AV Lecture in Summer Term 2018

Dr.-Ing. Alexander **Willner**

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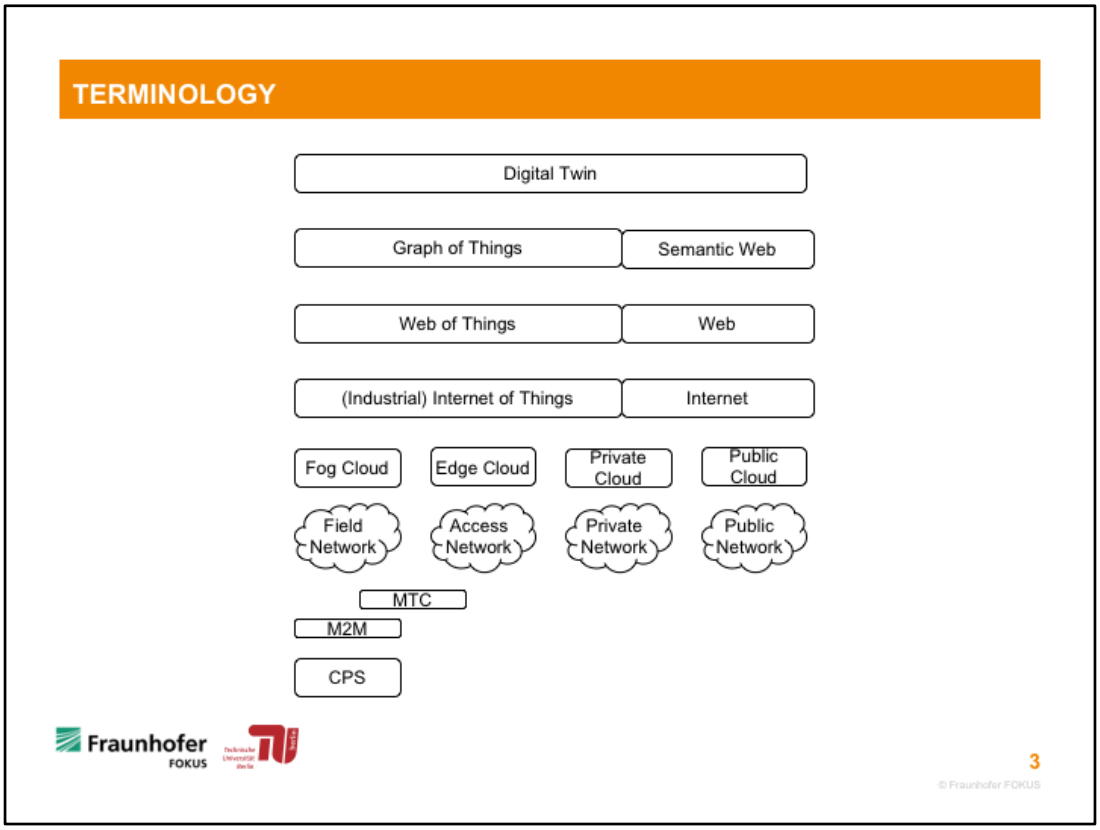
THE LAST LECTURE

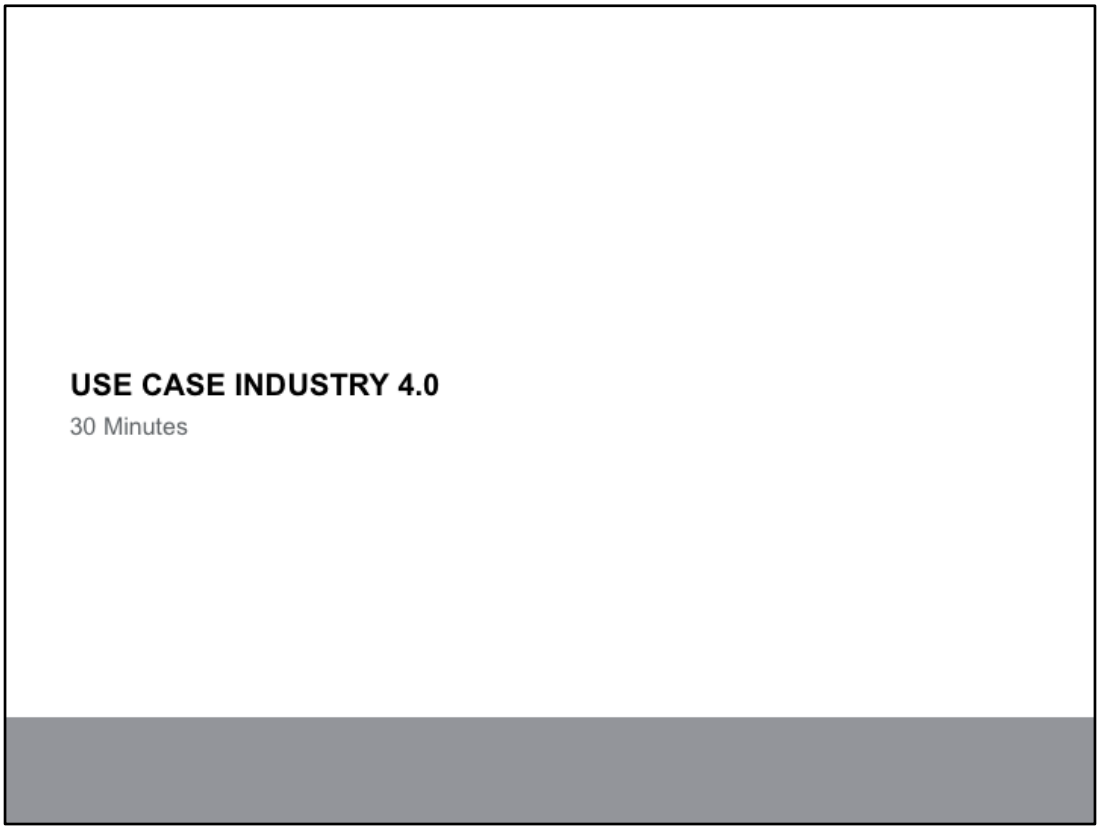
5 Minutes



- We‘ve talked about the relevant terminology from CPS to Digital Twins
- It‘s important to have a basic understanding of the general concepts in the IIoT context
- In particular, we talked about CPS, M2M vs. MTC, Fog/Edge Computing, IIoT, WoT, GoT, DT

OVERALL TERMINOLOGY

Questions?



- Most of these components play an important role in the next industrial (r)evolution.
- What is Germany known for?

- We‘re focussing on the manufacturing part in this lecture

INDUSTRY 4.0
USE USE OF IOT TO MANUFACTURING VALUE-CHAINS

Industry 4.0 [or Smart Manufacturing or Factories of the Future] combines production methods with state-of-the-art information and communication technology towards intelligent and flexible production [http://www.plattform-i40.de]. The term "Industrie 4.0" was revived in 2011 at the Hannover Fair.

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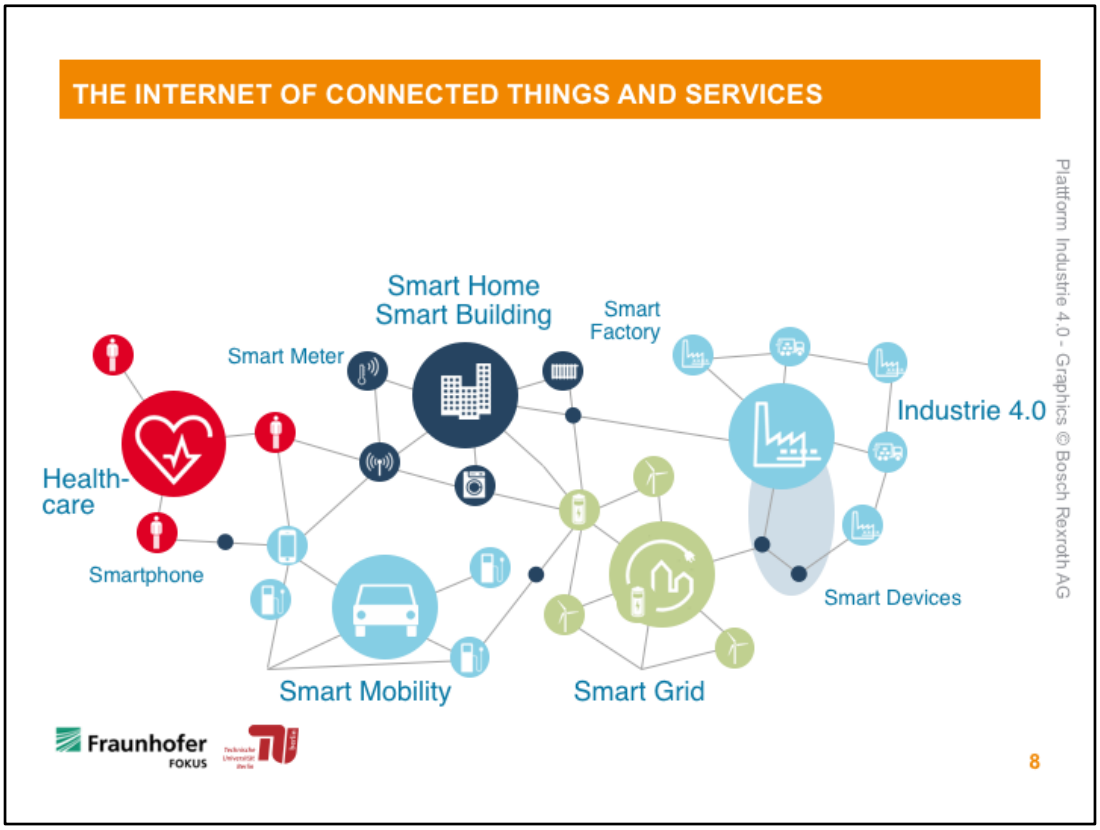
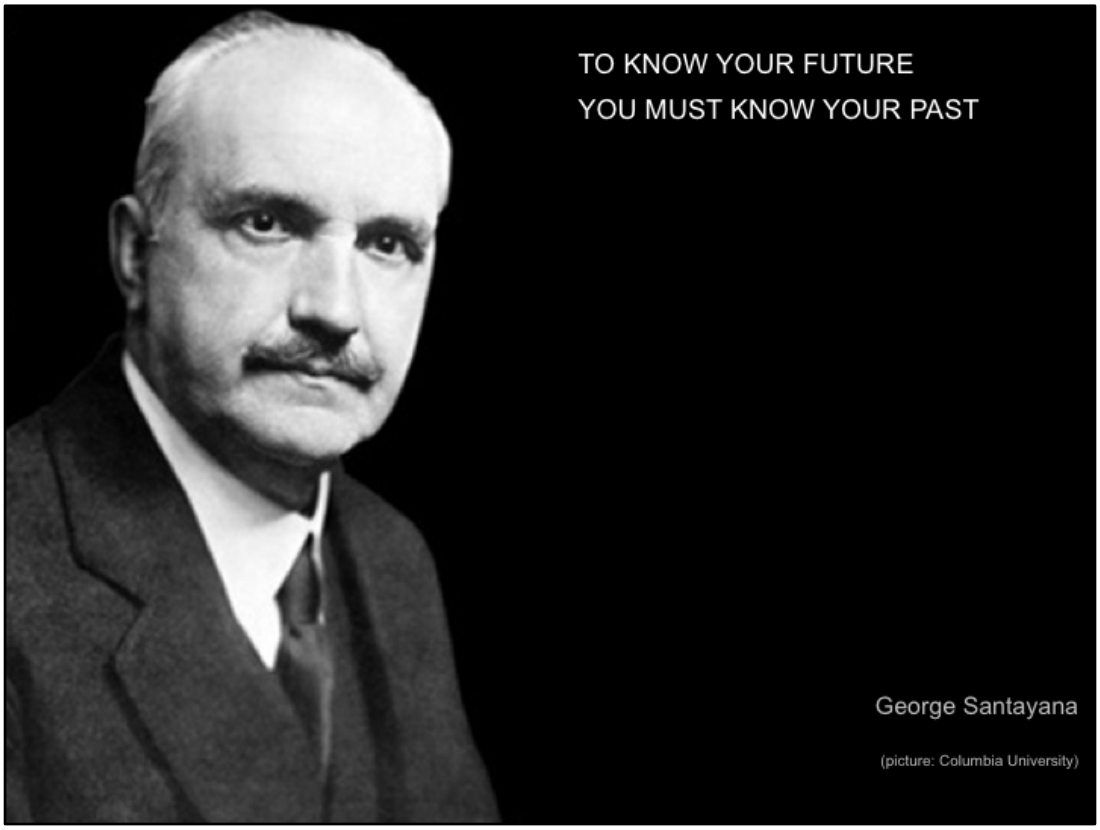
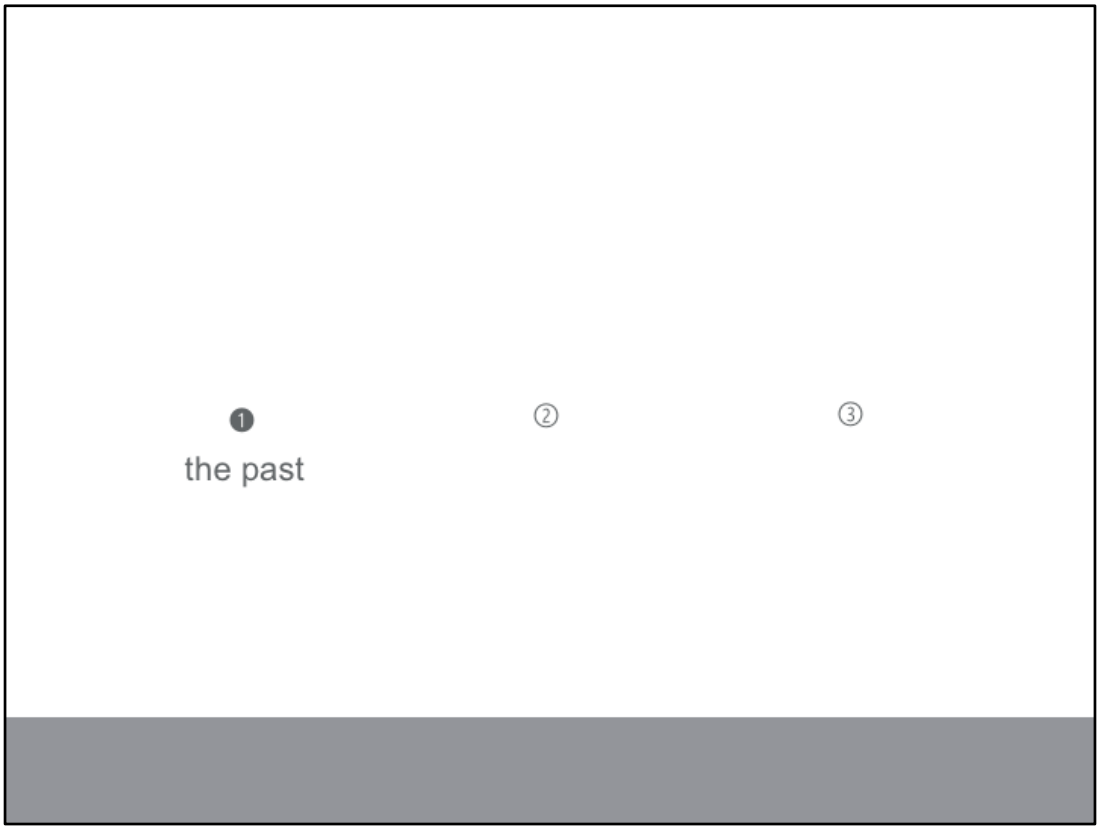


- Smart Mobility: Thanks to intelligent traffic control, traffic jams become a thing of the past.
- Smart Grids: Networking and management of electricity producers, storage facilities, consumers, and grid equipment.
- Smart Homes: Improved living conditions, quality of life, and security. More efficient energy use due to networked devices and installations as well as automated processes.
- Smart Healthcare: Monitoring systems for people with chronic conditions, health-oriented exercise programs, and intelligent emergency call systems.
- Smart Factories: In the world of Industrie 4.0, intelligent components and machines form networks and autonomously control production processes.

INDUSTRIE 4.0 IS EITHER A SUBSET OF THE „INTERNET OF THINGS AND SERVICES“ OR DESCRIBED THE OVERALL IDEA OF INTERCONNECTING THE WHOLE VALUE CHAIN.

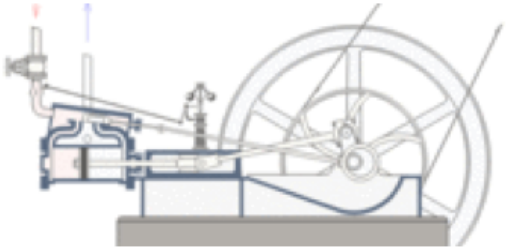


- Spanish philosopher
- So, why is it called Industry 4.0?



