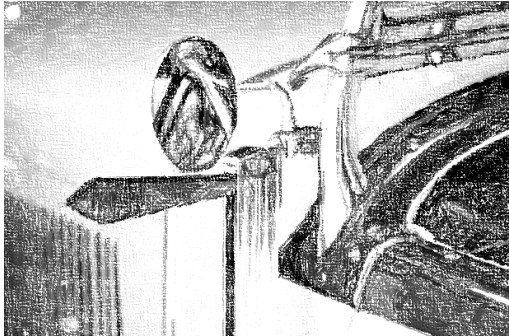# Systems Engineering

Why the heck do we need this?

Alexander Feulner, Sebastian Keller
March 12th, 2024

Earlier Development

Pioneers of development
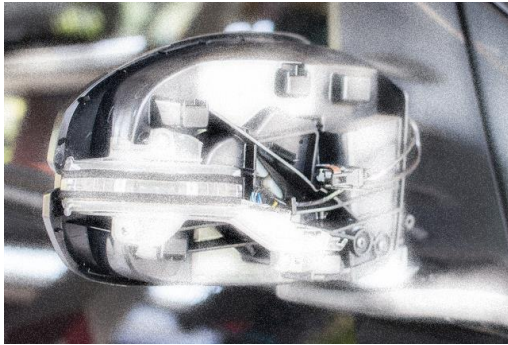
One component was supervised by one person

The component had a clearly defined function

The solution space was mostly open and there was comparatively little financial pressure

The development usually took place over a longer period of time.

For the most part, a prototype was quickly produced and optimized on the basis of trials

Development Nowadays

Shorter development times

A component must fulfil several functions

The component must interact with HW and SW

Development is mostly distributed, sometimes even internationally

Development is under greater cost pressure

Classical mechanics development is increasingly becoming part of modern system development

The development of aerospace

Europa

Challenges:
- Different countries
- Different languages
- Different units (metric/imperial)
- Work packages according to country
→ The Europa program was a failure

Better development approach

Changes:
- Work packages according to knowledge
- Central coordination
- Usage of same language and units

