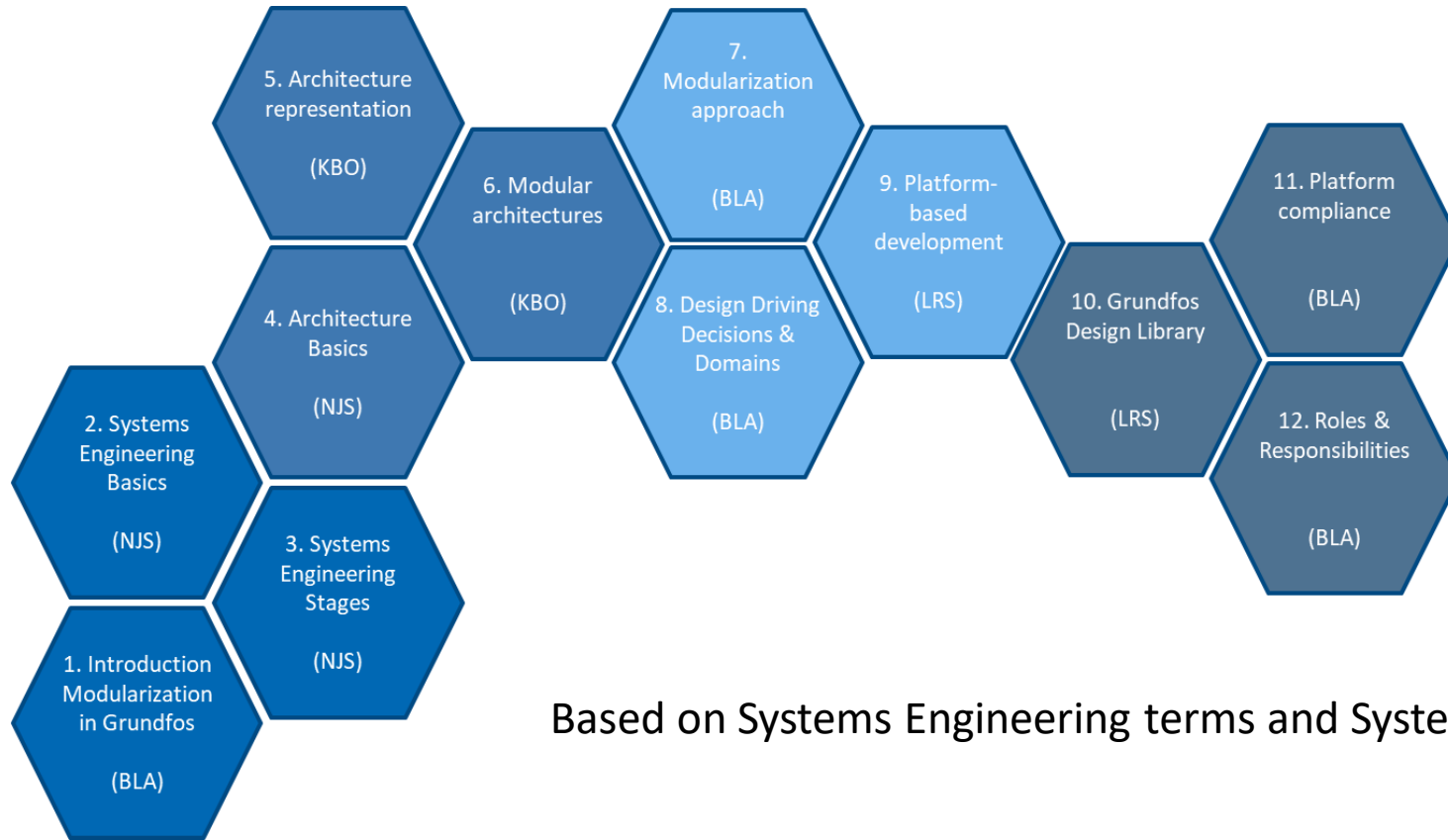
Only visible for employees with document reader access

Document Title (click to view)	Document Type	Document Status	Unique ID (click to edit)	Accountable	Responsible
<a href="#">Domain Architecture [Dosing]</a>	Mechanical Engineering:Archi...	Released	GFDID4168		
<a href="#">Control Box Design Checklist</a>	Mechanical Engineering:Other	Released	GFDID4647		