- We'll talk about three points here.
- First: the past

IT ALL STARTED WITH THIS…



https://de.wikipedia.org/wiki/Industrielle_Revolution

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- A steam engine

VIDEO | MY SON IS FASCINATED BY A REAL STEAM ENGINE

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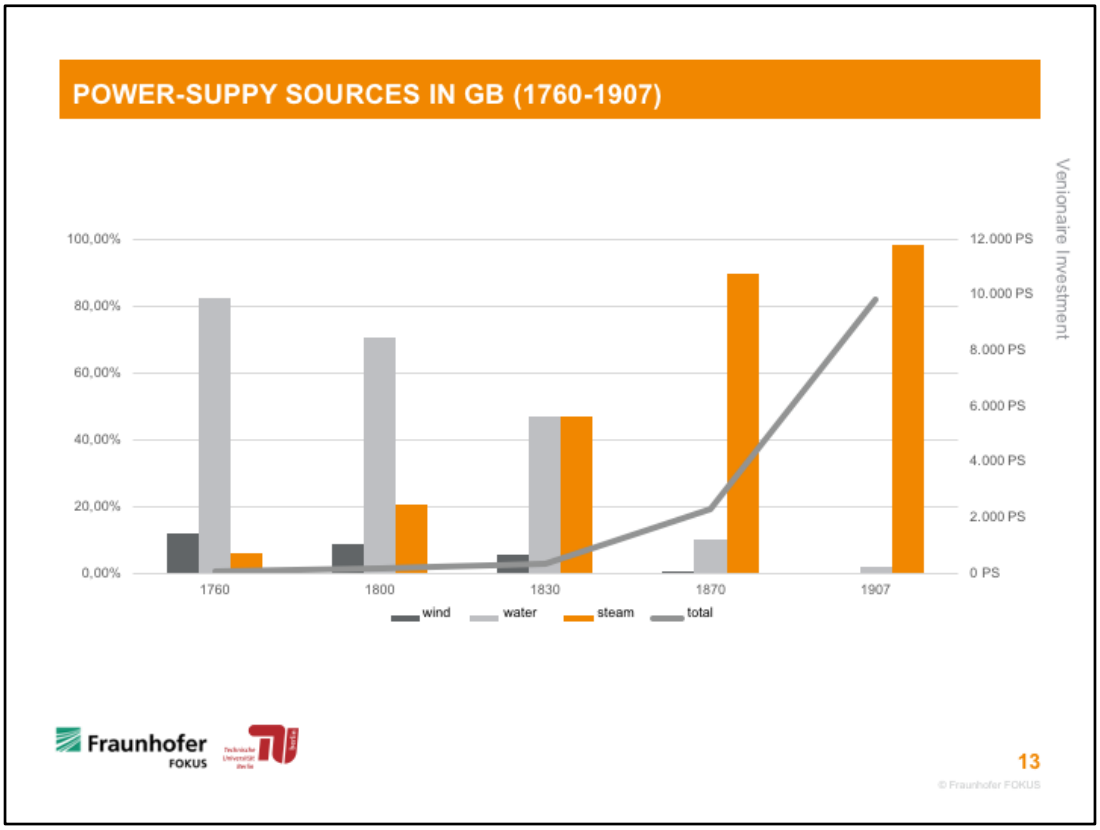

- Massive change from water-based to steam-based power supply in 150 years.

THE INDUSTRIAL REVOLUTION

First Industrial Revolution
Mechanical production powered by water and steam

End of 18th century	Start of 20th Century	Start of 70's	The Future

Complexity

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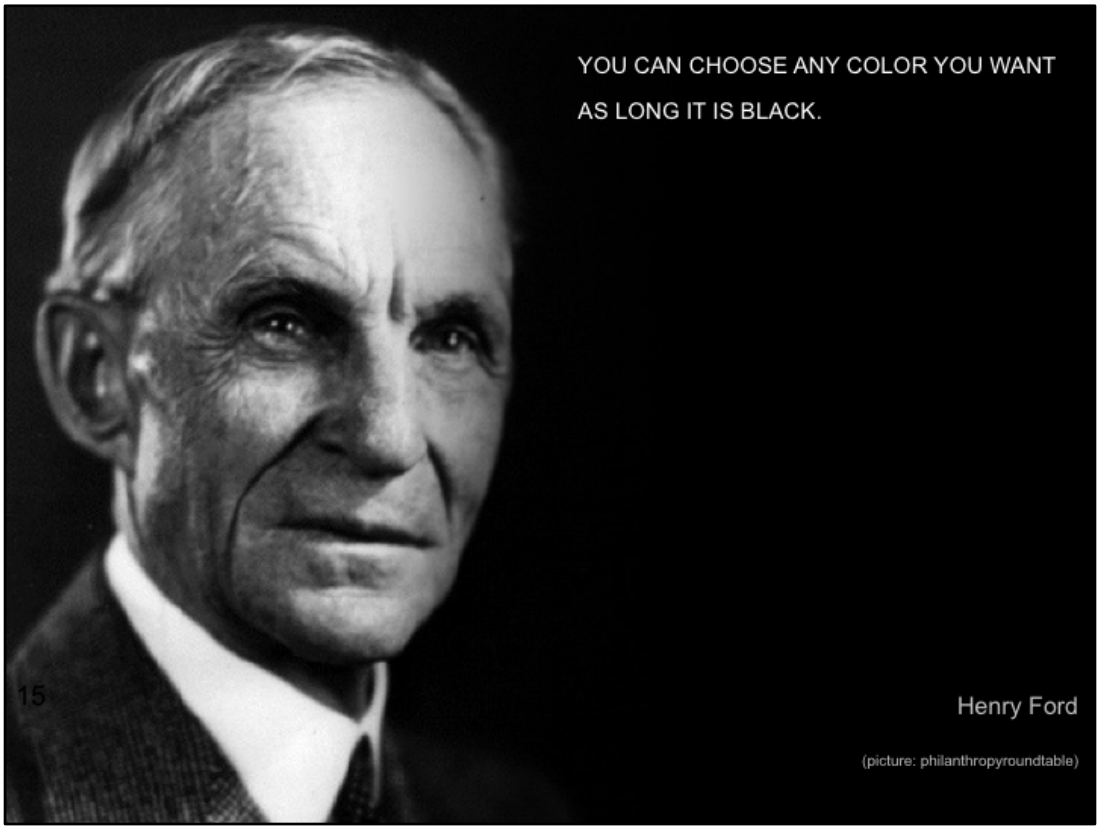
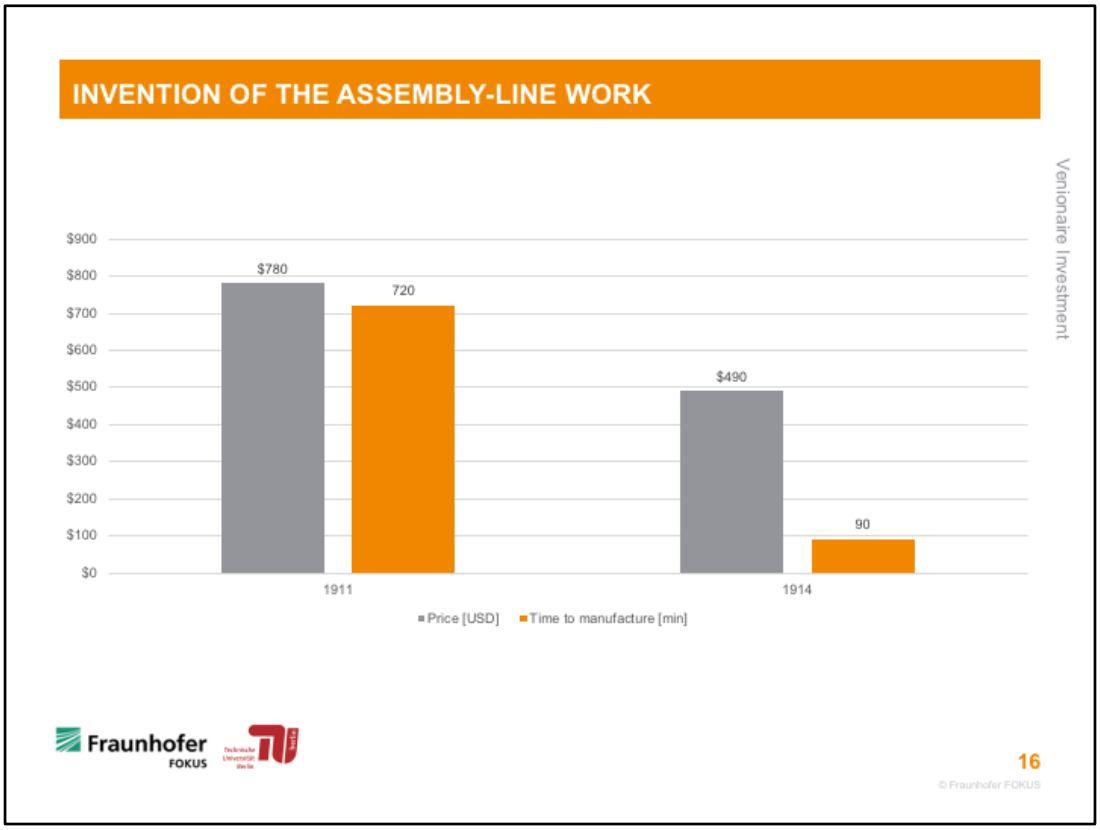

YOU CAN CHOOSE ANY COLOR YOU WANT
AS LONG IT IS BLACK.
15
Henry Ford
(picture: philanthropyroundtable)



- Massive reduction of costs and time to manufacture within 3 years

THE INDUSTRIAL REVOLUTION

Second Industrial Revolution
Mass production based on division of labour and electrical energy

First Industrial Revolution
Mechanical production powered by water and steam

End of 18th century	Start of 20th Century	Start of 70's	The Future

Complexity

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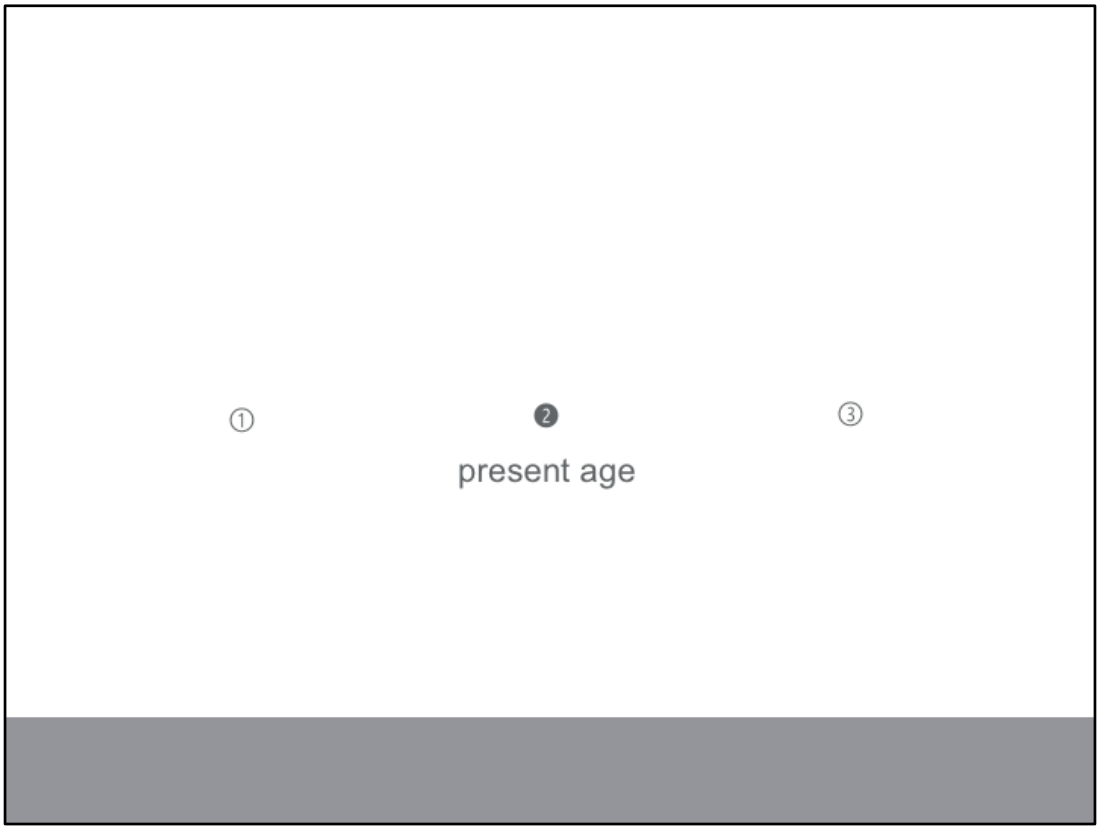
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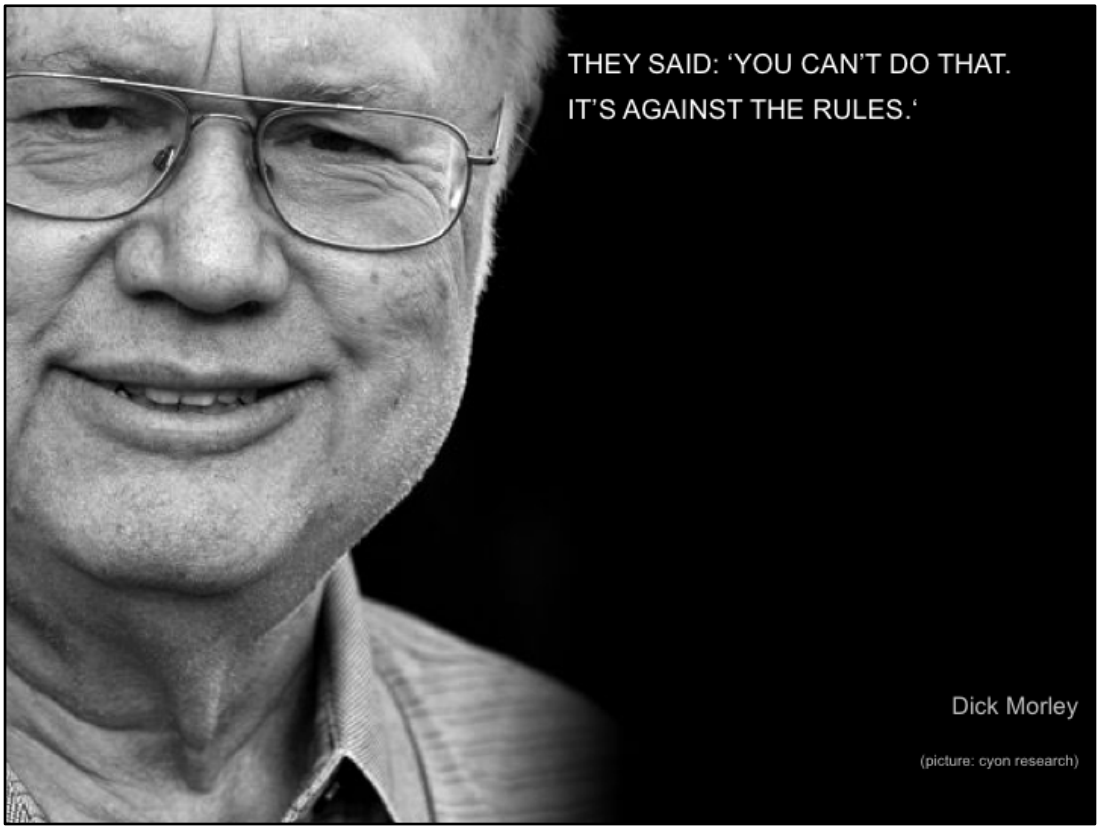
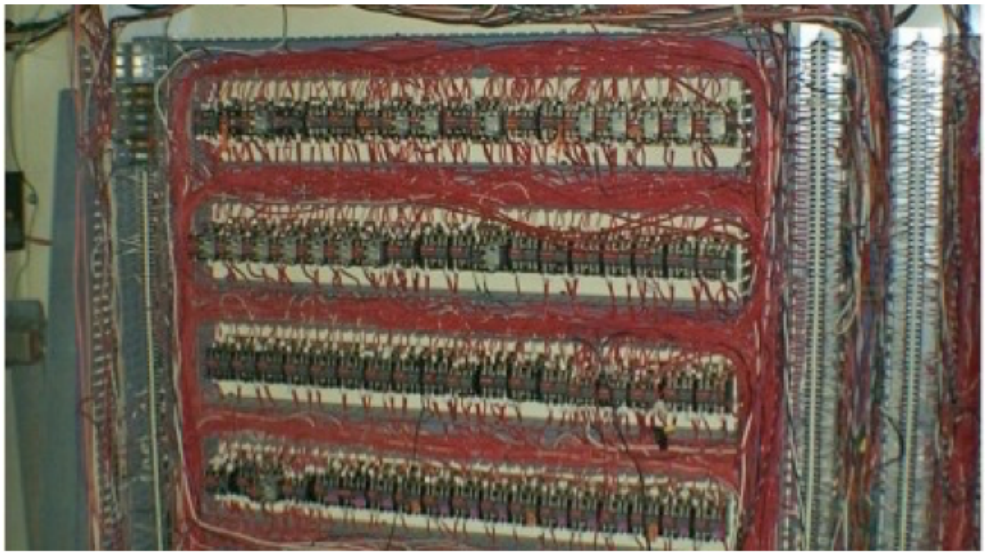
present age