→ The Ariane is one of the most successful carrier rocket in History

Ariane

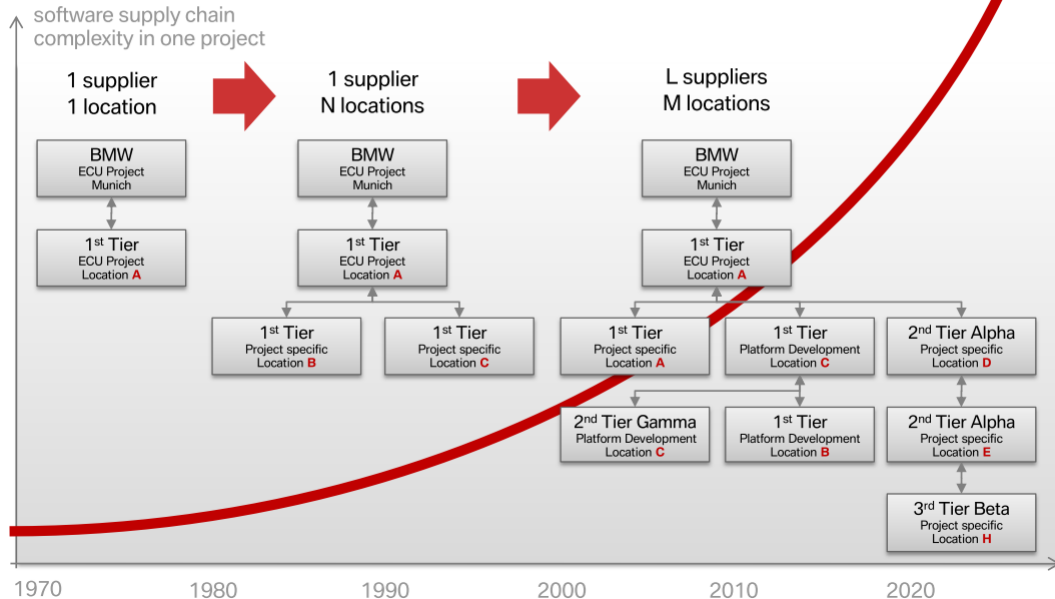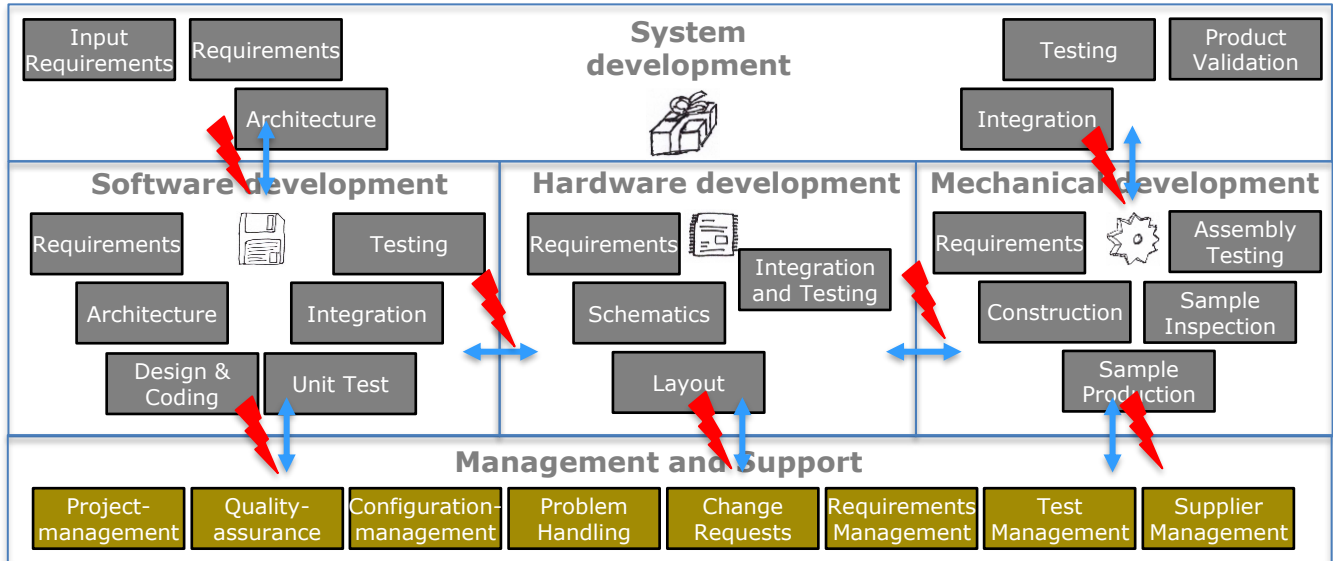# What are the biggest challenges?

Functionality

Complexity

What are the biggest challenges?

