

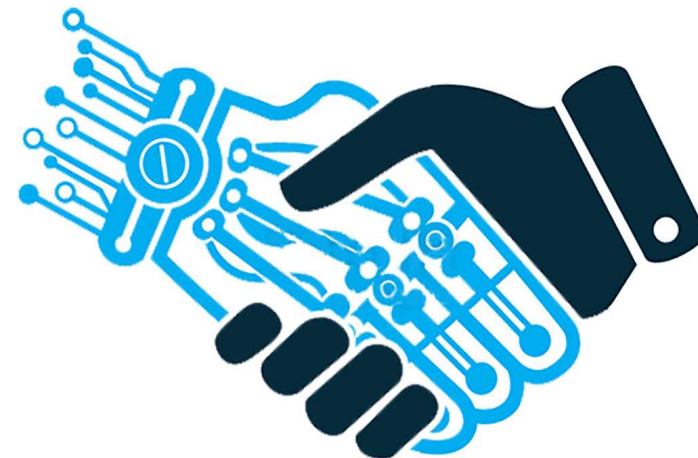
Industry 4.0 Smart Factory

Prof. Dr.-Ing. Stephan Sauter



Smart Factory Fundamentals

- Industrial Revolutions
- Goals of the Smart Factory
- Internet of Things
- Cyber-Physical Systems
- Cyber-Physical Production Systems
- Smart Factory
- Summary & Outlook



INDUSTRY 4.0

Industrial Revolutions

Part 1 of 7



- Industrial Revolutions

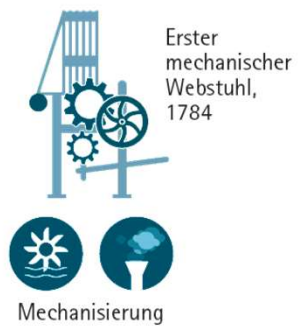


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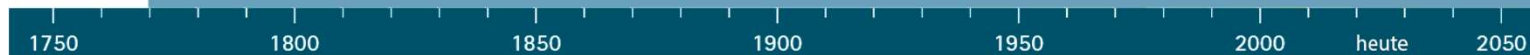
• Industrial Revolutions

Complexity ↑ over time

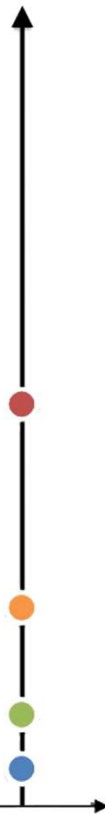
1. **Mechanisation** – first mechanical loom, 1784



1.