- Morley invented the Programmable Logic Controller (PLC) 1968 at General Motors

AROUND 1965



Tofino Security

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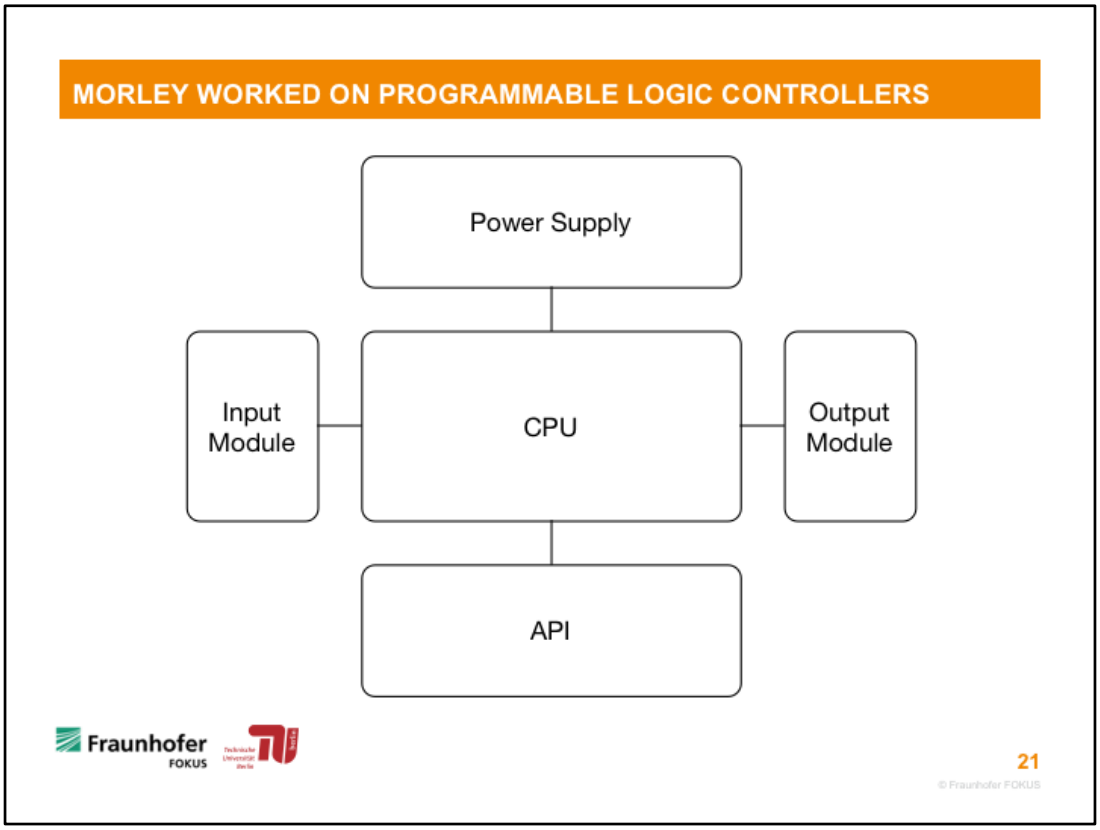
- Before mainly relays, timers and dedicated closed-loop controllers were used.

Updating such facilities was very time consuming and expensive.



- Simplified and modernized version (see “API”) of the components of a PLC (1968)

THE ORIGINAL 084

Automation.com

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SINCE THEN PLC'S EVOLVED

profibusgroup.com

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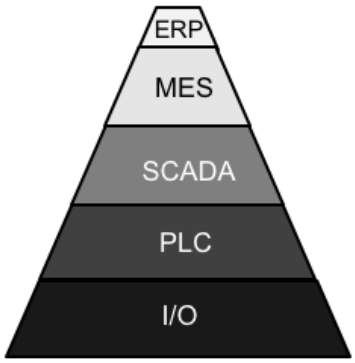
- An example: a WAGO 750-375 PROFINET Coupler

5-LAYER AUTOMATION PYRAMID



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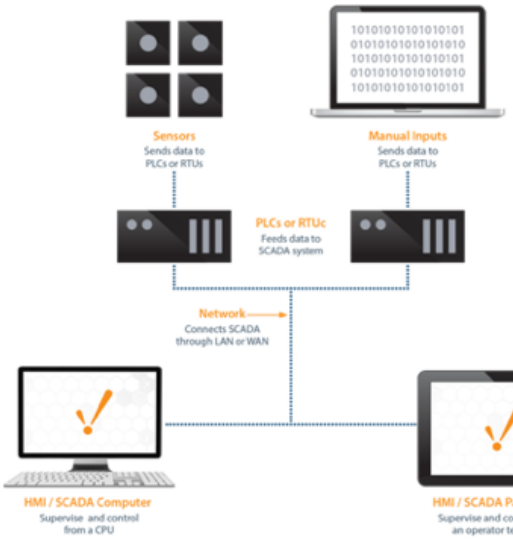
- Within the last centuries, the 4-layer automation pyramid has been established in the manufacturing context.
- Input/Output (I/O)
- Programmable Logic Controller (PLC)
- Supervisory Control and Data Acquisition (SCADA)
- Manufacturing Execution System (MES)
- Enterprise Resource Planning (ERP)

SUPERVISORY CONTROL AND DATA ACQUISITION (SCADA)



Inductive automation

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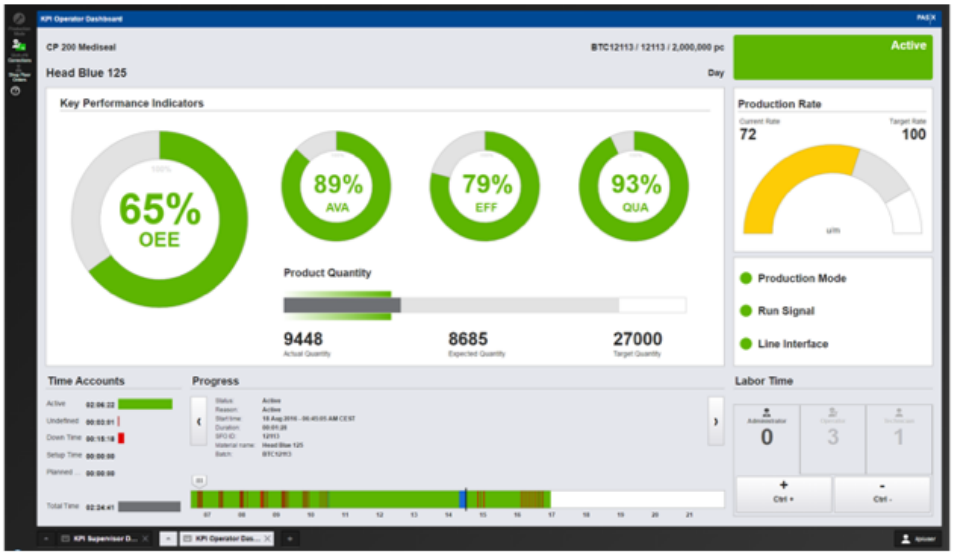
- An industrial network to connect PLC's and HMI's with each other.
- SCADA systems are the backbone of modern industry.
- RTU = Remote Terminal Unit.
- HMI = Human Machine Interface.

MANUFACTURING EXECUTION SYSTEM (MES)



Werum IT Solutions

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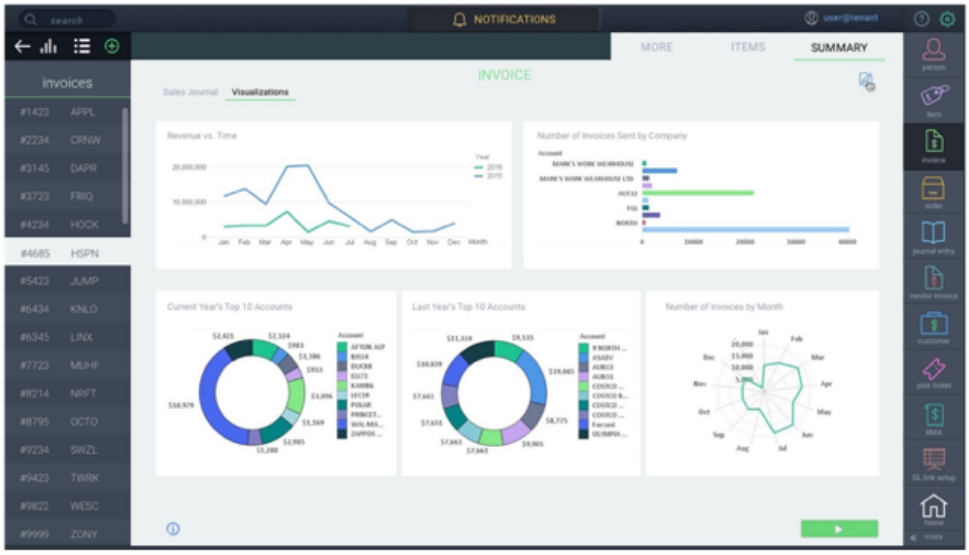
- Centralized monitoring and control instance to optimize the production.

ENTERPRISE RESOURCE PLANNING (ERP)



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- Integration into further processes such as invoicing, order management, demand estimation, … for further optimization.
- Often not yet established in smaller/medium sized factories.

THE INDUSTRIAL REVOLUTION

Third Industrial Revolution
Electronics & IT for further automatization of production

Second Industrial Revolution
Mass production based on division of labour and electrical energy

First Industrial Revolution
Mechanical production powered by water and steam

Complexity

End of 18th century	Start of 20th Century	Start of 70's	The Future

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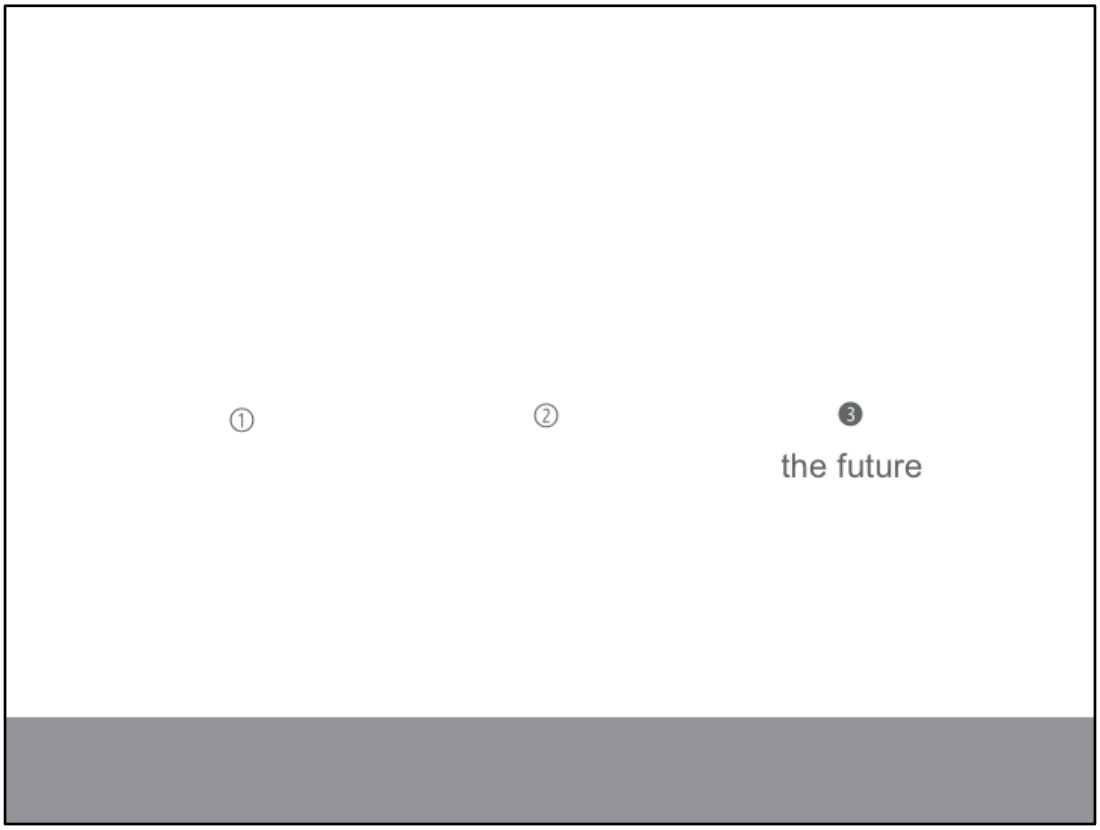
①
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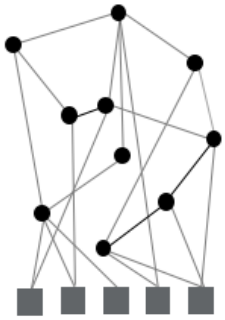
the future

CYBER-PHYSICAL SYSTEM (CPS) BASED AUTOMATION



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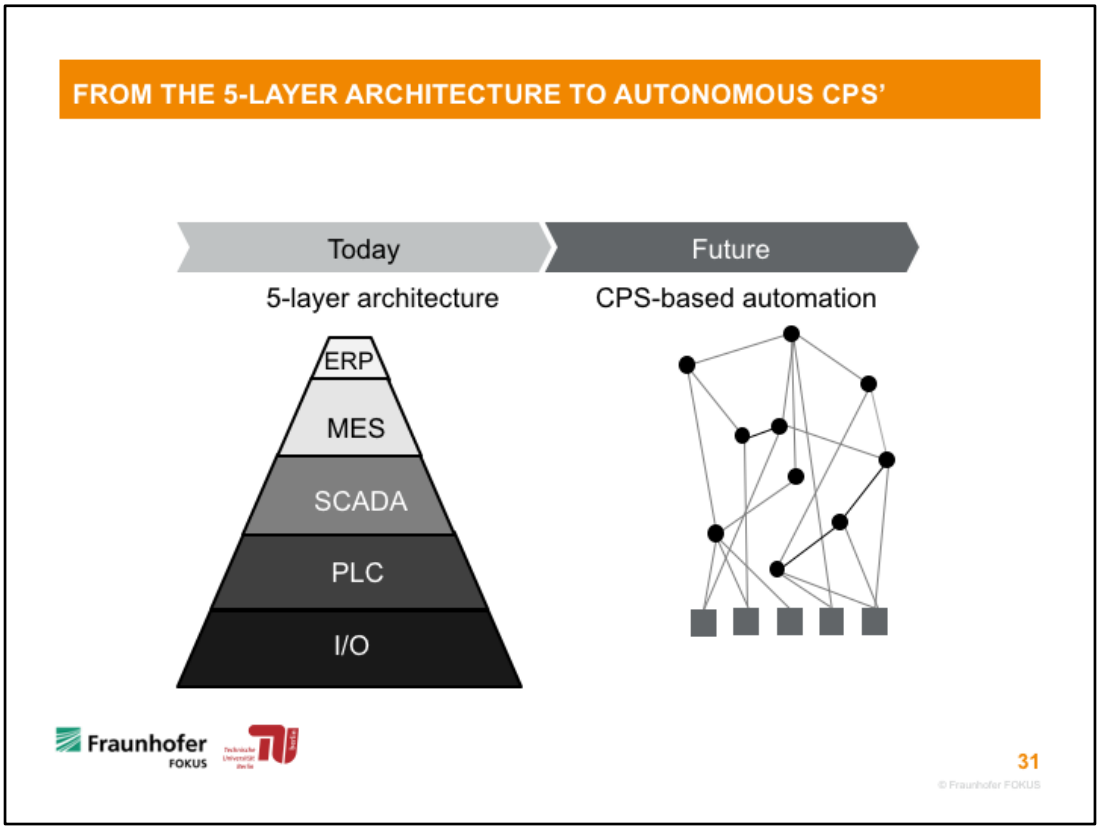
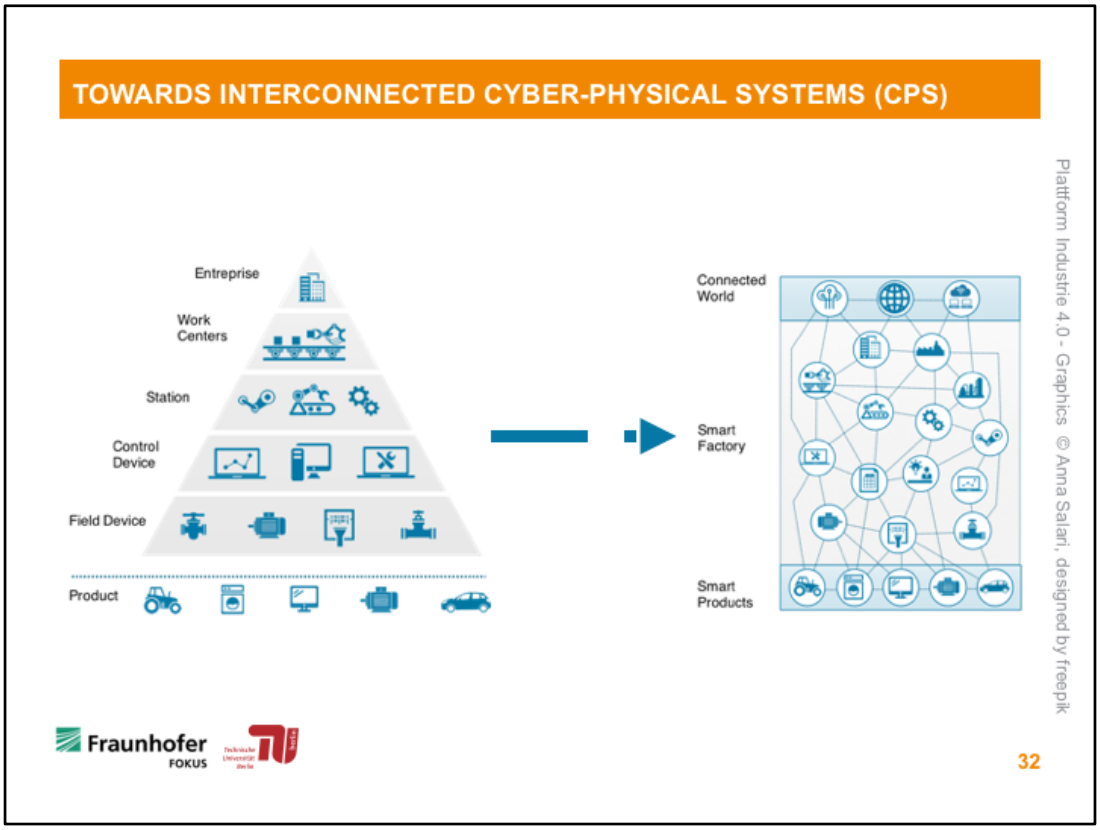
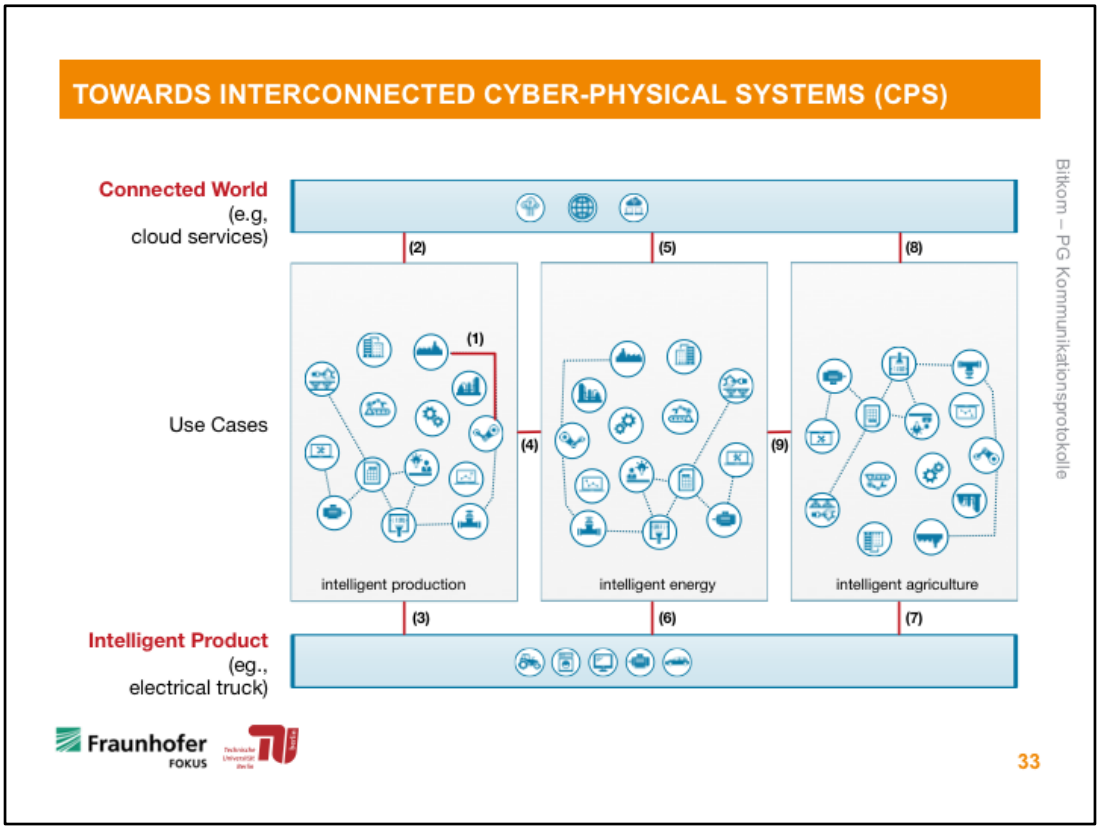
- We discussed already what a CPS is.
- The idea is to have autonomous CPS‘s that communicate with each other to enable a flexible manufacturing process.