Distributed Development

Development of value-added shares at 1st tier suppliers gets realized more and more by usage of distributed development or global software engineering approaches.
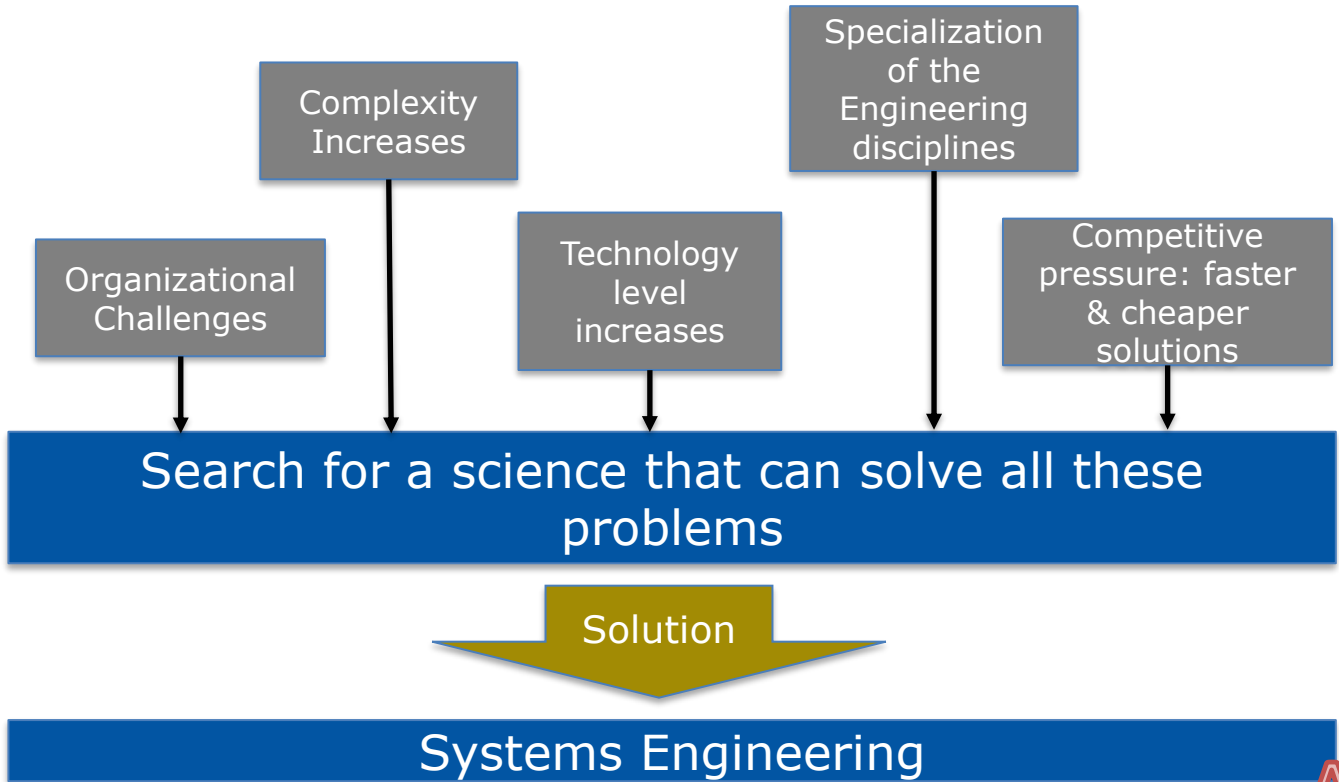
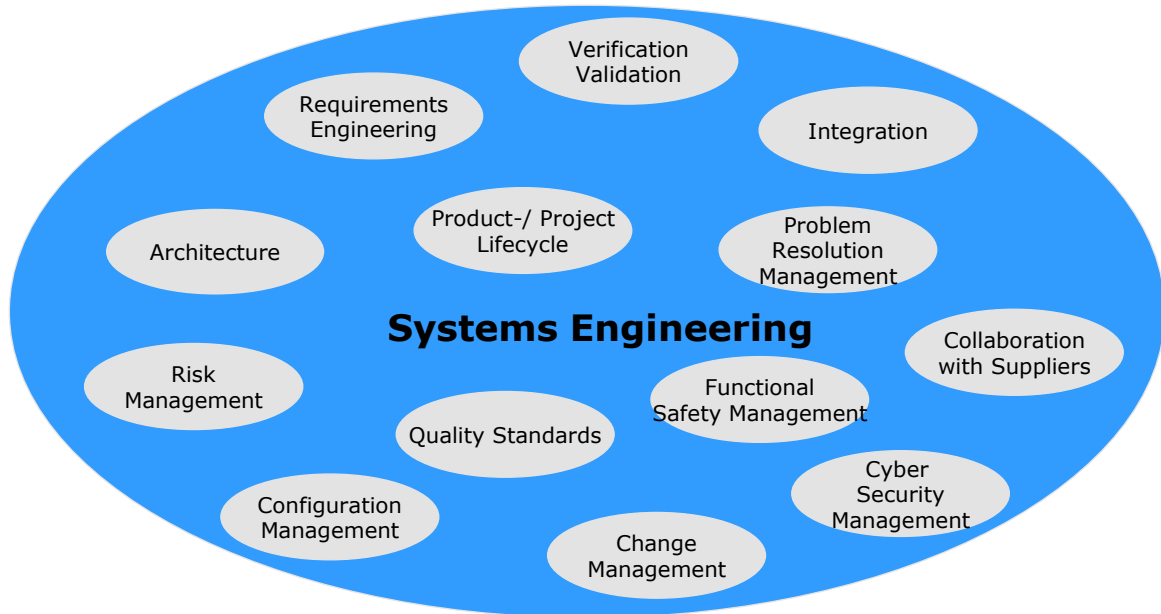# Challenges of the system development

- Problems/challenges typically occur within the domain transfer
- A false interpretation of requirements is often the starting point of several mis-interactions between domains

Reasons for Systems Engineering

Complexity Increases

Specialization of the Engineering disciplines

Organizational Challenges

Technology level increases

Competitive pressure: faster & cheaper solutions

Search for a science that can solve all these problems

Solution

Systems Engineering

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The "umbrella" systems engineering