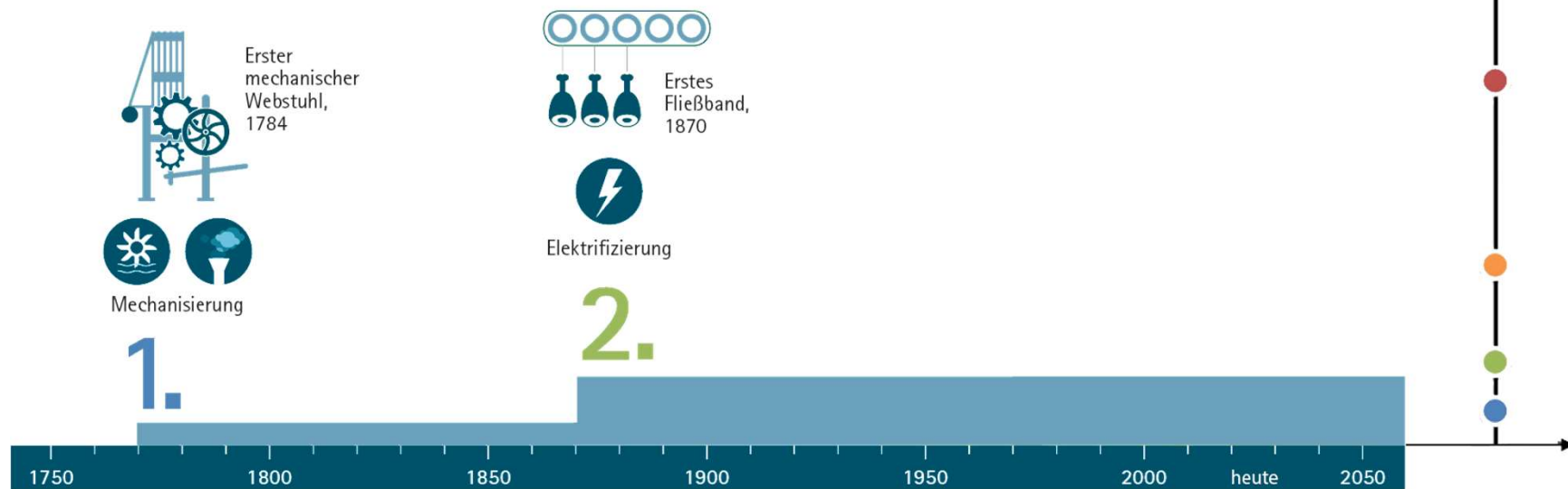
Komplexität



• Industrial Revolutions

Complexity ↑ over time

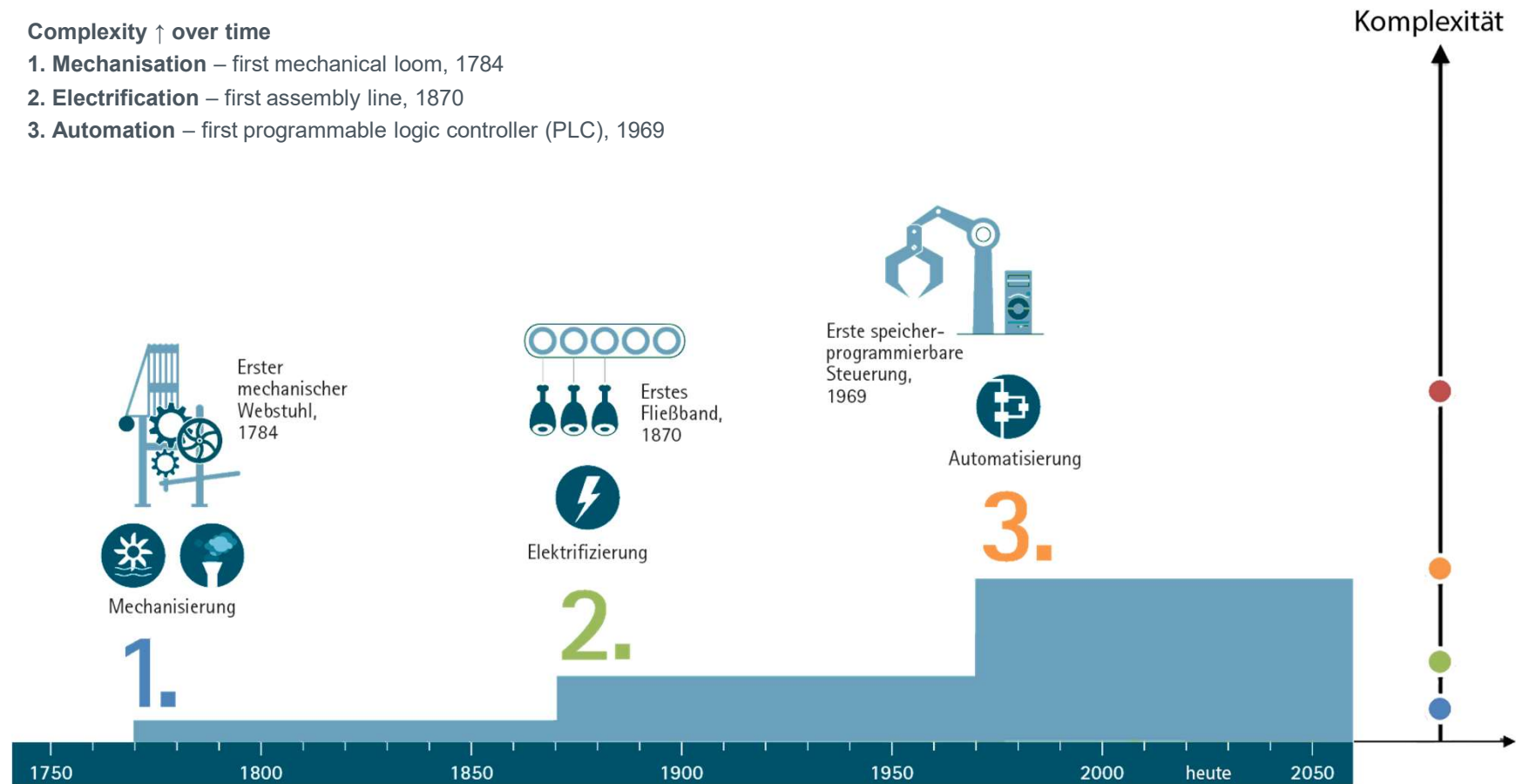
1. **Mechanisation** – first mechanical loom, 1784
2. **Electrification** – first assembly line, 1870



• Industrial Revolutions

Complexity ↑ over time

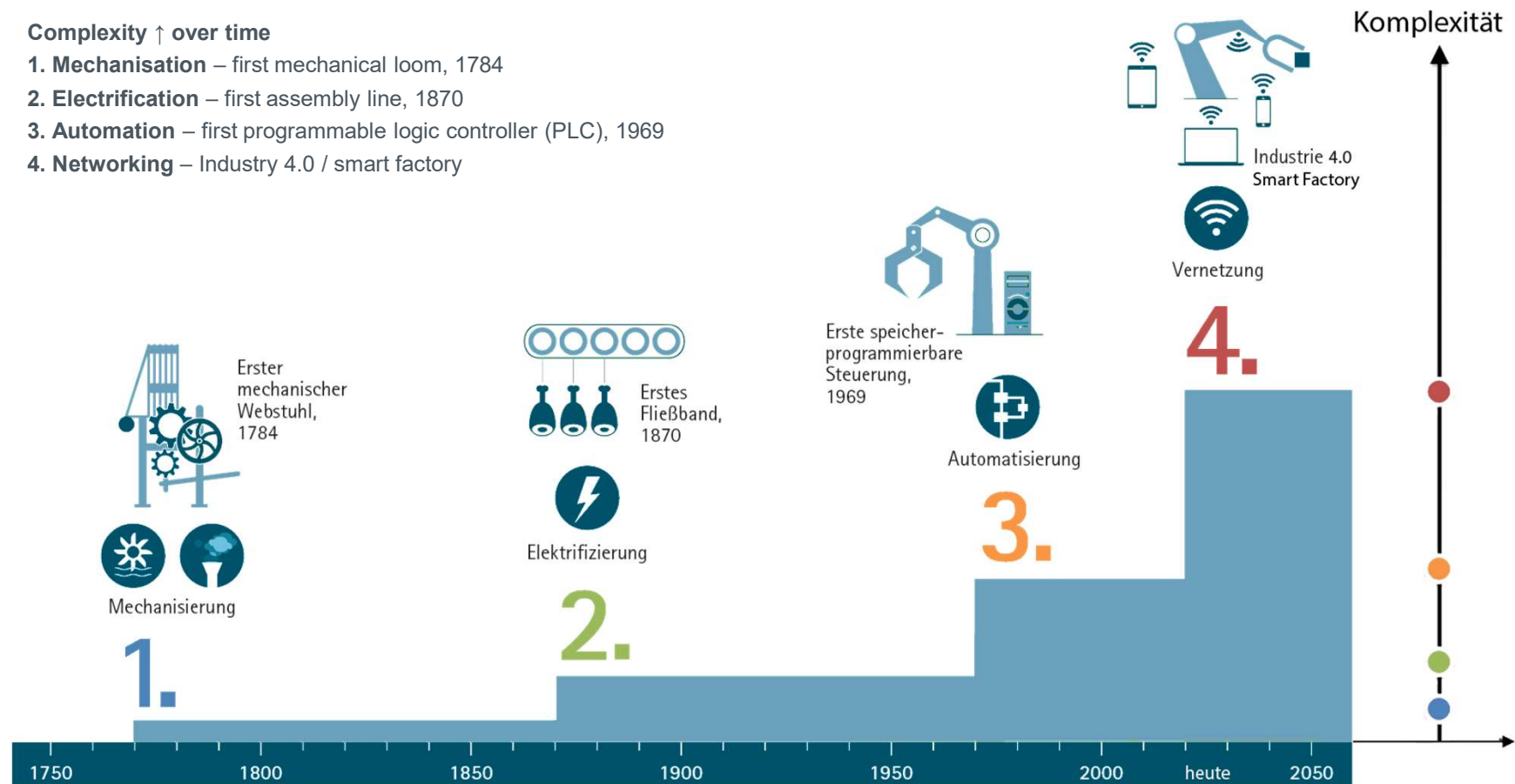
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3. **Automation** – first programmable logic controller (PLC), 1969



Industrial Revolutions

Complexity ↑ over time

1. **Mechanisation** – first mechanical loom, 1784
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3. **Automation** – first programmable logic controller (PLC), 1969
4. **Networking** – Industry 4.0 / smart factory