- The functionalities of the typical automation pyramid might move, step by step, towards CPS-based automation.

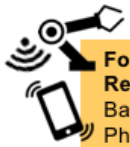


- As a result, we'll have "smart products", "smart factories" and a "connected world"



- However, the vision might go further.
- An example of a electrical truck
    - 1: Communication between machines
    - 2: Communication between the factory and the cloud
    - 3: Communication between the product and the factory
    - 4: Communication between domains (e.g. energy and manufacturing) for flexible energy demand response.
    - 5: Communication between the product and the cloud
    - 6: Communication between the product and the power grid
    - 7: Communication between the product and the agriculture domain
    - 8: Communication between the agriculture domain and the cloud (e.g., for optimizing the tracks of the truck)
    - 9: Communication between the agriculture domain and the power grid (see 4)

THE INDUSTRIAL REVOLUTION



Fourth Industrial Revolution
Based on Cyber-Physical Systems

Third Industrial Revolution
Electronics & IT for further automatization of production

Second Industrial Revolution
Mass production based on division of labour and electrical energy

First Industrial Revolution
Mechanical production powered by water and steam

Complexity

End of 18th century	Start of 20th Century	Start of 70's	The Future

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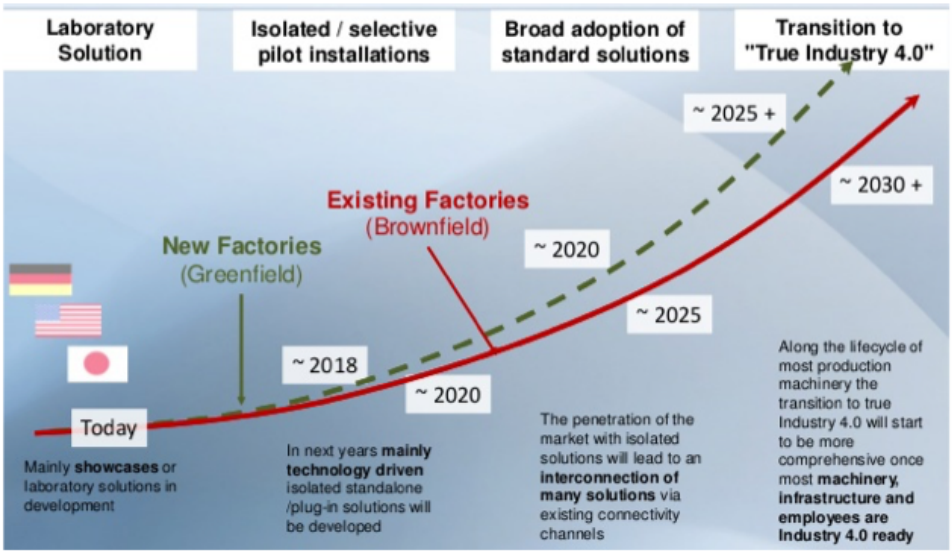
ROADMAP FOR THE NEXT 20 YEARS



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Jürgen Kreuz – 29th Int. Conf. of the TOC Practitioners Alliance

- This transition will take a few more years.

INDUSTRIAL INTERNET (OF THINGS)

https://youtu.be/YTAP2ZYU_D0

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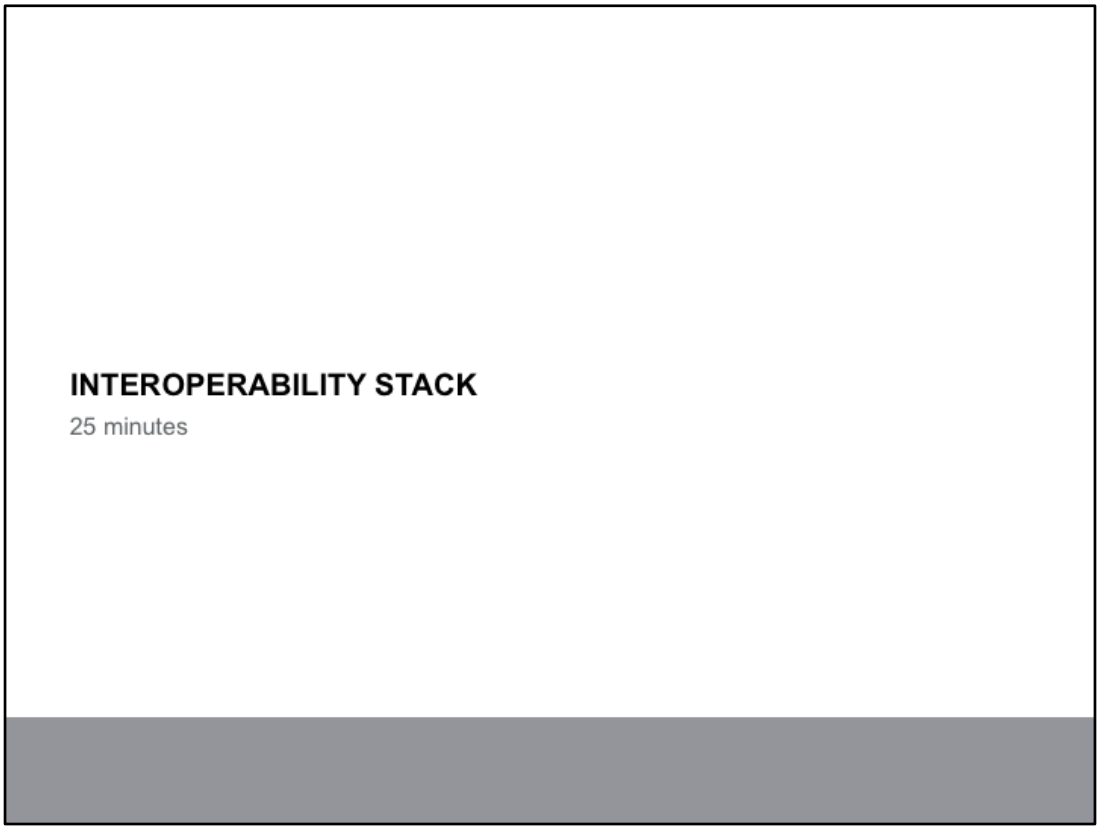
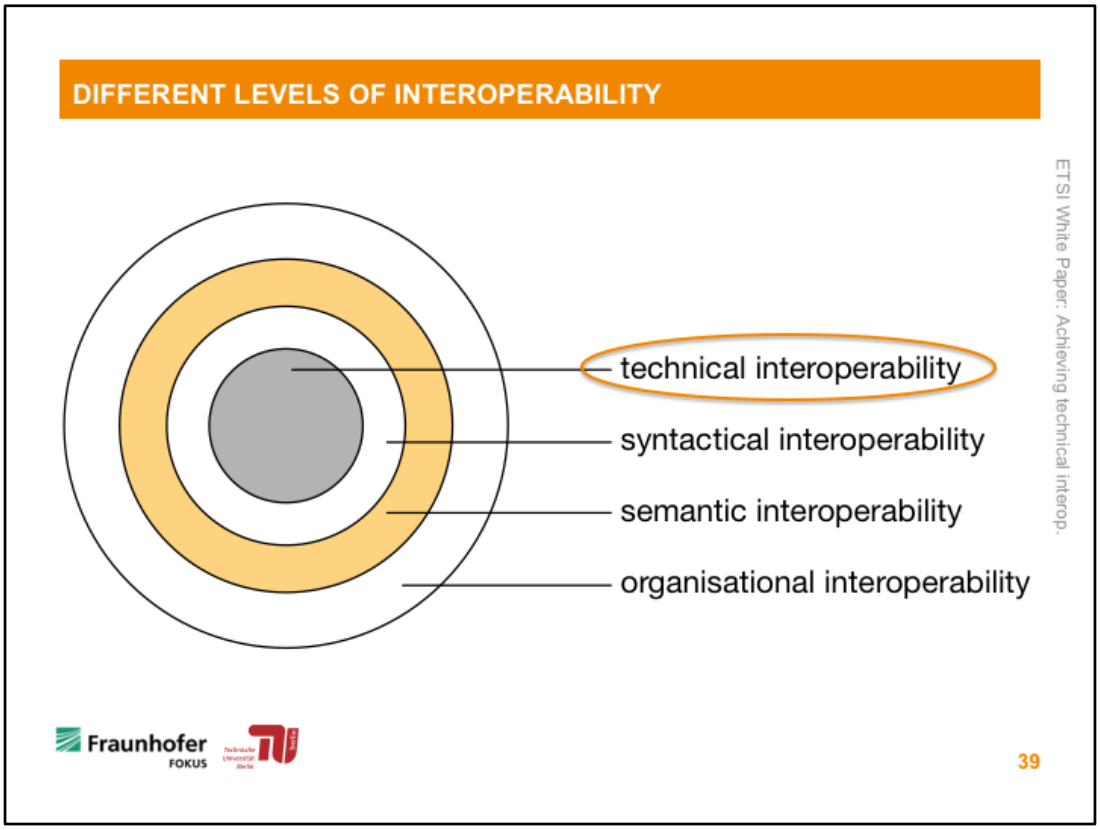
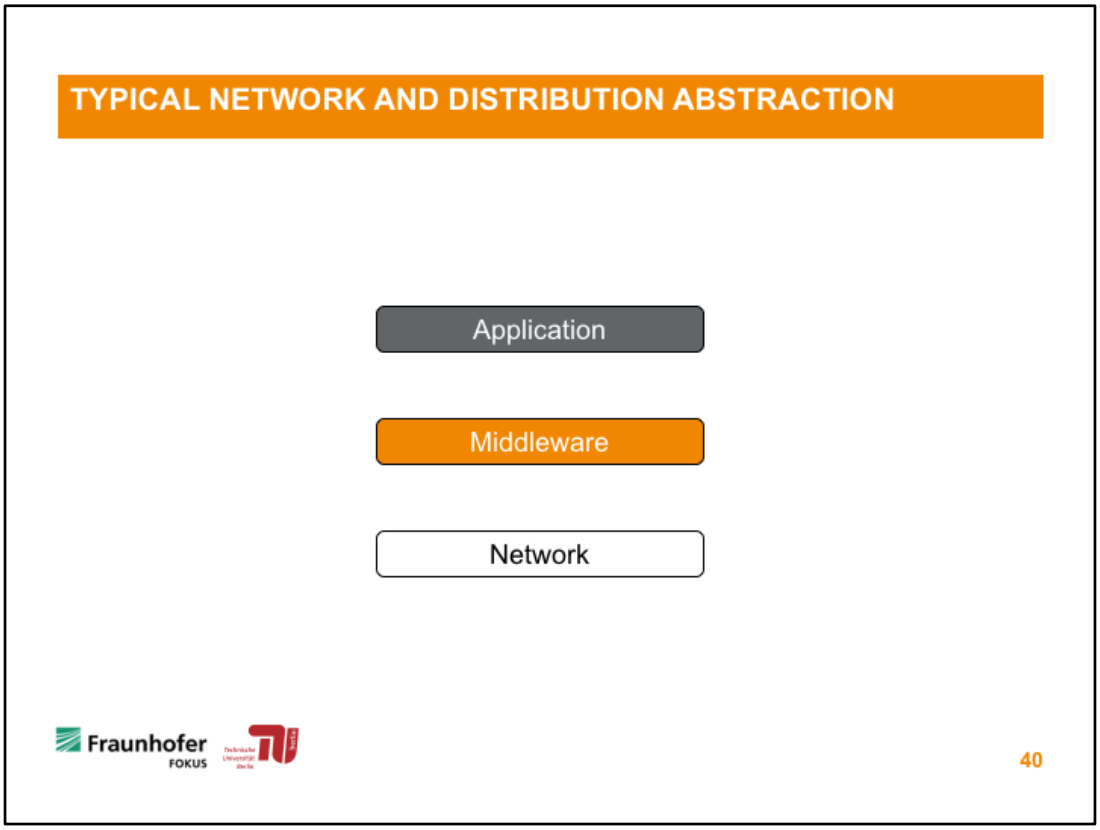
- What are the most important/pressing challenges? Why are we not there yet?