Systems Engineering

- Verification Validation
- Requirements Engineering
- Integration
- Product-/ Project Lifecycle
- Problem Resolution Management
- Architecture
- Collaboration with Suppliers
- Risk Management
- Functional Safety Management
- Quality Standards
- Configuration Management
- Change Management
- Cyber Security Management

- Systems Engineering is an **interdisciplinary and holistic approach** to support the realization of successful systems
- SE focuses on **meeting customer needs** and to consider the **required functionality as early as possible** in the development process, and the complexity caused by the problem statement

Main Activities of Systems Engineering

- **Hierarchization:** Identification of system levels
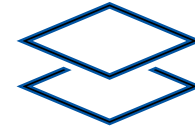
- **Structuring:** Identification of components and interfaces

- **Managing:** Maintaining of interfaces and communication between different domains

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Hierarchization: Identification of system levels
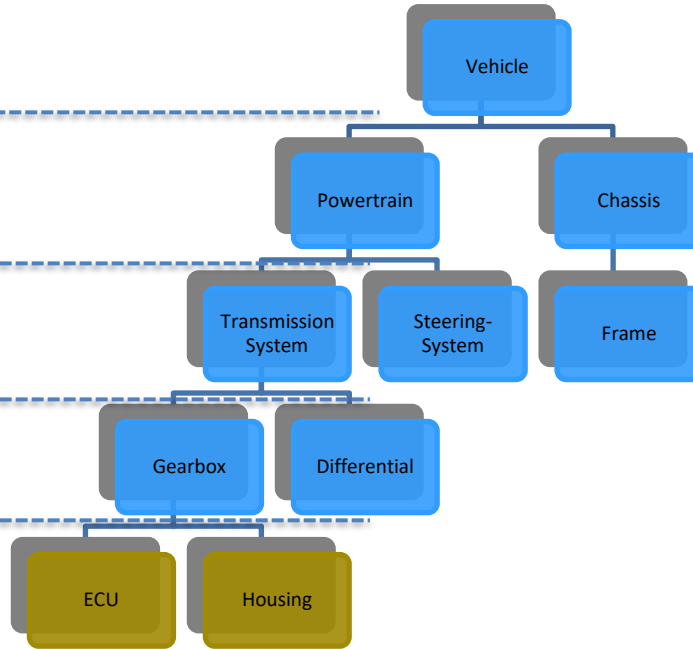
Example: Structure of a vehicle

Vehicle System Level

Vehicle

Sub System Level 1

Powertrain | Chassis

Sub System Level 2

Transmission System | Steering-System | Frame

Sub System Level 3

Gearbox | Differential

Component Level (HW/SW/Mech)