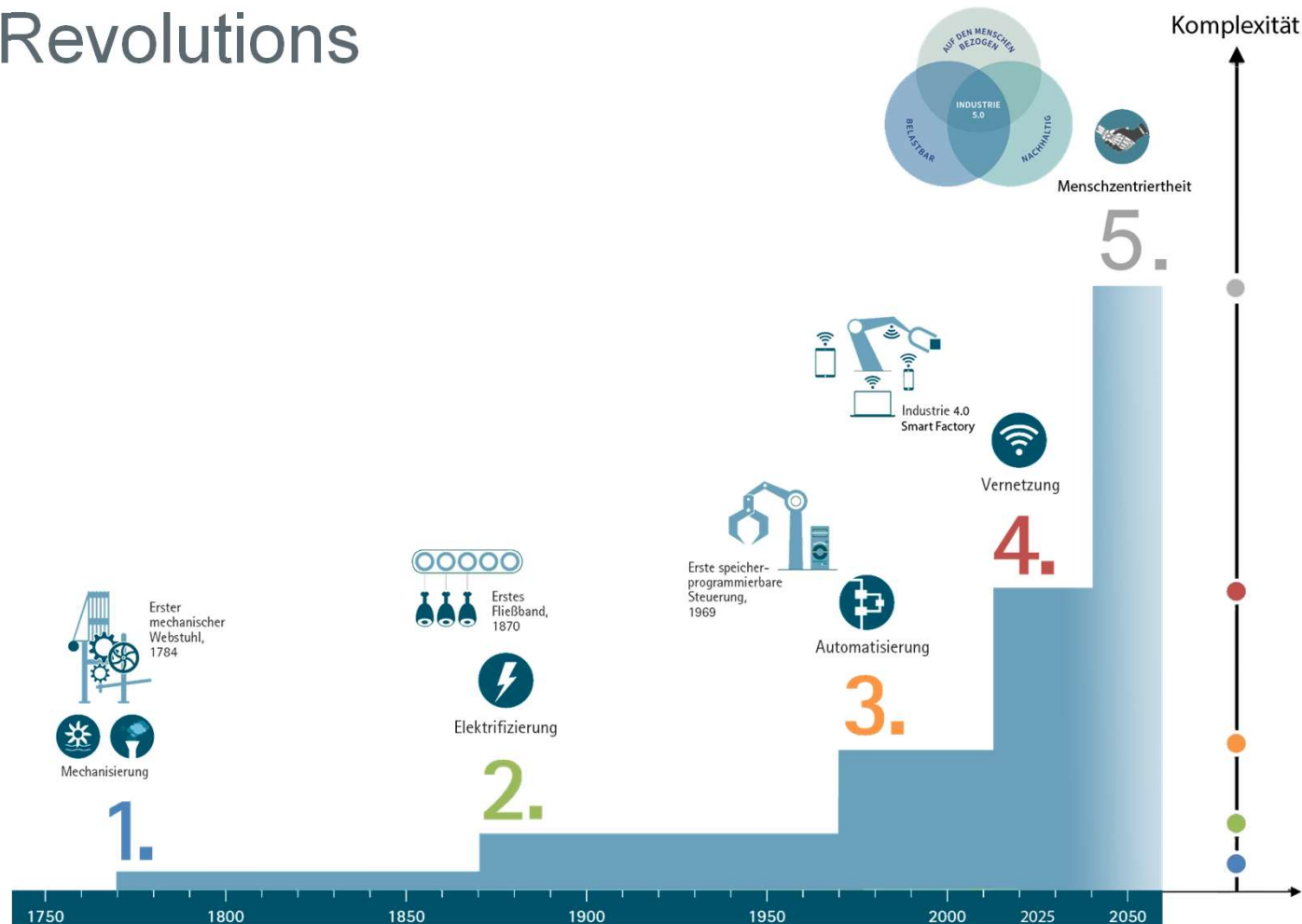
Industrial Revolutions

Industry 5.0

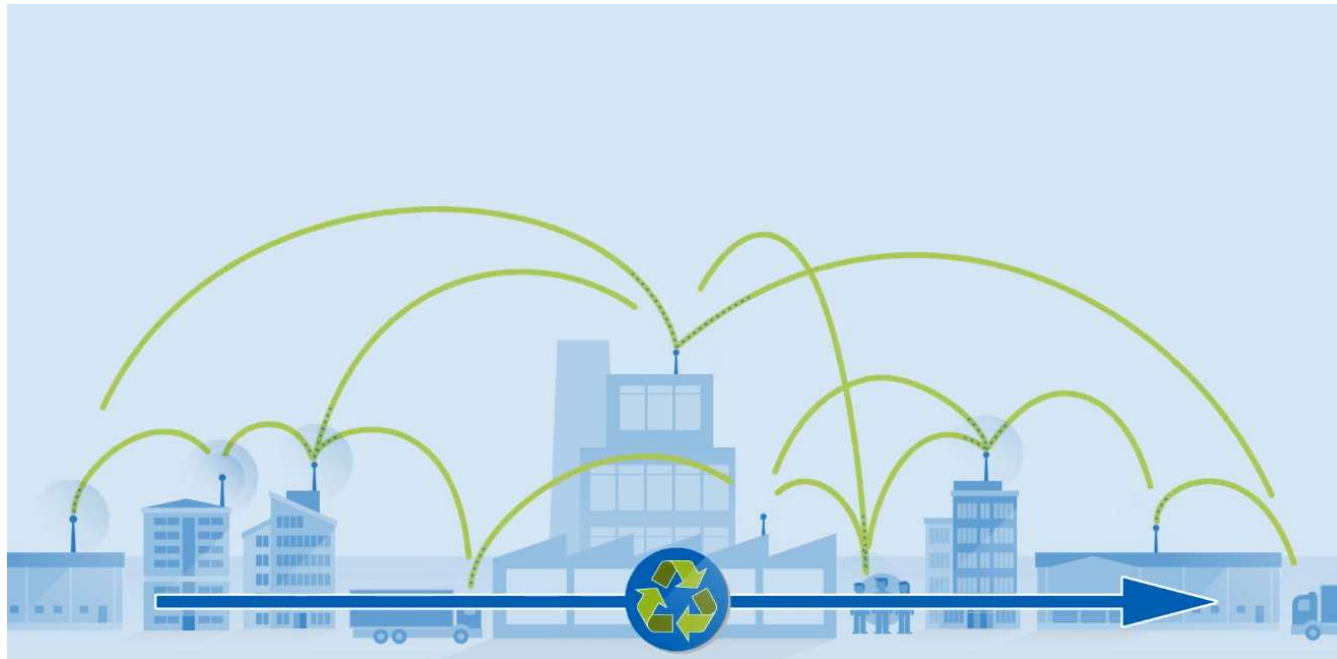
European Commission 2021:
human-centric · sustainable · resilient

Complements Industry 4.0
with values and goals – not a
separate technical
revolution.