- When it comes to communication between distributed, heterogeneous devices (IIoT/Industry 4.0), interoperability is a major concern

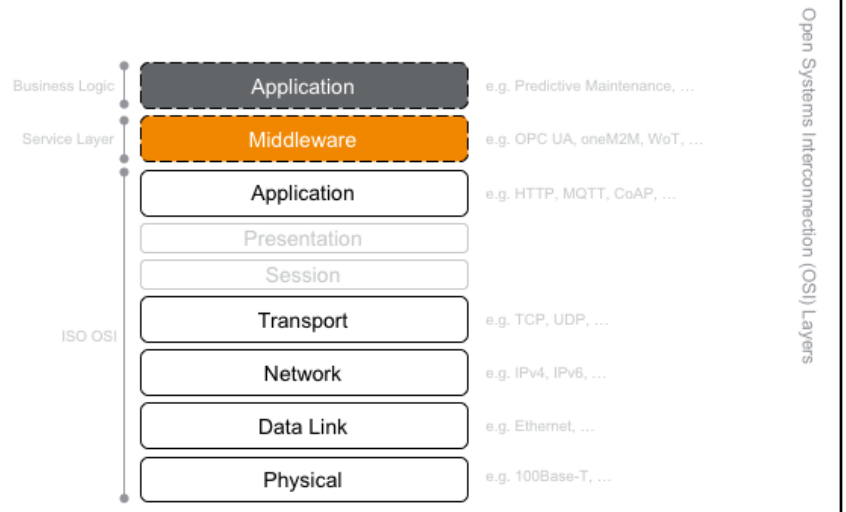


- Depending on the literature, different levels of interoperability can be identified
- Today, we'll start with technical interoperability
- Over the next weeks, we'll go through these layers
- At the end of this term we'll end with semantic interoperability



- Typically, when looking at distributed systems, we distinguish between three different layers.
- Network: the physical connections and protocols. That is what we'll focus on today and the next lectures.
- Middleware: an interoperability layer between the actual application and the network. We'll talk about the middleware later.
- Application: the actual busines logic (and user interface).
- We'll extend this stack lecture after lecture.

EXTENDED NETWORK AND DISTRIBUTION ABSTRACTION



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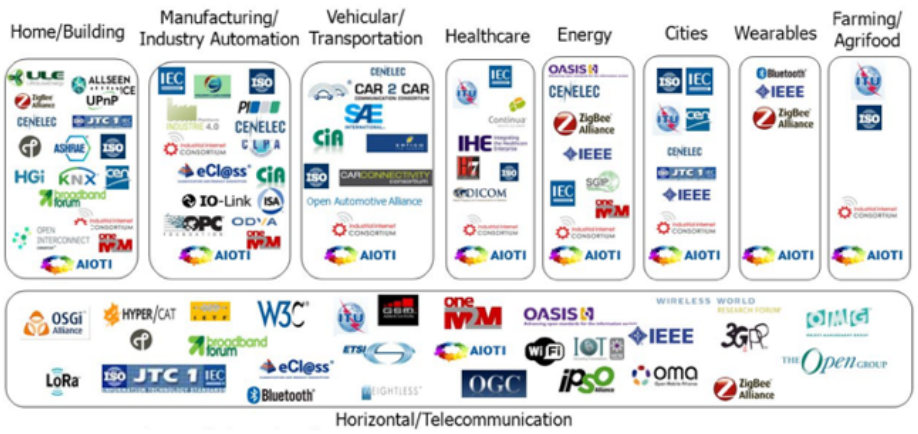
- Starting with looking closer at the ISO OSI stack.
- Note that this stack is about the network only.
- A common misconception is that the ISO OSI „Application“ layer is about the application. It‘s actually the interface for applications to the network.
- This stack is an important guide for the next lectures.

THE IIOT SDOS AND ALLIANCES



AIOTI WG3

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- Of high importance for achieving interoperability, is the standardization.
- As shown before, many Standards Developing Organizations (SDO) and alliances exist.
- In particular we've different initiatives in different verticals.
- Which is challenging for the implementation of true vertical communication.

THE IIOT SDOS AND ALLIANCES

AIOTI WG3

Manufacturing/
Industry Automation

Horizontal/Telecommunication

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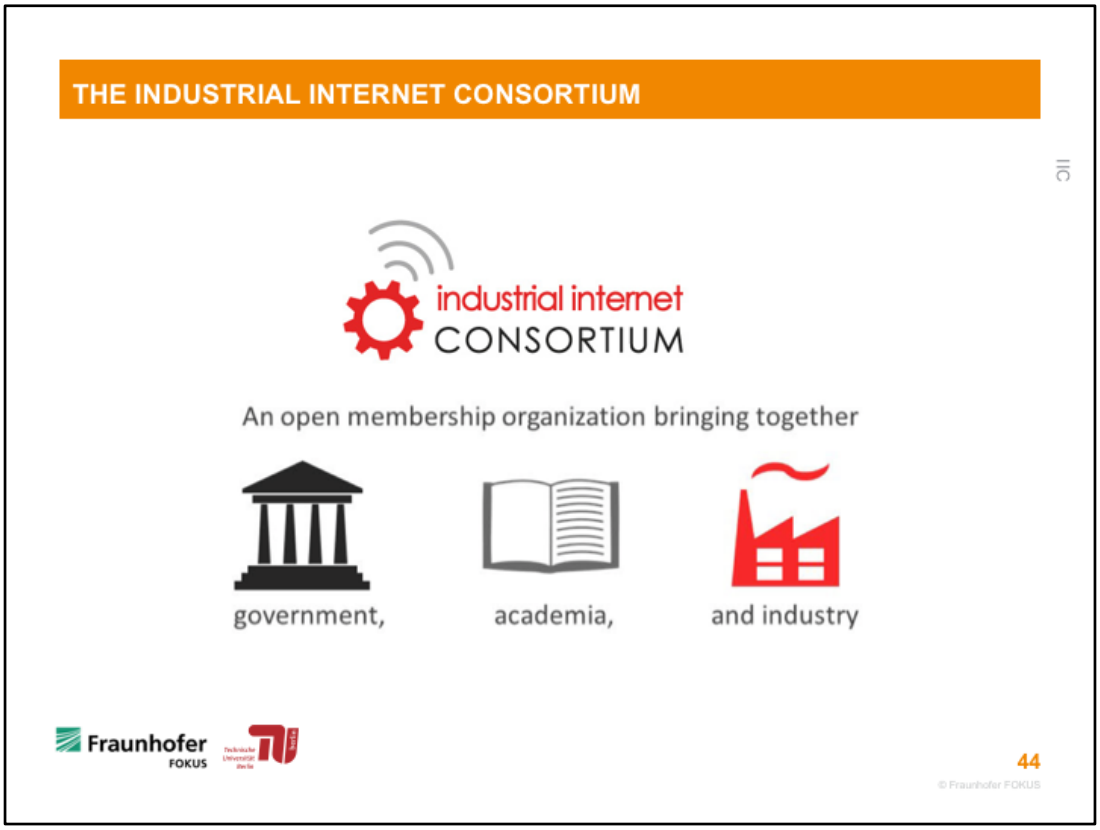
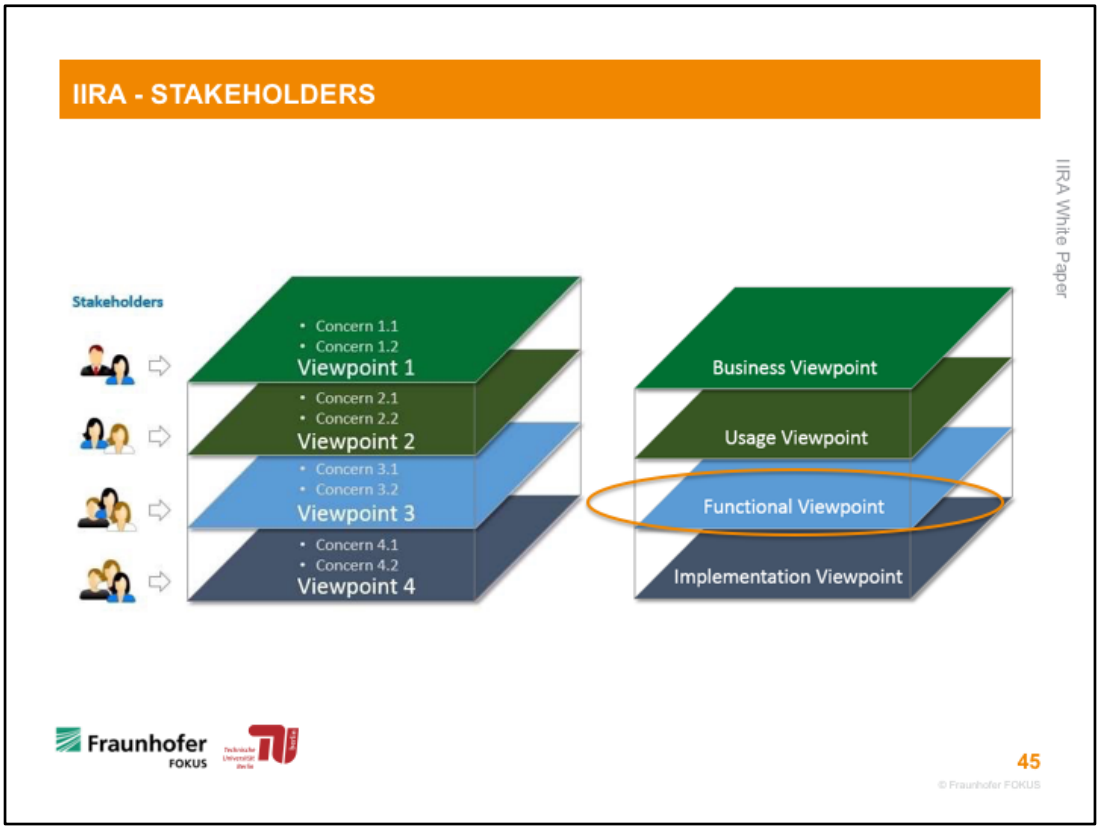
- By focusing on manufacturing, we reduce complexity.
- Still, many different initiatives, technologies and standards have to be considered.

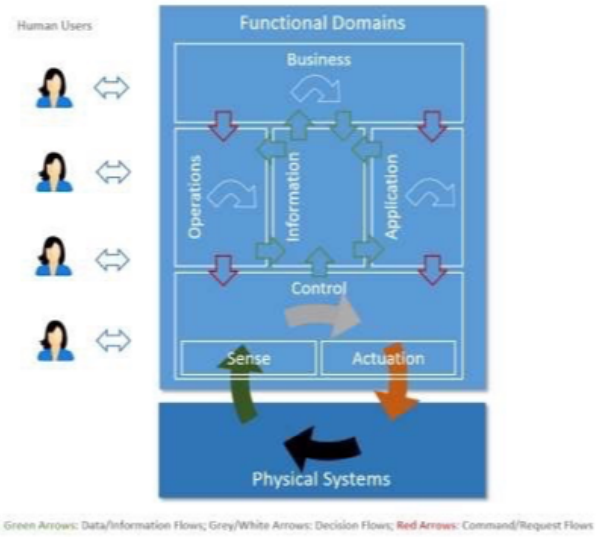


- One of the most important initiatives is the Industrial Internet Consortium (IIC).
- Focus on the United States.
- It is NOT a standardization organization.
- However, it‘s closely coupled with the Object Management Group (OMG), that standardized the Unified Modelling Language (UML).



- The IIC defined and is regularly updating the Industrial Internet Reference Architecture (IIRA).
- The **business viewpoint** attends to the concerns of the identification of stakeholders and their business vision, values and objectives in establishing an IIS in its business and regulatory context. These concerns are business--oriented and are of particular interest to business decision-makers, product managers and system engineers.
- The **usage viewpoint** addresses the concerns of expected system usage. It is typically represented as sequences of activities involving human or logical users that deliver its intended functionality in ultimately achieving its fundamental system capabilities.
- The **functional viewpoint** focuses on the functional components in an IIS, their interrelation and structure, the interfaces and interactions between them, and the relation and interactions of the system with external elements in the environment, to support the usages and activities of the overall system.
- The **implementation viewpoint** deals with the technologies needed to implement functional components, their communication schemes and their lifecycle procedures. These components are coordinated by activities (Usage viewpoint) and supportive of the system capabilities (business viewpoint).

IIRA – FUNCTIONAL DOMAINS (FOR A CYBER-PHYSICAL SYSTEM)



IIRA White Paper

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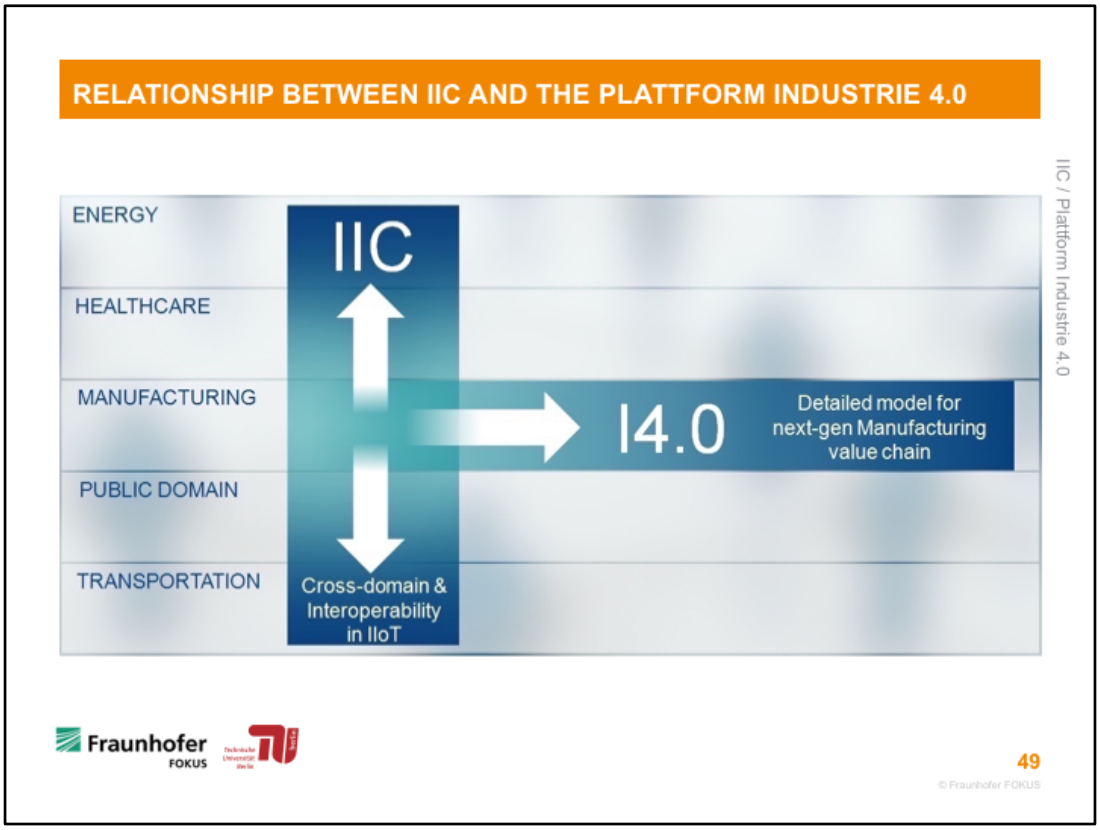
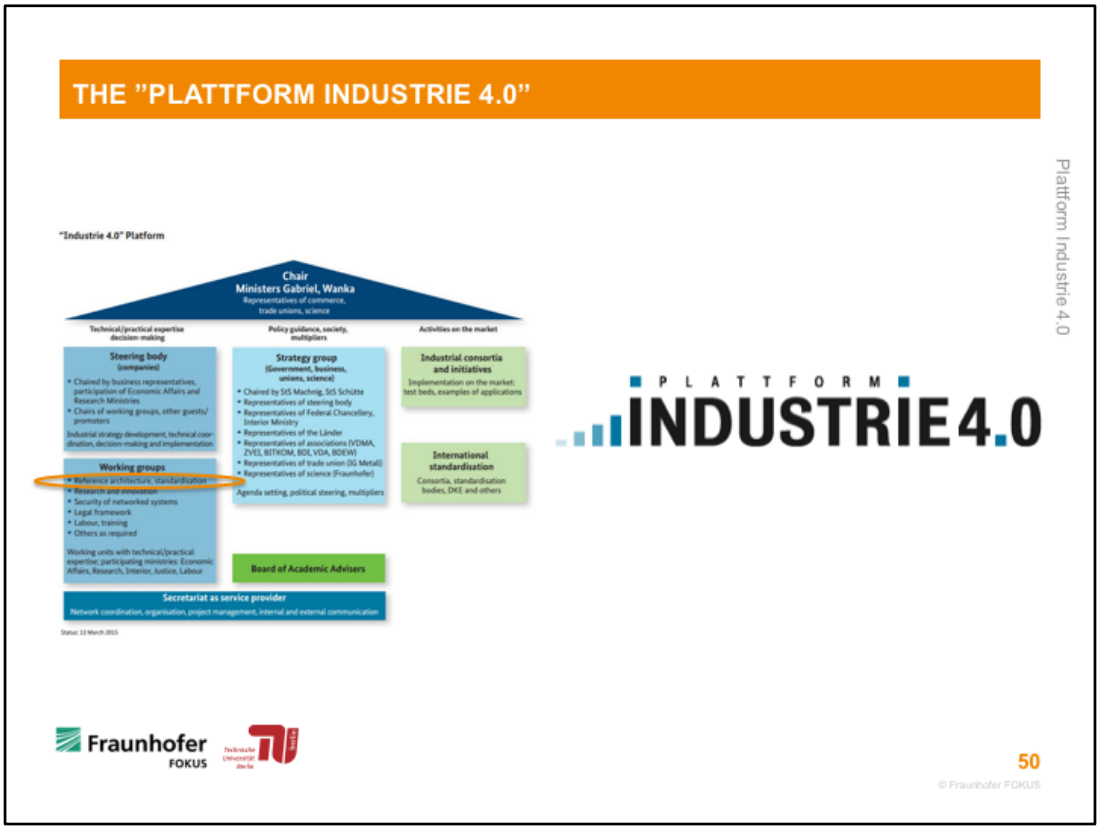
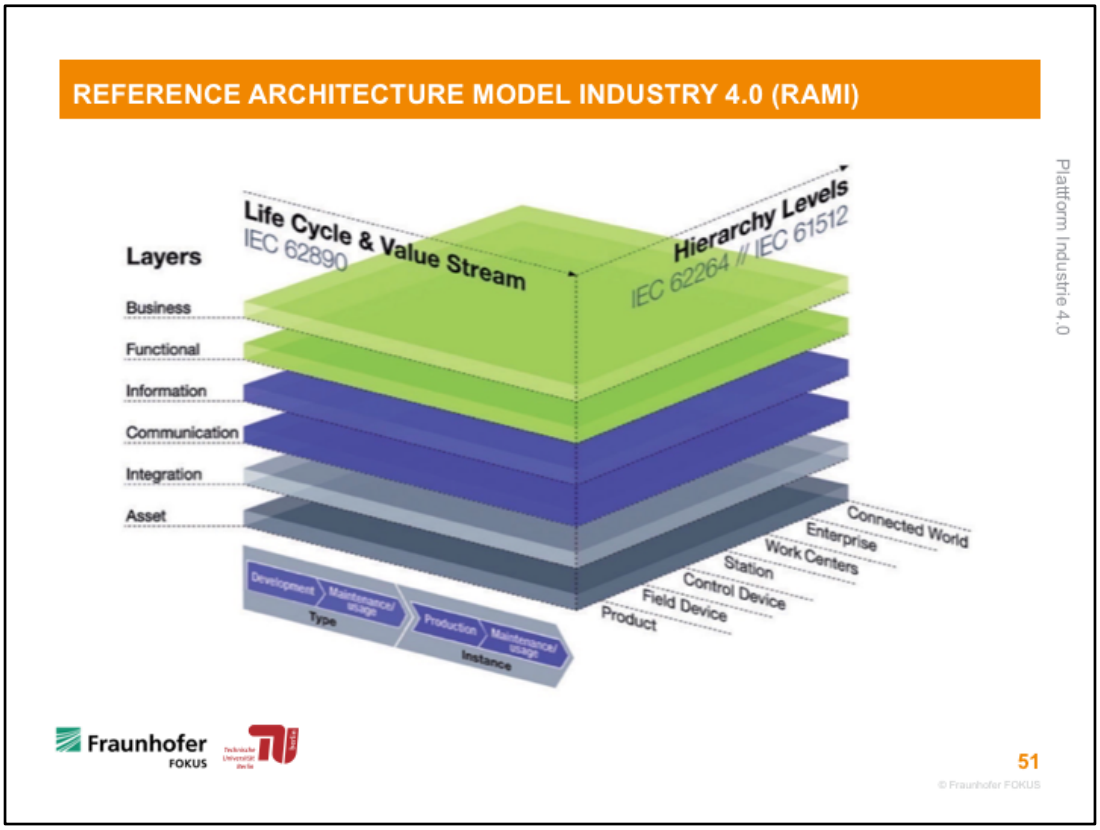
- The functional domain identifies needed components and interfaces.
- Within the white paper, we can see the specification of a CPS.
- **Control domain:** Functions performed by the industrial assets or control systems executing closed-loop control that may involve sensing, control and actuation.
- **Operations domain:** Functions for assets and control systems management and maintenance to ensure their continuing operations. These functions may include remote health monitoring, configuration and update, diagnosis and preventive maintenance.
- **Information domain:** Functions for collecting, transforming and analyzing data to acquire high-level intelligence of the entire system.
- **Application domain:** Functions for applying use-case-specific logic, rules and models based on the information obtained from the information domain to achieve system-wide intelligent and optimal operations.
- **Business domain:** Functions for integrating information across business systems and applications to achieve business objectives, such as work planning, customer relationship management (CRM), enterprise resource planning (ERP), manufacturing execution system (MES).