ECU | Housing

Structuring: Identification of components and interfaces

Example: Door System

window

HW ME engine

ME lifting device ME

ME

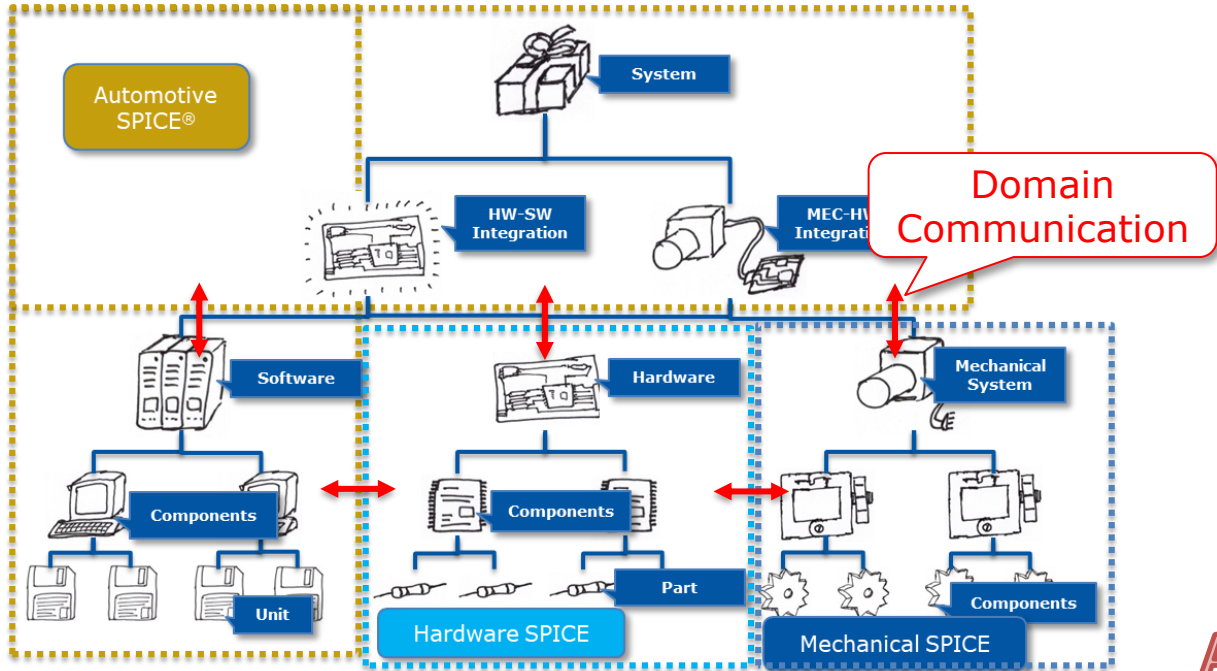control HW SW

ME HW

user → switch HW

System context

external control unit

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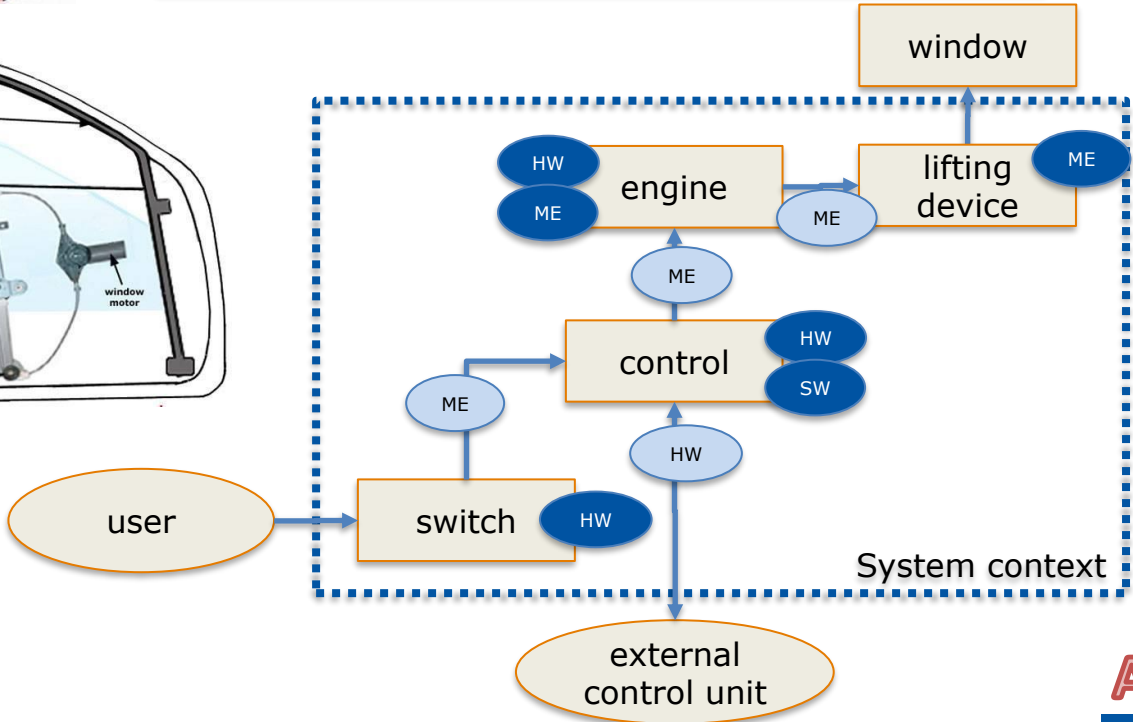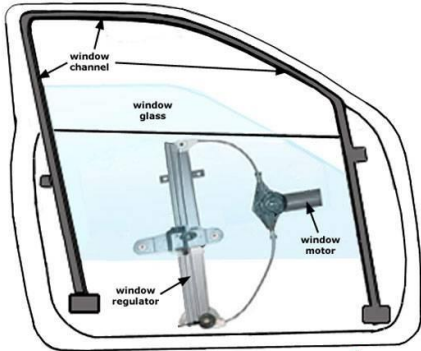
Managing: Maintaining of interfaces and communication between different domains