5. = human-centricity (graphic
labels: human-centric · resilient
· sustainable)



- Industrial Revolutions



<https://freiwilligschlauwerden.de/l401/Videos/Industrie%204.0%20erkl%C3%A4rt.mp4>

- Industrial Revolutions



<https://freiwilligschlauwerden.de/l401/Videos/DDR.mp4>

- Industrial Revolutions



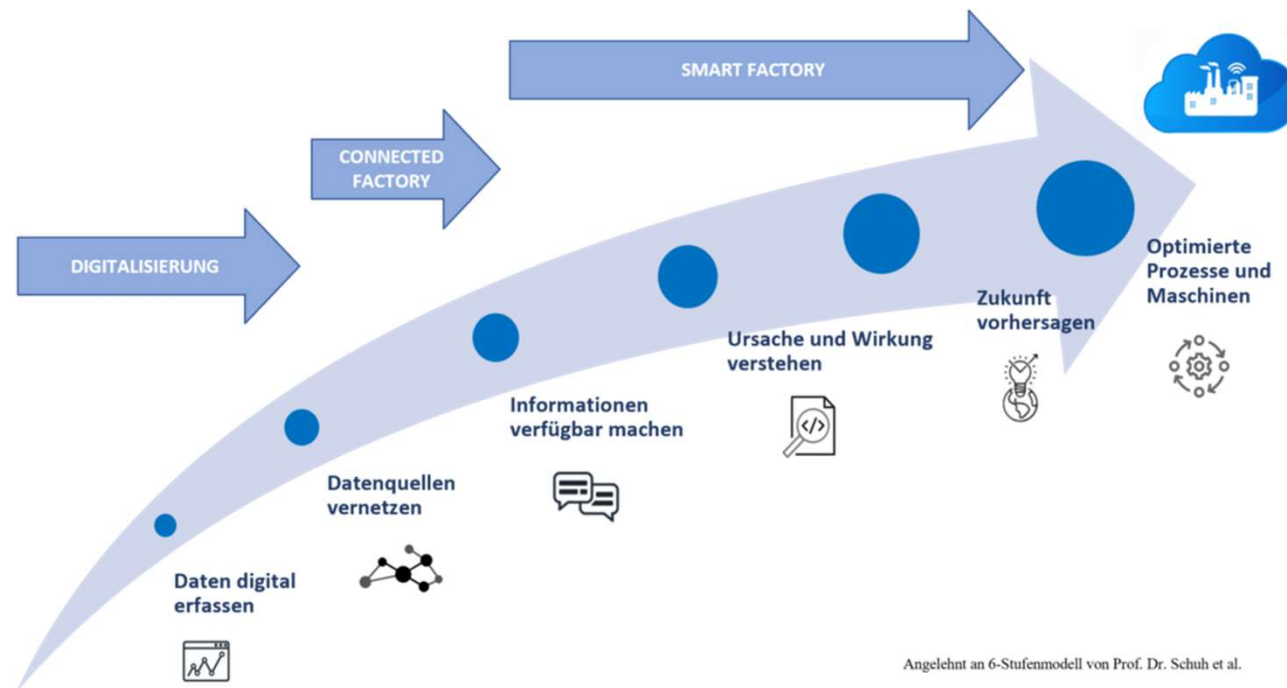
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Goals of the Smart Factory

Part 2 of 7



• Goals of the Smart Factory



Stages in the graphic

Capture data digitally → Connect data sources →
Make information available → Understand cause
and effect → Predict the future → Optimised
processes and machines

Digitalisation → Connected factory → Smart
factory

Angelehnt an 6-Stufenmodell von Prof. Dr. Schuh et al.

acatech Industrie 4.0 Maturity Index: 1 Computerisation · 2 Connectivity · 3 Visibility · 4 Transparency · 5 Predictive capacity · 6 Adaptability
Source: Schuh, G. et al. (2020): Industrie 4.0 Maturity Index – Update 2020. acatech STUDY.

• Goals of the Smart Factory

1. Individualisation:

- Short-term customer requests considered in planning, design and production
- Individual products (batch size 1) at mass-production prices

2. Flexibility:

- Greater production flexibility (e.g. digital engineering, 3D printing for prototypes)
- Rapid implementation of innovations
- Shorter time-to-market for new products
- Consumption-driven supply of production
- Fast adaptation to new or changed product requirements

3. Productivity increase:

- Lower production costs (e.g. by optimising resource and energy efficiency)
- Predictive maintenance (anticipatory maintenance & service)
- Shorter production times
- Automated, efficient and transparent ordering processes

4. Sustainability & resilience (Industry 5.0):

- Less energy and material use, CO₂ transparency along the supply chain
- Robust, adaptable production in case of disruptions (e.g. supply shortages)

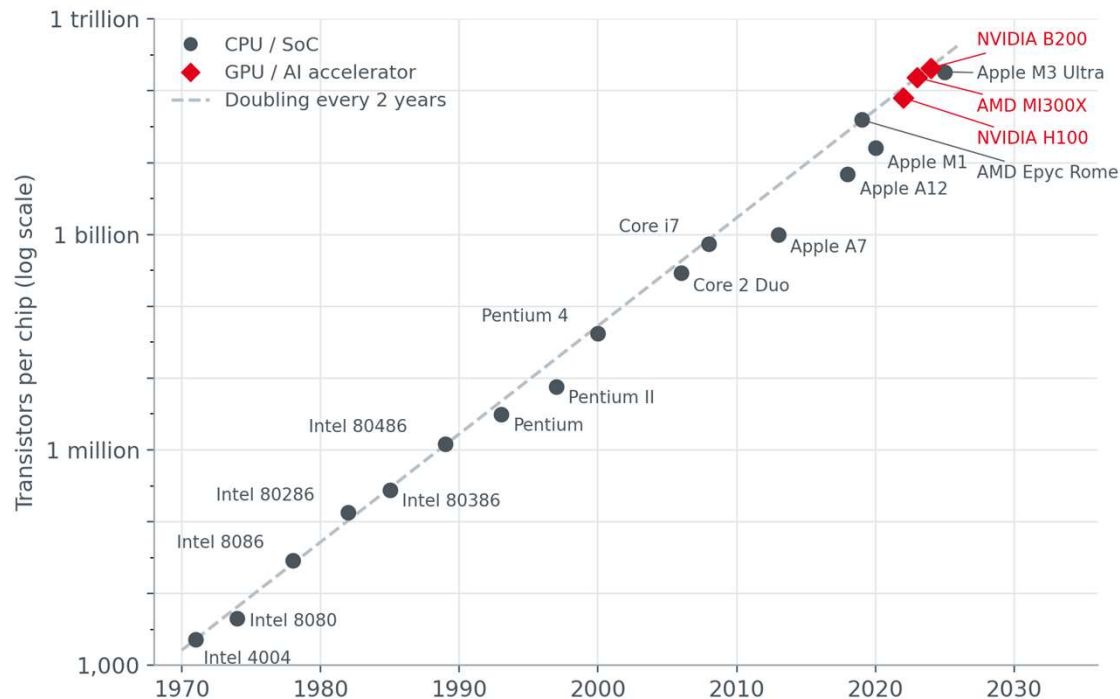
Internet of Things

Part 3 of 7



• Internet of Things (IoT)

Moore's Law: transistors per chip double roughly every 2 years



Gordon Moore (Intel)