- While the IIC is covering most IIoT domains, Industry 4.0 initially focusses on manufacturing.



- The Platform Industry 4.0 was founded in 2013 as a joint project of the German trade associations
- In 2015, the platform was expanded to include players from companies, associations, trade unions, science and politics.
- White papers, specifications, architectures, position papers, … are createed within different working groups
- The Working Group 1 „Reference architecture, standards and standardization“ is the most important one for us.



- RAMI is NOT a technical architecture.
- It is an abstract framework in order to encourage clear communication.
- It has high international visibility and puts three different dimentions into relation.

RAMI – LAYERS

- **Business (ERP):** value chains, service orchestration, ...
- **Functional:** integration, runtime environment, rules, …
- **Information:** persistance, data models, …
- **Communication:** API's for sensing and actuation, …
- **Integration**: adaption to hardware and humans, …
- **Asset:** hardware, humans, …

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- First: the layers on the left side.
- In this lecture, we'll cover the highlighted areas, starting with the integration/communication.

RAMI - HIERARCHY LEVELS

- Based on International Electrotechnical Commission (IEC) 62264: Enterprise-control system integration
  - Models and terminology
  - Object model attributes
  - Activity models of manufacturing operations management
  - Business to manufacturing transactions
- Added "Product", "**Field Device**" and "**Connected World**" for Industry 4.0 applicability

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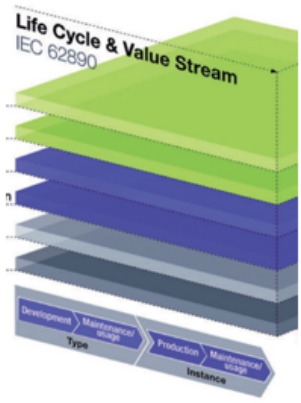
- Second: the hierarchy levels on the right side.
- This reflects an extended 5-layer automation pyramid.
- We'll cover the highlighted parts.

RAMI – LIFE CYCLE

- Based on International Electrotechnical Commission (IEC) 62890: Life-cycle management for systems and products used in industrial-process measurement, control and automation
- **Added object oriented paradigm (Digital Twin)**
  - Type: template / abstract definition (e.g. of a product)
  - Instance: concrete implementation (e.g. serial number)



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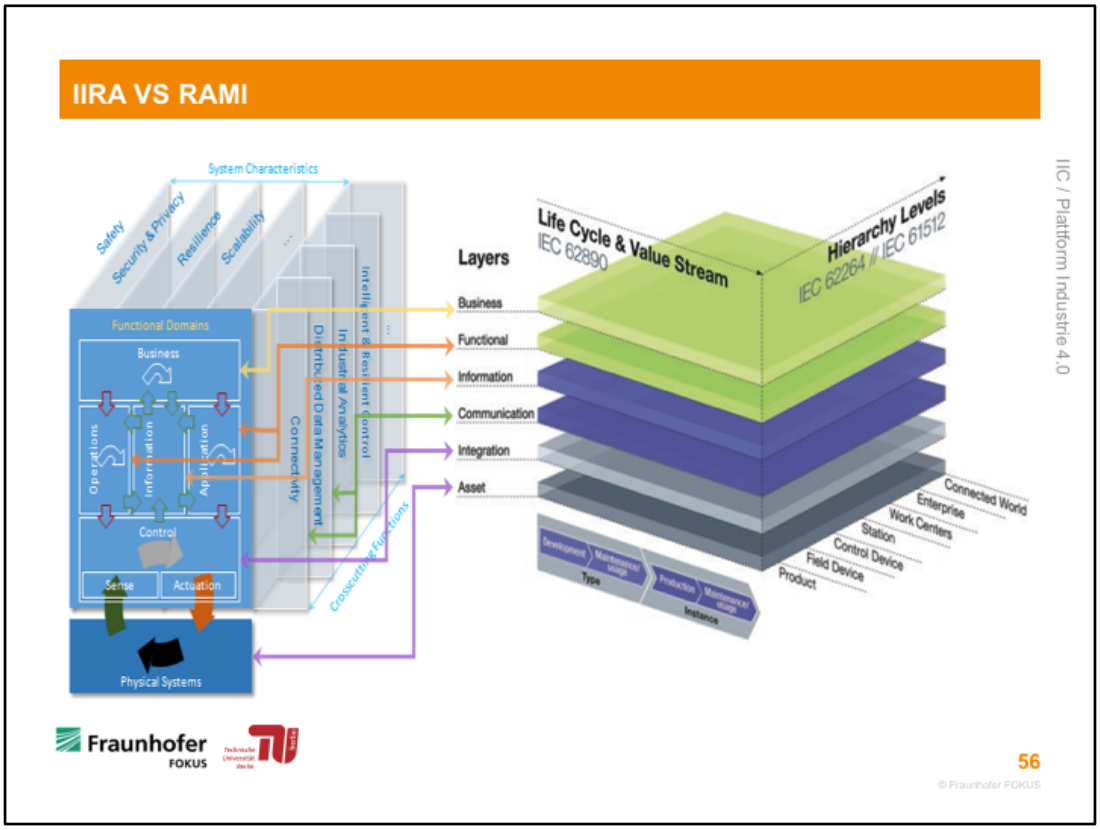
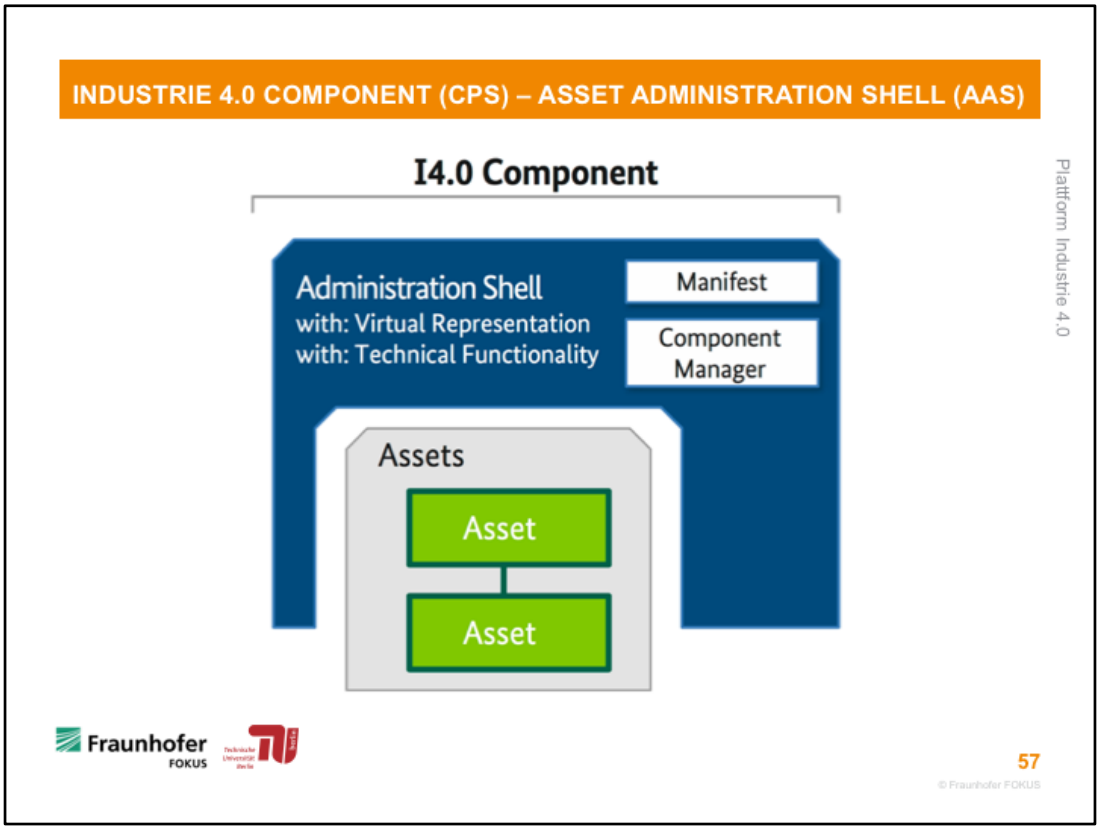
- Finally: the life cycle.
- Important is the differentiation between the virtual/abstract model of products, factories and processes (digital twin) and the concrete instantiation of produced goods and controlled devices.
- Costs can be reduced by simulating and optimizing planned production processes first.



- The IIRA and RAMI can nicely be mapped to each other.
- A strong collaboration between the IIC and the PI4.0 is ongoing.



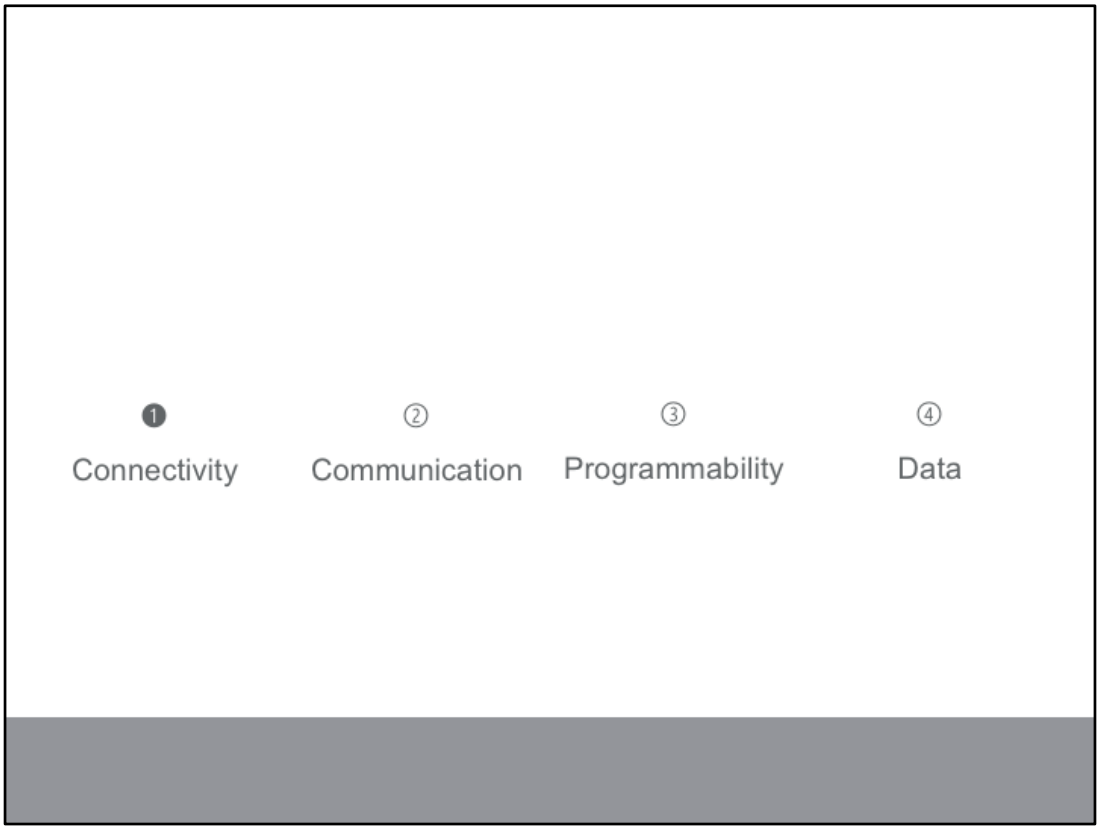
- One important concept that has been defined by the Plattform Industry 4.0 is the so called Asset Administration Shell (AAS).
- The combination of asset and AAS is called Industry 4.0 Component.
- Again, this depicts an autonomous CPS.
- One or multiple assets are virtually represented, controlled and monitored by software (administration shell).
- The shell holds static and dynamic information about the asset(s) and offers various components to interact with the asset(s).

INTEROPERABILITY STACK

Questions?

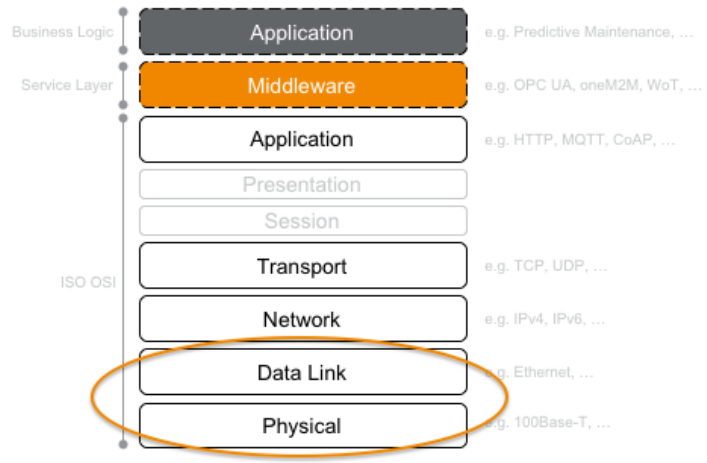
CONNECTIVITY OVERVIEW

15 minutes



- This lecture is divided into 4 different areas
- Today, we start with the first one

CONNECTIVITY: LAYERS 1 + 2



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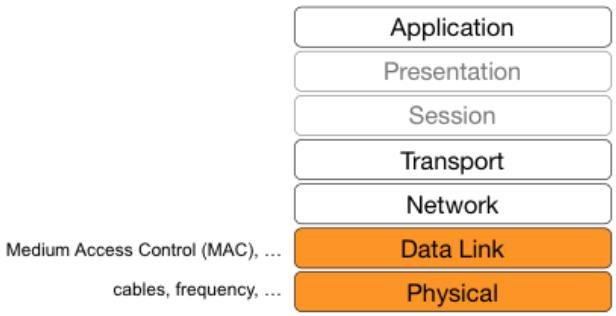
- This lecture is about connectivity.
- Therefore, we focus today on layers 1 + 2.