Example: Domain Development

Automotive SPICE®

System

HW-SW Integration

MEC-HW Integration

Domain Communication

Software

Hardware

Mechanical System

Components

Components

Components

Unit

Part

Hardware SPICE

Mechanical SPICE

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Competencies of a Systems Engineer

✓ Trying to understand the "**big picture**"

✓ Observe how system elements change over time

✓ Are aware that the structures of a system trigger a certain behavior

✓ Changing their **point of view** to come to a better understanding and **handling complexity**

✓ Look at a **problem from all angles** and don't let yourself be tempted to prefer a quick solution

✓ Consider both **short-term** and **long-term consequences**

✓ Keep an eye on **cause-and-effect** relationships

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# Responsibilities/Solution of Systems Engineering

Responsibilities:

- **Balancing the conflicting** notions of specialist departments
- **Efficient and goal-oriented** management of interdisciplinary project teams
- Promotion of **strategic thinking** and acting
- **Improve communication** between all project stakeholders
- Bringing the **knowledge to all levels**
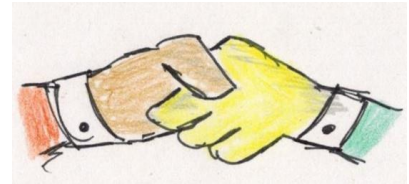
Solutions:

- Distribution of **systems engineering methods**
- Establishment of system engineering teams on organizational and project level
- Enhancement of **generic/ platform development**
- Enterprise Architecture Management → **Harmonization of the tool chain**
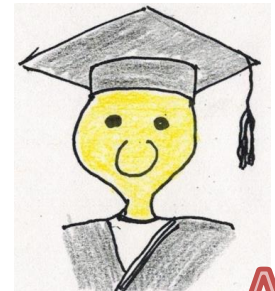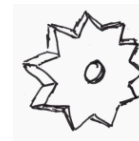
Increasing demand of Systems Engineering – OEMS

Stellenbörse

Meine Suche ∨   Mein Profil ∨

Systems Engineer Research & Development (f/m/d)

📍 Wolfsburg 👤 Forschung und Entwicklung ⬙ Berufserfahrene 🗓 Veröffentlicht am 06.04.2023 ⬗ Tarif/Tarif Plus

Diese Stellenausschreibung ist bereits abgelaufen.

CENTER SYSTEMS ENGINEERING

Home   Über uns ∨   Angebot   SEC ∨   Aktuelles   Karriere   Kontakt

BMW Group wird neues Mitglied im Center for Systems Engineering auf dem RWTH Aachen Campus

Home ▸ Pressemitteilungen ▸ BMW Group wird neues Mitglied im Center for Systems Engineering auf dem RWTH Aachen Campus

Transformation des Volkswagen Entwicklungsprozesses.

System Engineering verkürzt Entwicklungsprozess um rund 25 Prozent
Die zunehmende Vernetzung des Fahrzeugs, dessen angestrebte nahtlose Einbindung ins digitale Ökosystem und der konsequente Fokus auf die User Experience erfordert eine Neugestaltung des Entwicklungsprozesses. Ausgangspunkt der Fahrzeugentwicklung sind die an den Kundenanforderungen orientierten neuen Funktionen. Der neue
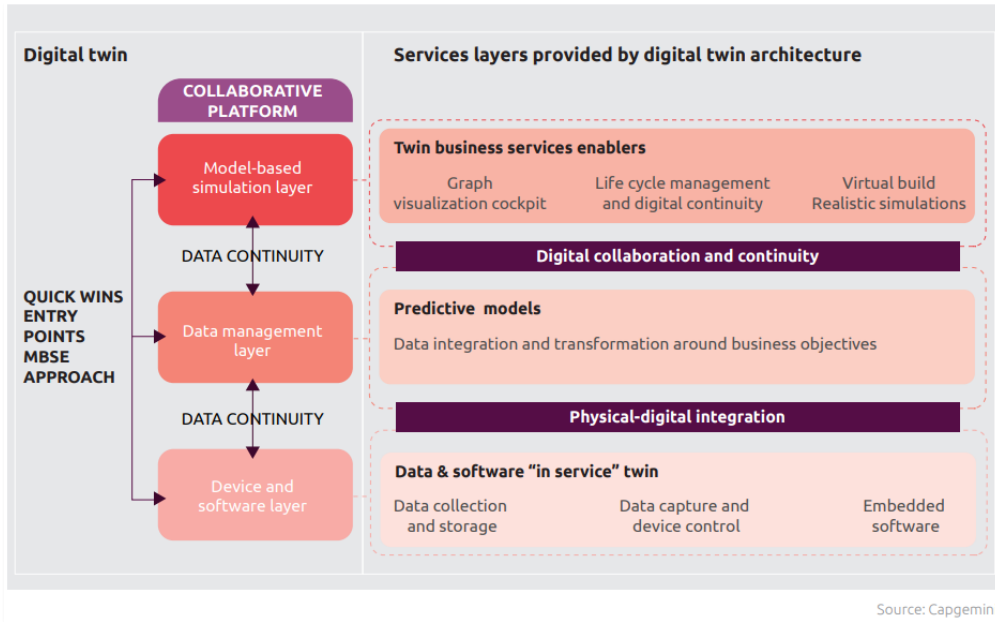
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Increasing demand of Systems Engineering – People, Jobs