1965: doubling every year, revised in 1975 to approx. every 2 years

Examples

Intel 4004 (1971): 2,300 transistors

Apple M3 Ultra (2025): 184 billion

NVIDIA Blackwell B200 (2024): 208 billion

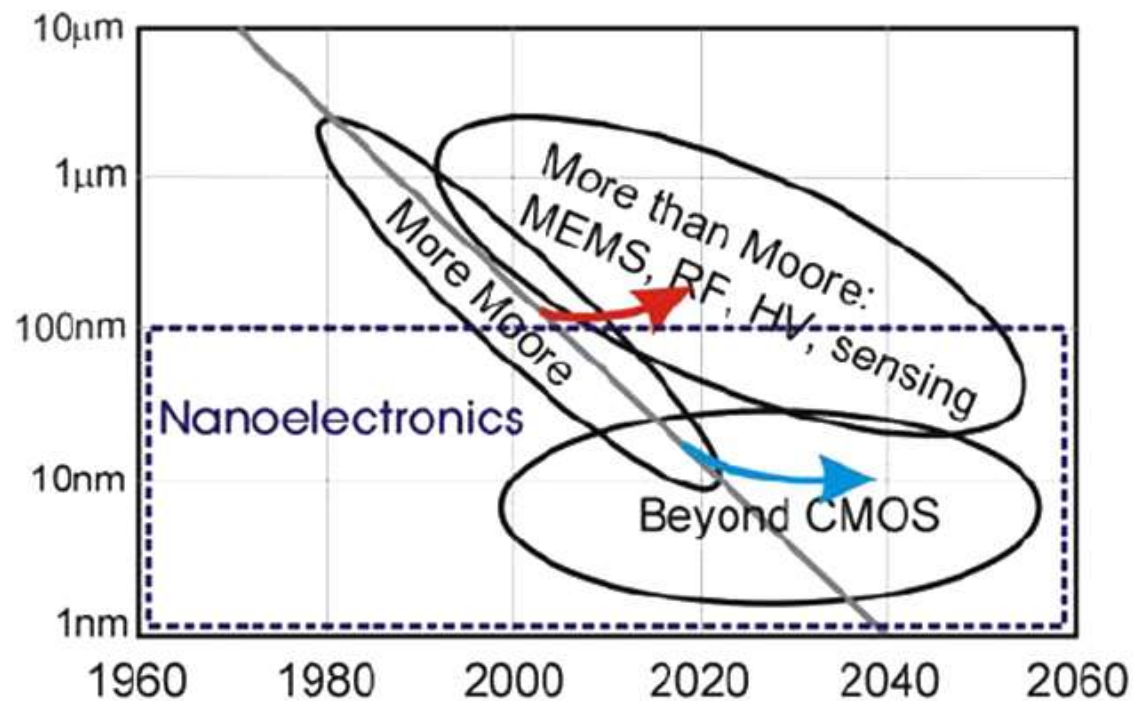
Consequence for IoT

Computing power, memory and radio become so small, cheap and energy-efficient that almost any thing can be connected.

Data: manufacturer information (selection), own illustration, as of 2025

• Internet of Things (IoT)

Driver microelectronics: Moore's Law → More Moore & More than Moore (SiP, chiplets)



Status 2026

Logic in volume production: 2 nm class (TSMC N2 since Q4/2025, Intel 18A)

More than Moore: sensors, MEMS, RF, power semiconductors – basis for IoT nodes

Heterogeneous integration: SiP / chiplets instead of scaling alone

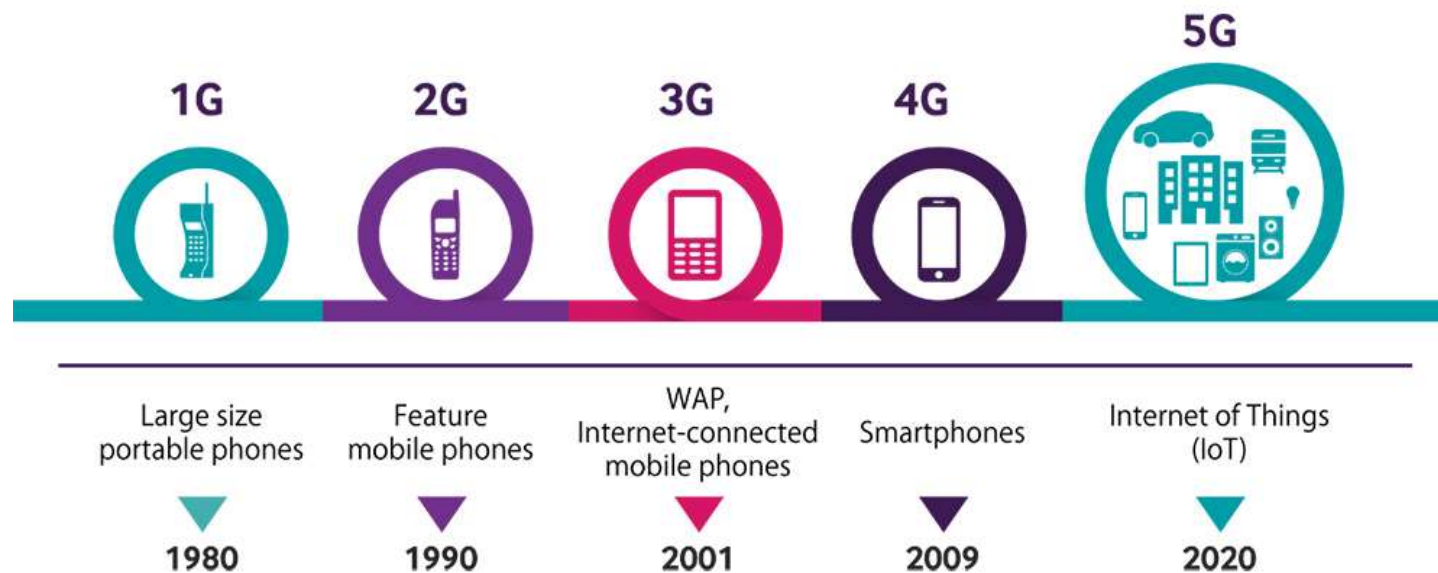
- Internet of Things (IoT)



Short version (German): [Elon Musk's new plan Terafab – the world's largest chip factory](#)

Long version (12 min, German): [the largest factory in history for \\$119 billion](#)

- Internet of Things (IoT)



Term "Internet of Things": Kevin Ashton, 1999 · IoT radio: NB-IoT, LTE-M, LoRaWAN, 5G RedCap · Outlook: 6G from approx. 2030
Approx. 21 billion connected IoT devices worldwide (IoT Analytics, 2025)

- Internet of Things (IoT)

Generation	Introduction	Peak data rate	Download of a 3 GB movie
1G	1980	2 kbit/s	≈ 139 days
2G	1990	100 kbit/s	≈ 2.8 days
3G	2001	8 Mbit/s	≈ 50 minutes
4G	2009	150 Mbit/s	≈ 2.7 minutes
5G	2020	10 Gbit/s	≈ 2.4 seconds
6G	≈ 2030	1 Tbit/s (target)	≈ 24 milliseconds

Calculation: 3 GB = 24 Gbit ÷ peak data rate. Theoretical peak values – real-world data rates are considerably lower.

6G: 3GPP standardisation from Release 20/21, commercial launch from approx. 2030; targets incl. Tbit/s, latency < 1 ms, AI-native networks, sensing.

- Internet of Things (IoT)

Latency

PING: Packet InterNet Groper
RTT: Round Trip Time

Think of a data packet as a ping-pong ball bouncing between user and server. The complete round-trip time is colloquially called "ping".