### Mandatory Document Types

- Mechanical Engineering:Architecture drawing

# Modular Architectures internal course



Based on Systems Engineering terms and Systems Thinking

# Modular Architectures internal course



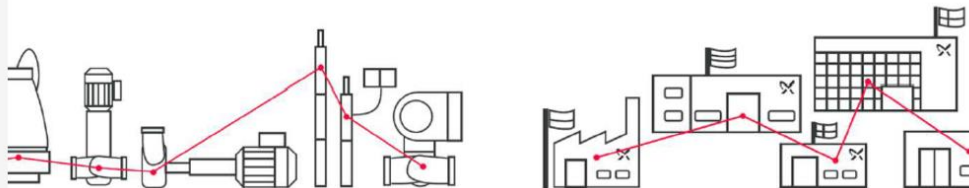
Modularization in Grundfos ★  
*This is a private community*



Notifications ON

Leave community

Welcome to the Modularization in Grundfos community. Here you can get updated on, learn more, and take part in the discussion about Product Development and Manufacturing systems



Learning plans



LEARNING PLAN  
**Modular Architectures**

68%

READ MORE

Inspiration

NEXT EXIT

Explore

Learning plans



LEARNING PLAN

**Modular Architectures**

Participants will get hands on developing and describing architectures based on state-of-the-art methodologies.

68%

Continue

Modules



TOPIC  
**Introduction and Systems Engineering**

Learn: Why we do modularization in Grundfos, and the basic Systems Engineering terms and processes which is the foundation for modularization

20 / 20



TOPIC  
**Architectures**

9 / 9



TOPIC  
**Platforms**

1 / 10



TOPIC  
**Apply and Manage**

0 / 5



# Modular Architectures internal course

## Lesson 2 – Systems Engineering Basics

Lesson 2 – Systems Engineering Basics



INTRO Modular Architectures  
Lesson 2 - Systems Engineeri...

WHAT IS SYSTEMS ENGINEERING?



Systems Engineering Basics -  
Definitions and basic thinkin...

First module on Value of Systems Engineering



Systems Engineering Basics -  
The value of Systems Engine...

A Systems Thinker ...

1. Understand the relationship between the system and its components.  
2. Understand the relationship between the system and its environment.  
3. Understand the relationship between the system and its users.  
4. Understand the relationship between the system and its stakeholders.

Systems Engineering Basics -  
Systems Thinking (2-3)

System Lifecycle



Systems Engineering Basics -  
System life cycle (2-4)

System Levels and System Hierarchy

1. Understand the relationship between the system and its components.  
2. Understand the relationship between the system and its environment.  
3. Understand the relationship between the system and its users.  
4. Understand the relationship between the system and its stakeholders.


Systems Engineering Basics -  
Systems Engineering terms (...)