CONNECTVITY AND INTEROPERABILITY

- Enable to share data between nodes within an Industrial IoT system
- Connectivity, as defined by the Industrial Internet Consortium (IIC): “provides the ability to exchange data amongst participants within a functional domain, across functional domains within a system and across systems”
- **Connectivity demands interoperable communications between endpoints**



Open Systems Interconnection (OSI) Layers

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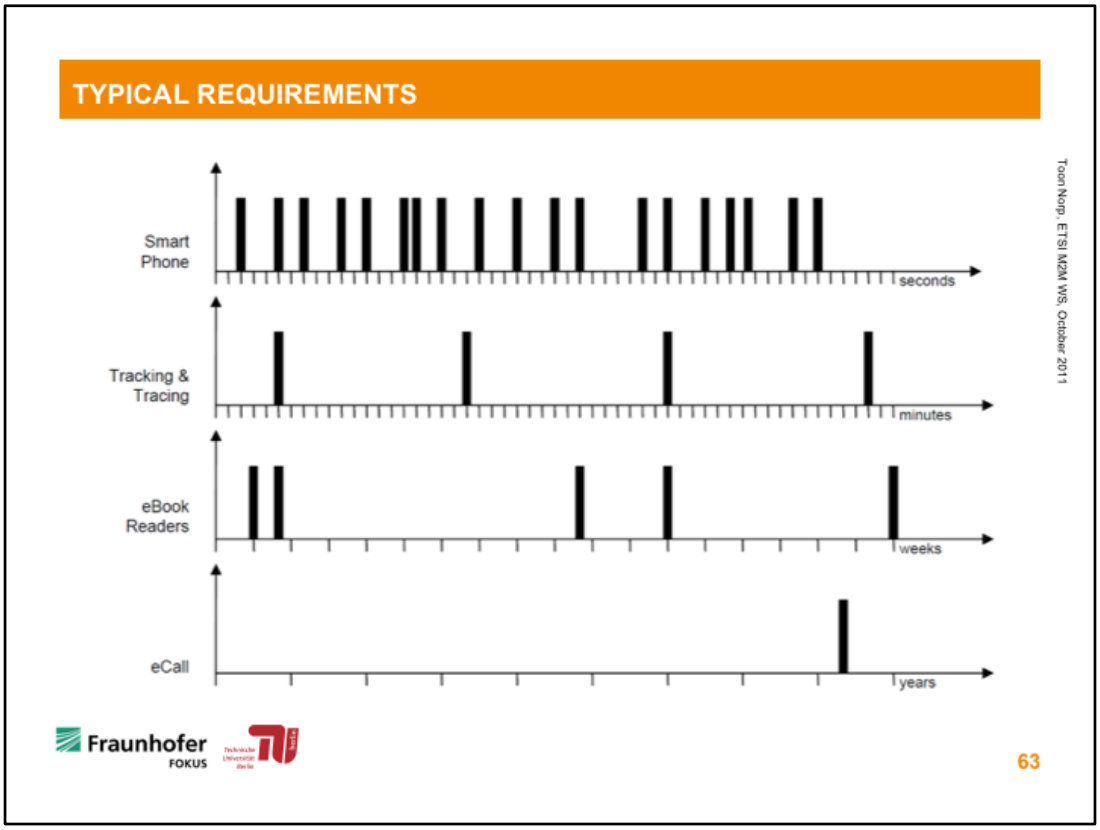
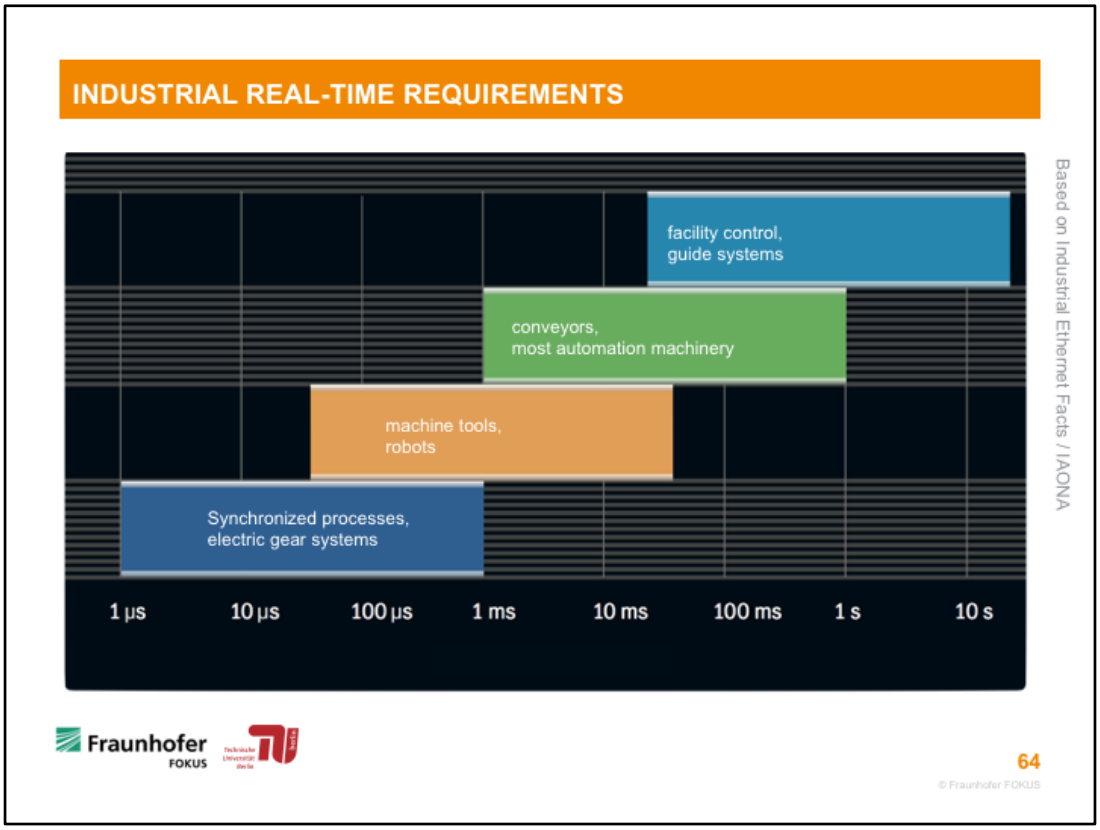
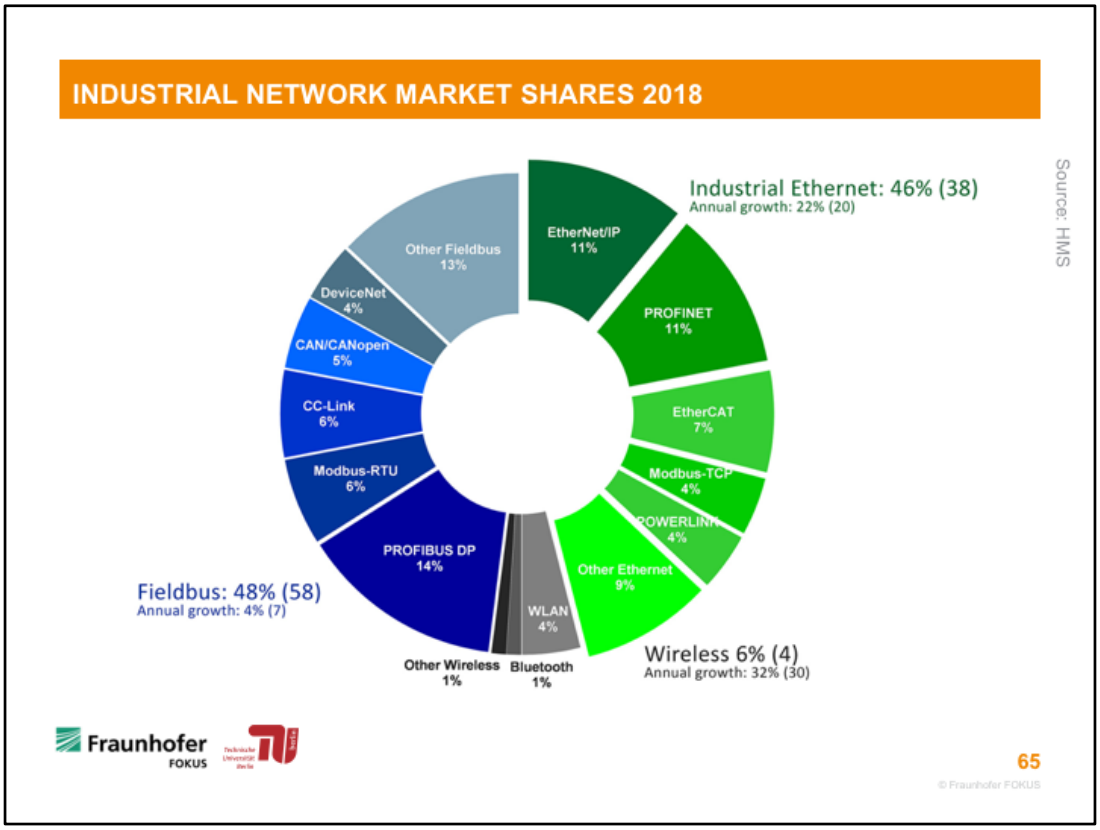
- This lecture will not provide a depth introduction into the functionality of these layers.
- They should already be known by former courses.



- We already learned these "Connectivity demands“ differ, depending on the use cases.
- From crucial connections once a year to best effort data exchange multiple times per second.

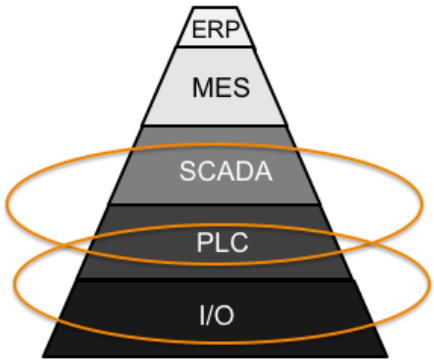


- Within industrial domains, however, the requirements are different to typical ICT (consumer) domains.
- Hard real-time response times, very low latency, … depending on the use case.
- With usual Carrier-sense multiple access with collision detection (CSMA/CD), as used in Ethernet, or Carrier-sense multiple access with collision avoidance (CSMA/CA), as used in Wi-Fi, these requirements can‘t be met.



- Therefore, within industrial domains, multiple field systems have been established starting around 1980.
- Examples are PROFIBUS, Modbus, CAN, …
- Since 1990/2000 industrial Ethernet solutions have been introduced that reuse and extend IEEE 802.11.3 (Ethernet) layers 1 + 2
- Examples are PROFINET, EthernNET/IP, EtherCAT, …
- Recently the number of sold Industrial Ethernet equipment superseeded Fieldbus components.
- Further, the largest annual growth can be seen in wireless technologies.

5-LAYER AUTOMATION PYRAMID



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- Connectivity between PLC‘s over SCADA
- Connectivity between PLC‘s and the assets

PLC'S EVOLVED OVER THE LAST 50 YEARS

profibusgroup.com

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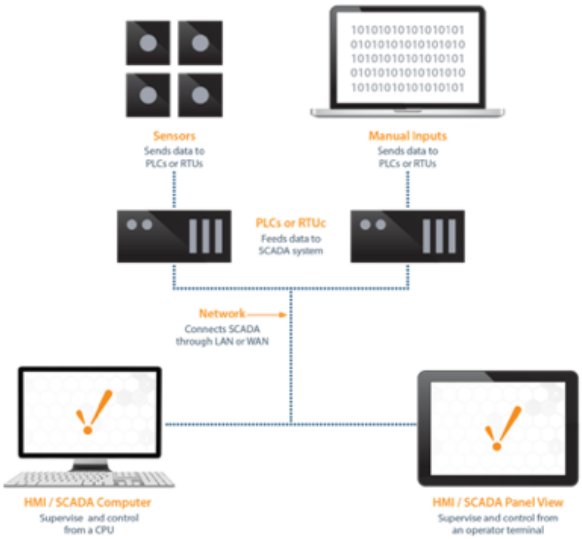
- PROFINET-based connectivity
- I/O-based connectivity

SUPERVISORY CONTROL AND DATA ACQUISITION (SCADA)



Inductive automation

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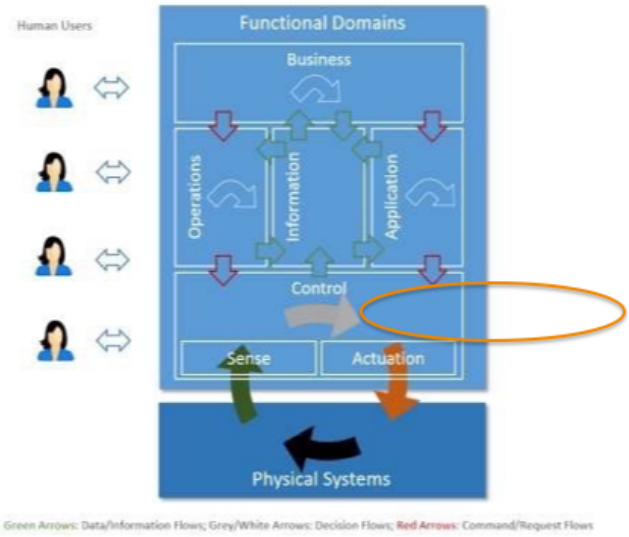
- Connectivity between PLC‘s over SCADA

IIRA – FUNCTIONAL DOMAINS (FOR A CYBER-PHYSICAL SYSTEM)



IIRA White Paper

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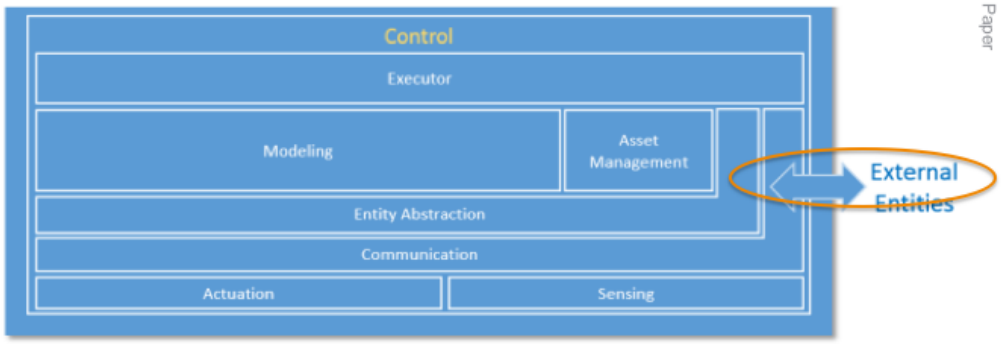
- Connectivity is part of the IIRA control domain