5G "1 ms" = URLLC target (ITU-R M.2410); in real networks typically 10–30 ms.

The name "ping" originally derives from the sonar echo.

- Internet of Things (IoT)

	IPv4	IPv6
Standard	1981 (RFC 791)	1998 (RFC 2460), current RFC 8200
Address length	32 bits	128 bits
Notation	dotted decimal 192.0.2.76	hexadecimal with colons 2001:db8:85a3::8a2e:370:7334
Prefix notation	192.0.2.0/24	2001:db8:85a3::/48
Number of addresses	$2^{32} \approx 4.3 \cdot 10^9$	$2^{128} \approx 3.4 \cdot 10^{38}$

Why IPv6 for IoT? IPv4 is not sufficient for ~21 billion IoT devices – IPv6 enables end-to-end addressing of every sensor/actuator.
 Example addresses from documentation ranges (RFC 5737 / RFC 3849).

Cyber-Physical Systems

Part 4 of 7



• Cyber-Physical Systems (CPS)

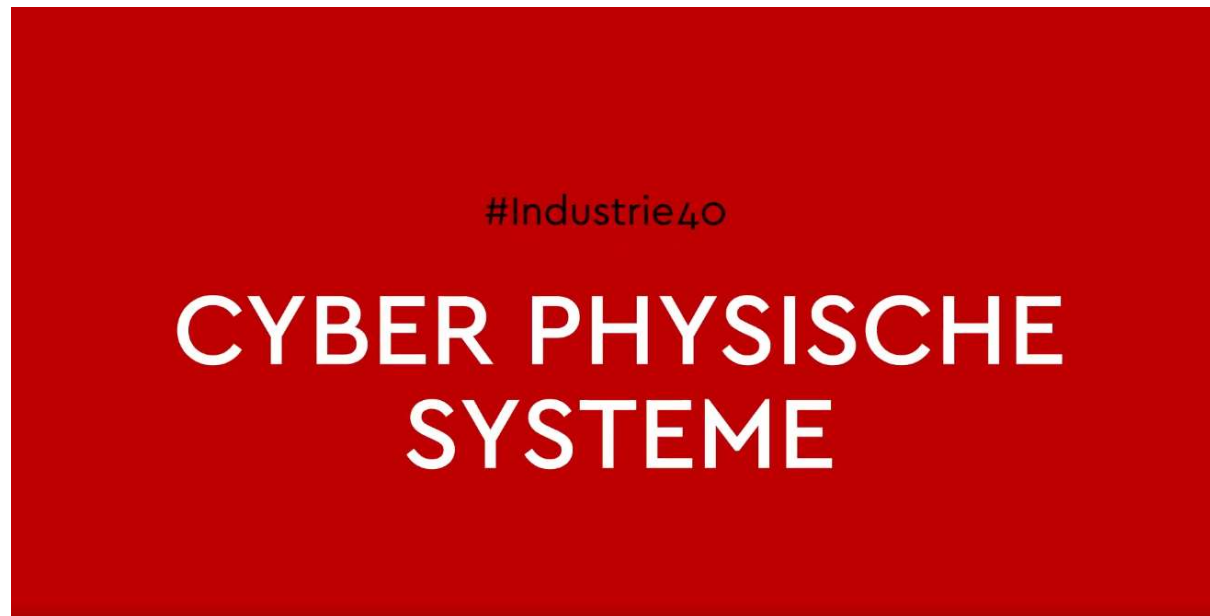
Embedded systems that capture the physical world with sensors, process data, communicate via networks and act on physical processes through actuators – connected across sites and, if applicable, across company boundaries.



Measure · Compute · Communicate · Act

after acatech (2011), E. A. Lee (2008)

- Cyber-Physical Systems (CPS)



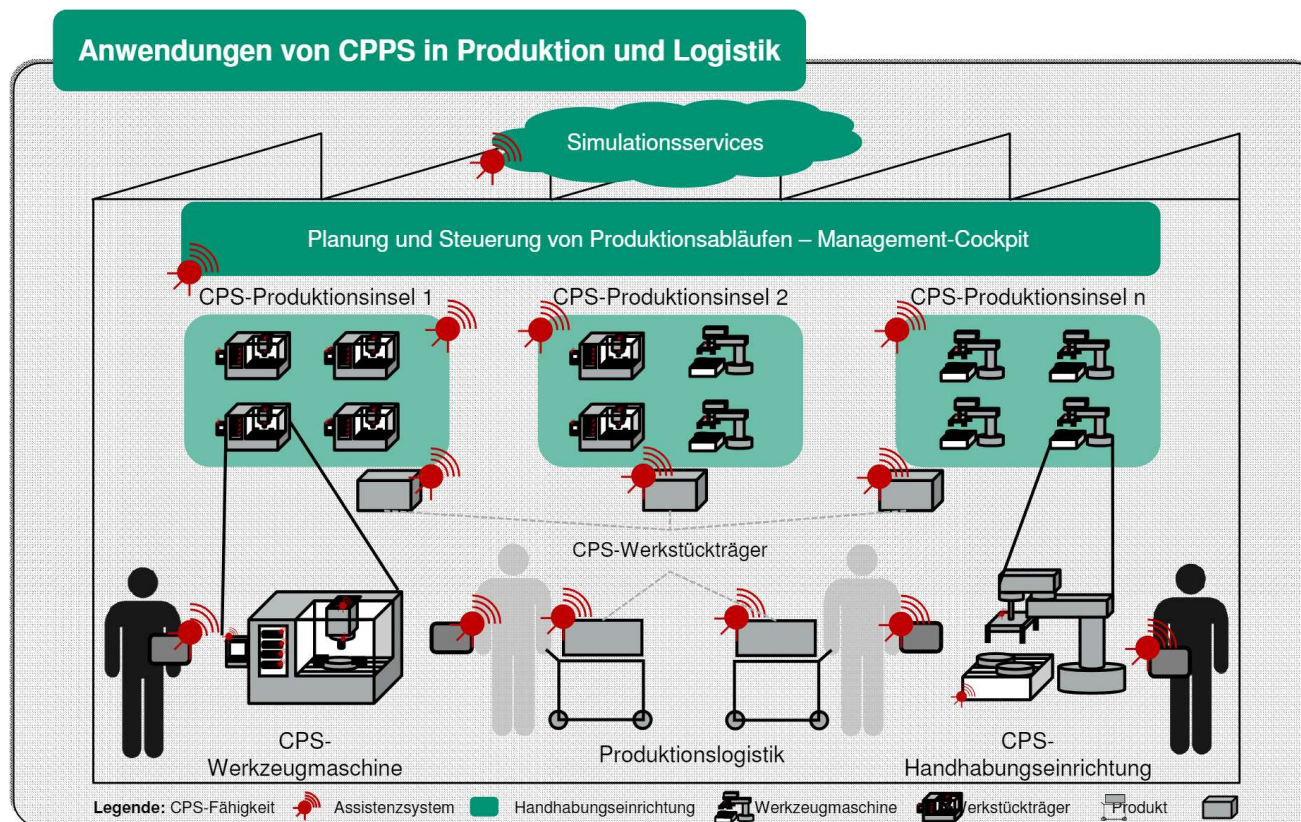
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CPPS