INCOSE



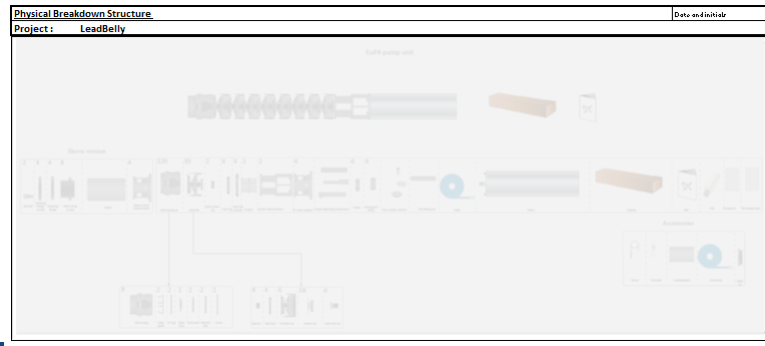
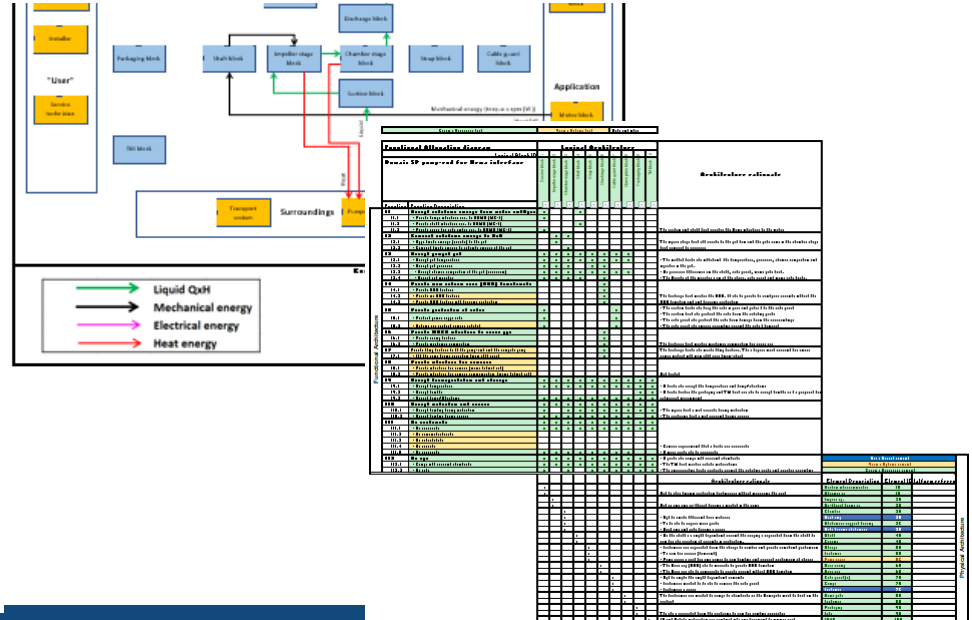
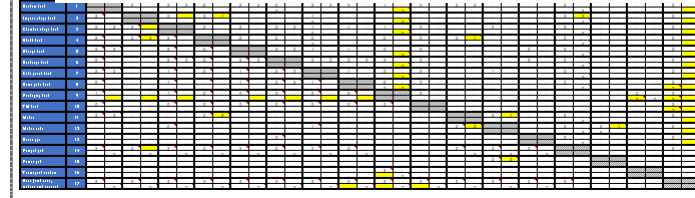
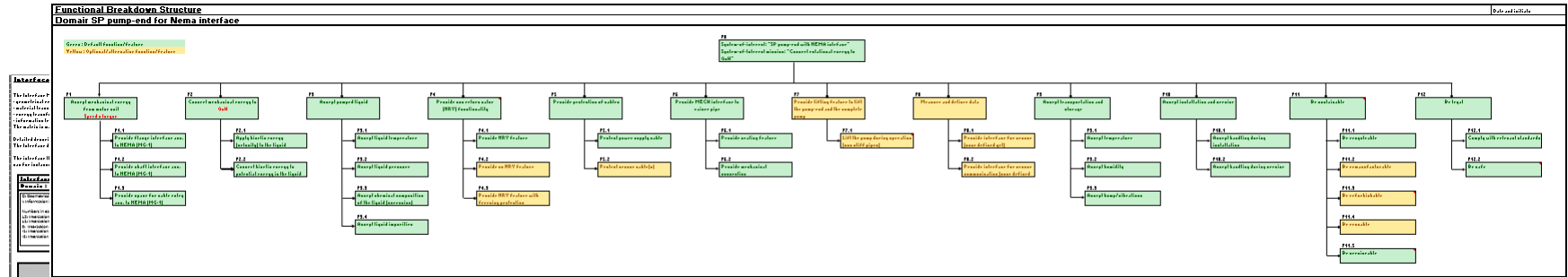
Systems Engineering Basics -  
INCOSE and ISO15288 (2-6)

Slides for Lesson 2 - Systems Engineering Basics



Get to know INCOSE

# Modular Architectures internal course



# Conclusion

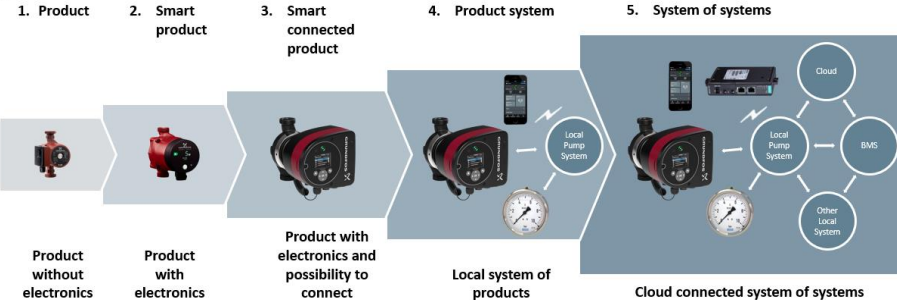
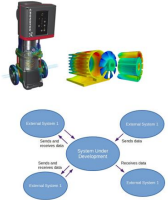
## Systems Engineering has provided us with...

- A common language and way of thinking systems
- A common cross disciplinary platform
- A way to cope with complexity
- A common identity for engineers across disciplines



Systems Engineering is ...

- Modelling
- Reflection
- Context
- Dividing
- Alternatives?
- Distinguish





## Our Purpose

We pioneer solutions to  
the world's water and  
climate challenges and  
improve quality of life  
for people



THANK YOU

# Any questions