IIRA – FUNCTIONAL DOMAINS / CONTROL



IIRA White Paper

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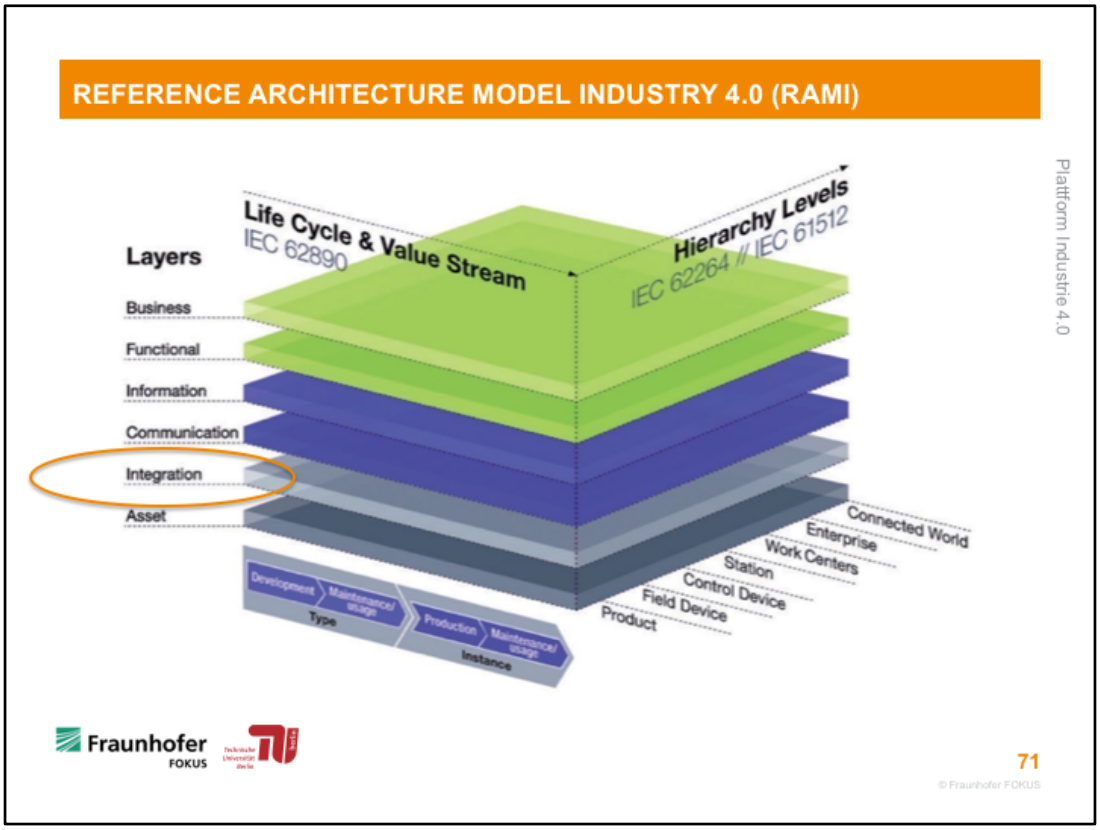
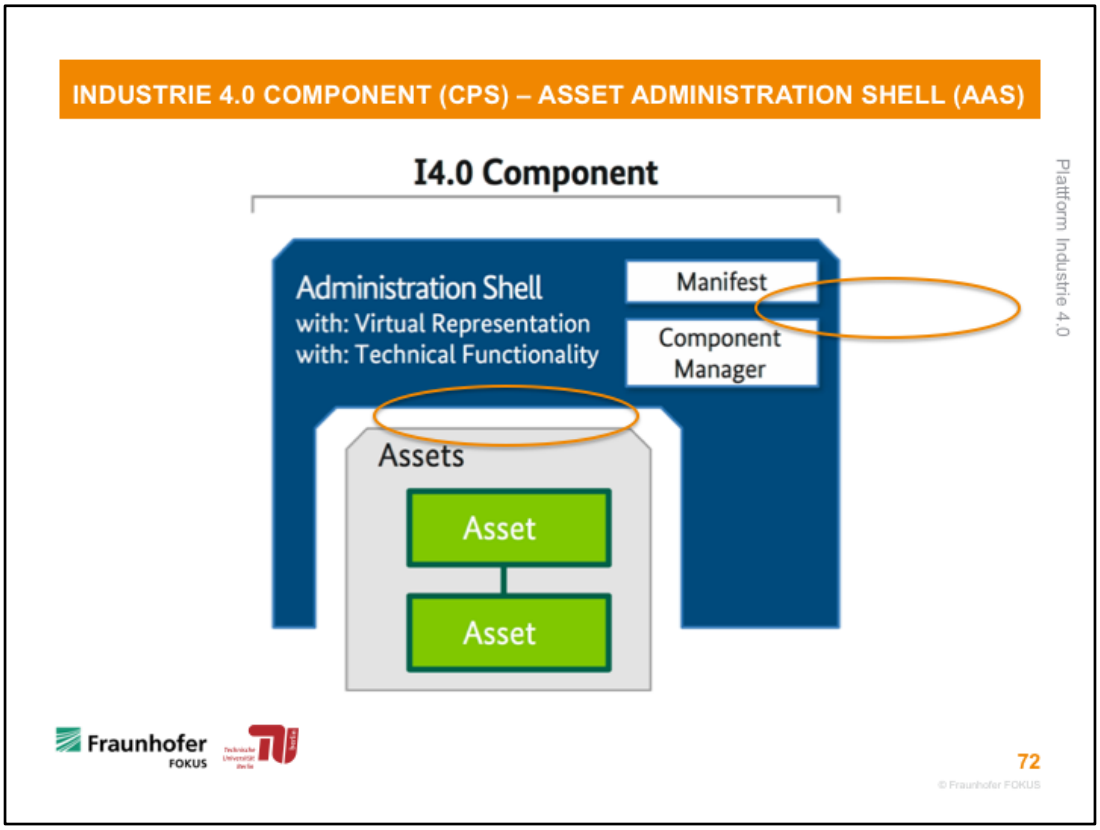
- More specifically, the control domain is devided into further functional blocks.
- The **communication** block is responsible for the communication with external entities.



- Connectivity between assets and the higher levels



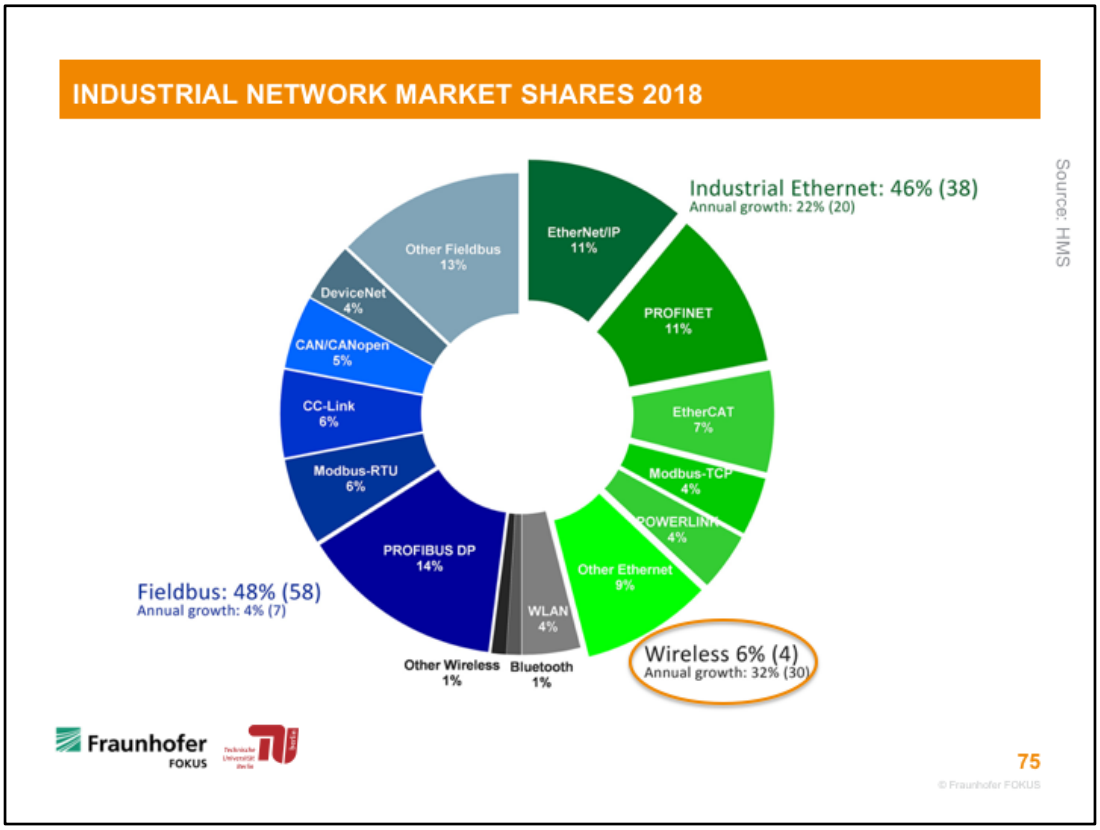
- Missing in this figure
  - the administration shell offers connectivity to other I4.0 components
  - the administration shell is connected to the asset(s)

CONNECTIVITY OVERVIEW

Questions?

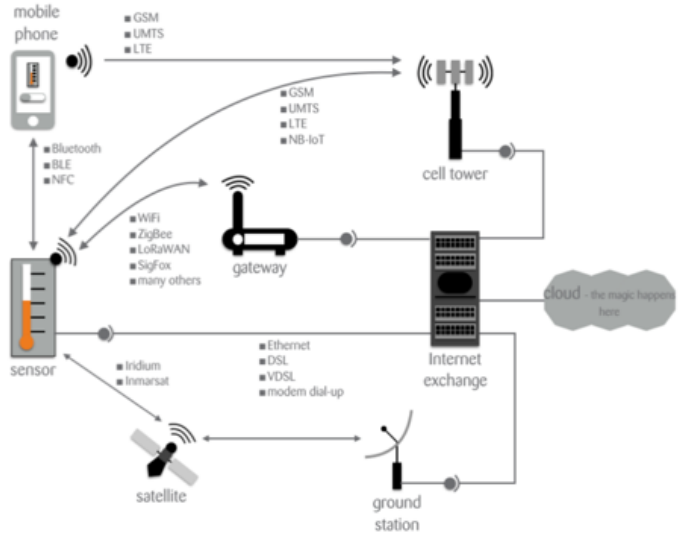
WIRELESS TECHNOLOGIES

25 minutes



- Significant annual growth.
- Often used to collect non-critical monitoring data.
- Due to the shift towards (mobile) autonmous CPS‘s, the demand for industrial wireless technologies will also rise.

SELECTION OF THE BEST WIRELESS TECHNOLOGY



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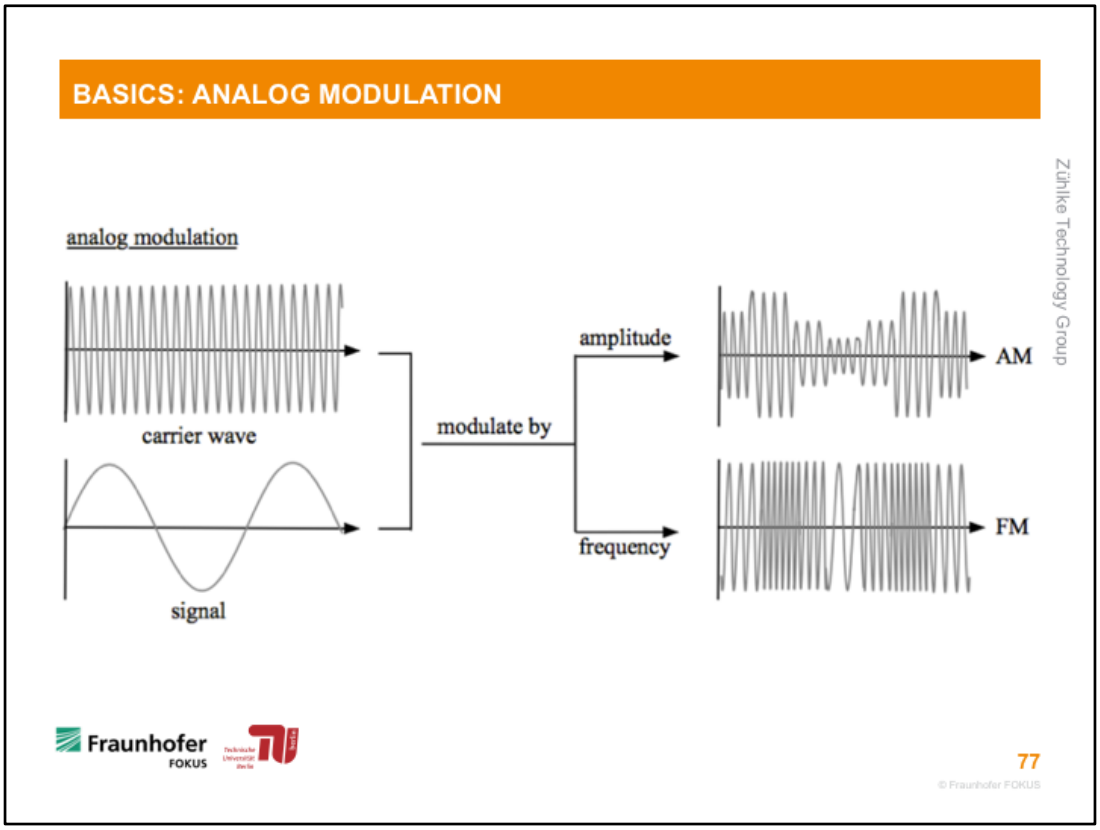
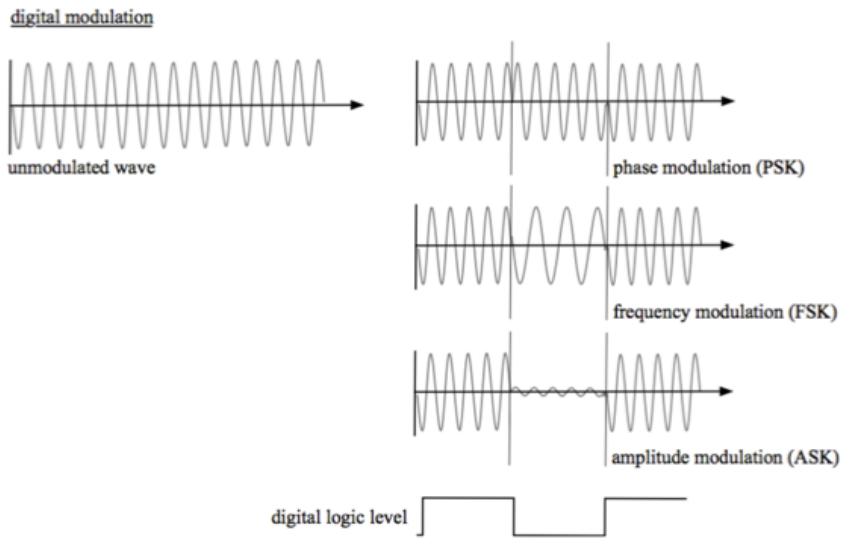
- Simple example of a temperature sensor.
- Multiple potential ways for connectivity.



- The next slides provide some basic facts abouts wireless communication
- Generally, analog information can be transmitten in two ways
    - Amplitude Modulation (AM)
    - Frequency Modulation (FM)
- Known from typical radio receivers

BASICS: DIGITAL MODULATION



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- However, for the transmission of digital information, we use similar approaches
  - Phase-shift keying (PSK)
  - Frequency-shift keying (FSK)
  - Amplitude-shift keying (ASK)

ISM (INDUSTRIAL, SCIENTIFIC, MEDICAL) UNLICENSED BAND

1. ~6 MHz
2. ~13 MHz: RFID, Smart Tags
3. ~27 MHz: baby phones
4. ~40 MHz:
5. ~433 MHz: remote plugs, alarm systems
6. ~868 MHz: wireless temperature sensors, LoRa
7. ~2,4 GHz: Wi-Fi, Bluetooth, ZigBee, micro waves
8. ~5 GHz: Wi-Fi
9. ~24 GHz: Radar
10. ~60 GHz: Wi-Fi
11. ~122 GHz
12. ~244 GHz

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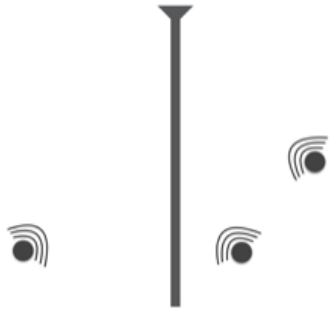
- As air is a shared medium, collisions have to be avoided.
- Generally, we‘ve licensed and unlicensed bands.

SHARING A FREQUENCY (USING TIME)

- TDMA
  - Time Division Multiple Access
  - Time-slot based
  - Cyclically repetitive frame structure
- CSMA
  - Carrier Sense Multiple Access
  - Statistical multiplexing
  - Collision Detection (CD) or
  - Collision Avoidance (CA)



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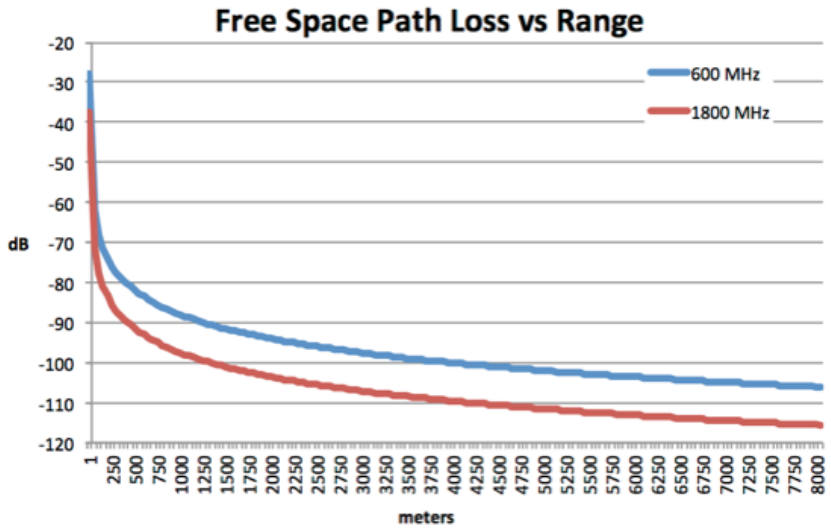
- Sharing the same frequency by
  - Time-division multiple access (TDMA): different time slots (hold your phone to a speaker).
  - Carrier-sense multiple access (CSMA): listen to the medium / use handshakes.
- Others:
  - Space division multiple access (SDMA): physical areas.
  - Power division multiple access (PDMA): variable transmission power.
  - Many others.

FREE SPACE PATH LOSS



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- Important: the path loss by distance
- However, many other effects apply: reflection, absorption, ….

WIRELESS TECHNOLOGIES

Questions?