Part 5 of 7



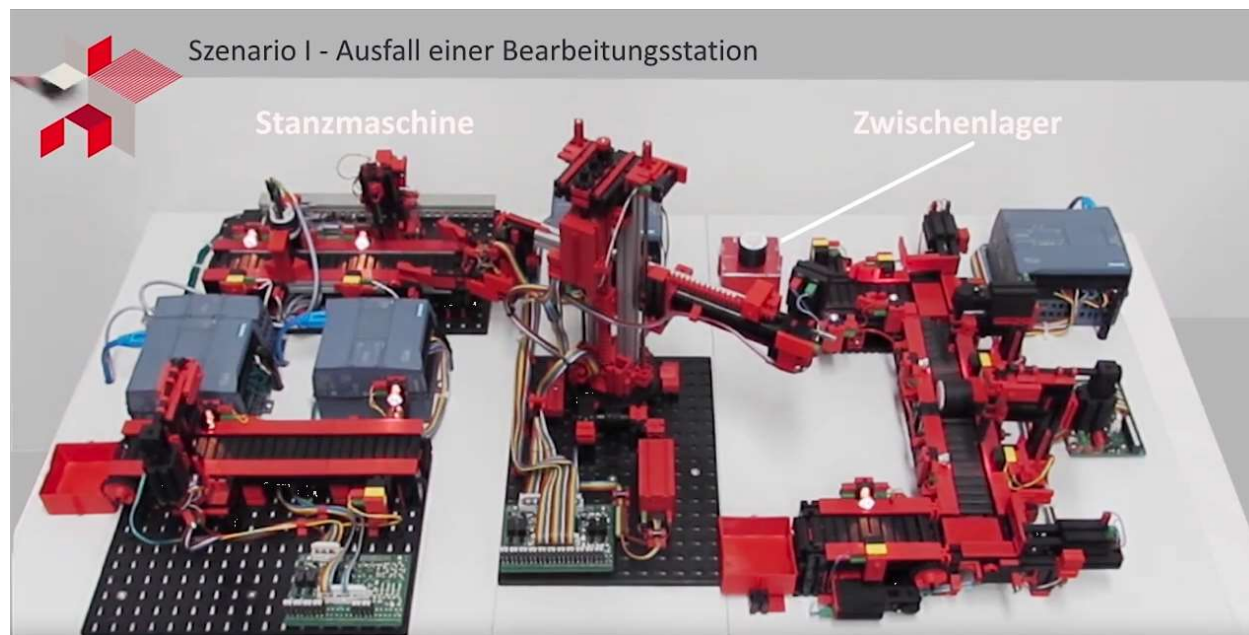
• Cyber-Physical Production Systems (CPPS)



Applications of CPPS in production and logistics

Simulation services · planning and control of production processes (management cockpit) · CPS production islands · CPS workpiece carriers · CPS machine tool · production logistics · CPS handling device

- Cyber-Physical Production Systems (CPPS)