	People*	Jobs*
XING	**10.000+**	**5.705**
Linked in	**4.190.000**	**4.173**
stepstone		**53.829**
Jobware		**2.915**
INCOSE International Council on Systems Engineering	**23.000+**	

data from 29.02.2024

Trends in Systems Engineering Enhancement via MBSE (Example: Digital Twin)

Source: Capgemini.

A **digital twin** is a **virtual replica** of a **physical system** that can model, simulate, monitor, analyze, and constantly optimize the physical world. A **digital twin architecture enhanced by MBSE** helps deliver the digital twin initiatives in a smooth manner.
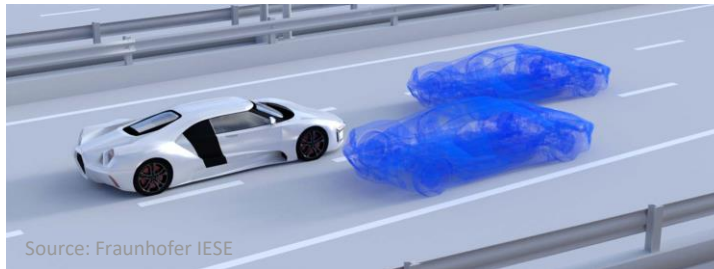
Digital Twin for testing

Cost reduction

Faster time-to-market

Higher variability

Higher quality

no real enviroment

Higher grade of automation

Initial effort of implementation

Cannot completely replace tests

Source: Fraunhofer IESE

Conclusion

- ✓ Development is getting more and more complex due to increased functionality and distributed development

- ✓ Solutions needed for exploding budgets, schedules and resource needs

- ✓ Demand for 'Systems Engineers' will increase due to interdisciplinary aspects

- ✓ Systems engineering means to take over responsibility to find solutions for complexity and organizational challenges

- ✓ Methods derived from systems engineering can be used for various challenges

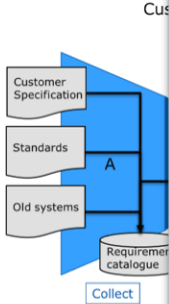- ✓ Future development has to follow strategic approaches
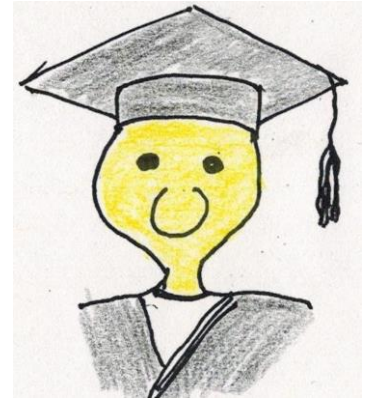
Next Training:

Systems Engineering aligned with Safety, Security and SPICE
June 3 – June 5, 2024, online, English (9 am – 5 pm CET)

What documents are included?

Customer Specification
Standards
Old systems

A

Requirement catalogue

Collect

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Relationship between architecture design and evaluation

Influencing factors and architectural

Basic design principles

Abstraction
Hierarchy-based
Loose coupling
Strong cohesion
open-closed principle
Secret principle
Encapsulation
Modularity
Separation of interests
Conceptual integrity

Typical component types

AUTOSAR modules
Control application
Sensors
etc.

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Test objects depending on testing levels

Acceptance testing
- Complete vehicle with the integrated component
- Device under Test (on a testbench)

System testing
- Complete Integrated System
- Operating System

Integration testing
- Partly integrated System
- Fully integrated System

Software (Unit) testing
- Software Unit
- Integrated software
- Feature/Function

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