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Smart Factory

Part 6 of 7

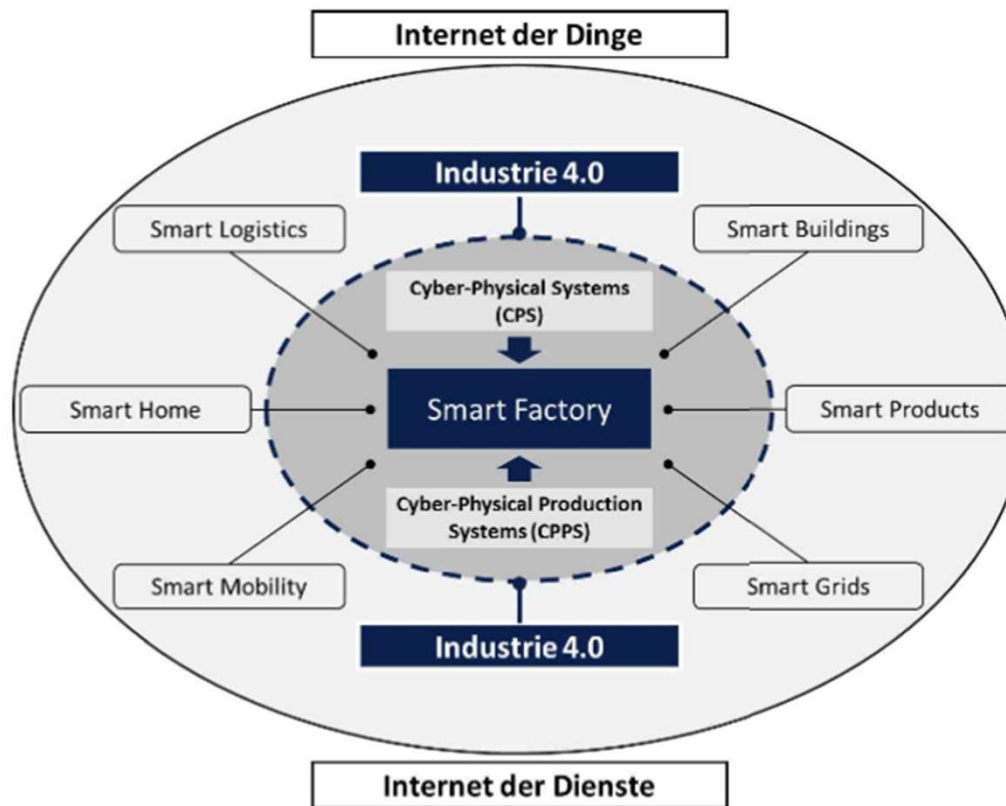


- Smart Factory

smart factory

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- Smart Factory

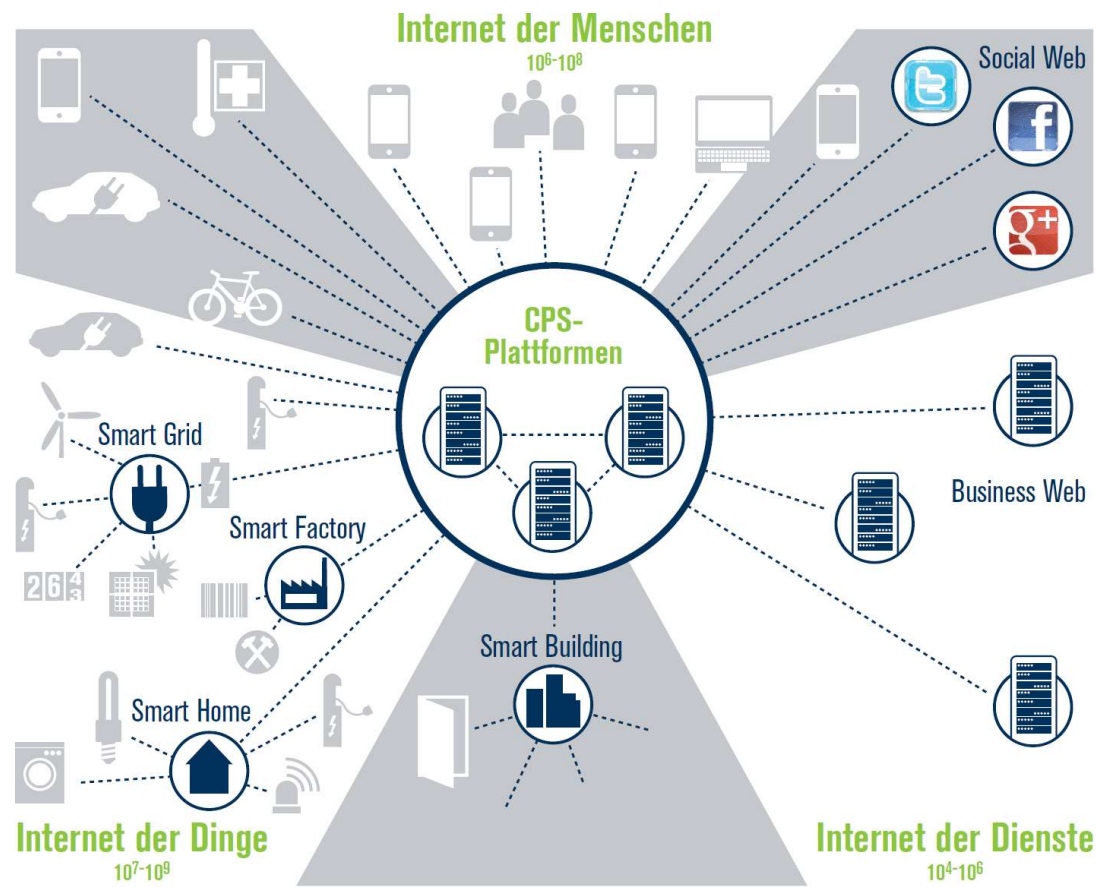


Summary

Part 7 of 7 · with Outlook



• Summary



Historical illustration

Bosch Software Innovations, 2012. Google+ was discontinued in 2019, Twitter is now X – the principle of CPS platforms still applies.

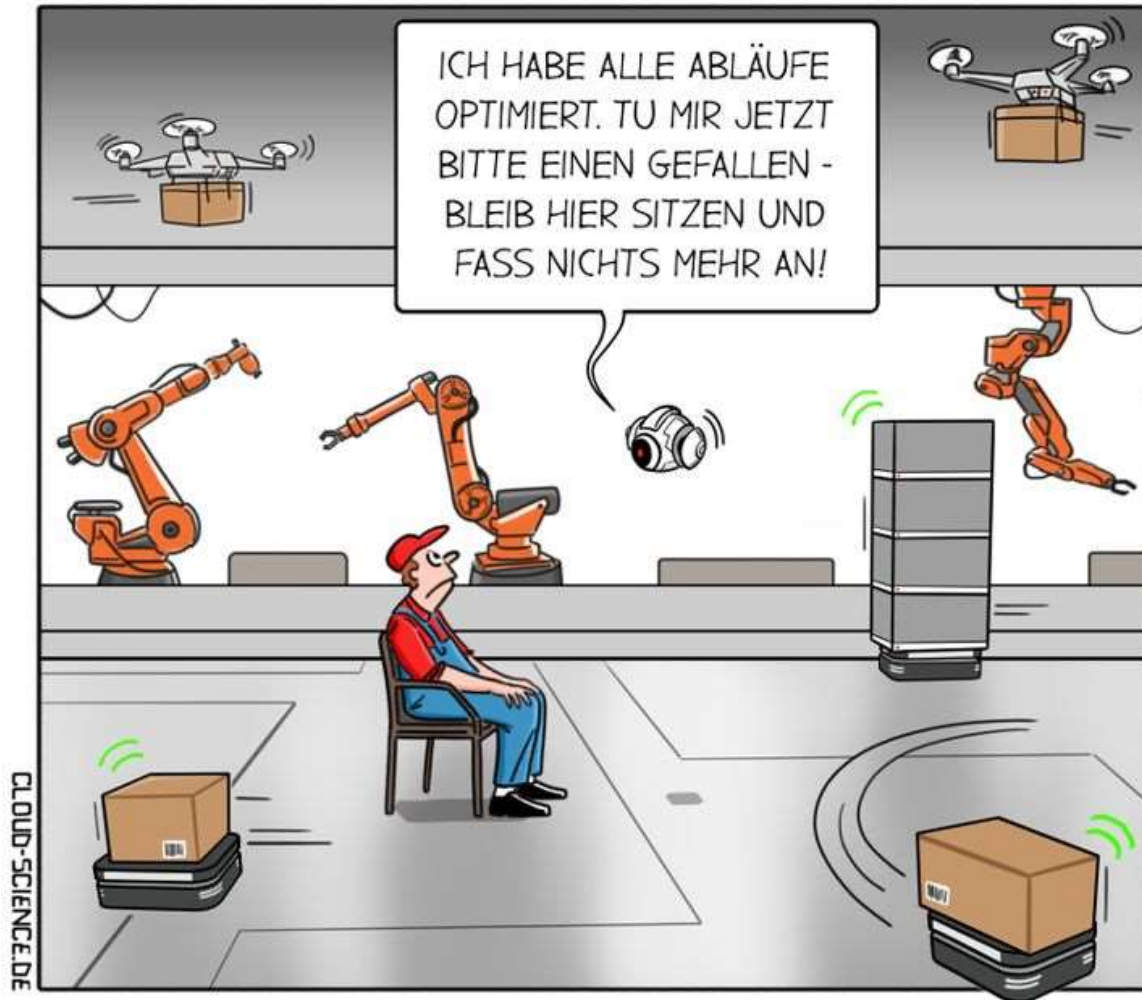
Labels: Internet of People · Internet of Things · Internet of Services

• Summary

- The smart factory is part of the Industrie 4.0 initiative. Goals: securing competitiveness through cost reduction, entering **new markets** and **new products and services**.
- The foundation is the **comprehensive digitalisation** of production and control (maturity: computerisation → adaptability).
- The Internet of Things (IoT) and cyber-physical systems (CPS) are the key technologies – integrated into production they form a **CPPS** that controls itself in real time.
- Required: IPv6 address space for billions of devices and networks with **more participants, more data and low latency** (5G, in future 6G).
- IoT, the Internet of Services and social networks are linked on **CPS platforms**.
- The vision is not the unmanned but the **human-centric**, sustainable and resilient factory (Industry 5.0).

• Outlook: Smart Factory 2026

- **Asset Administration Shell (AAS) & OPC UA** – standardised digital representations and communication (→ Reference Architectures)
- **Data spaces Manufacturing-X / Catena-X** – sovereign data exchange along the value chain
- **Digital twin** – simulation and optimisation across the entire life cycle
- **AI / generative AI in production** – quality inspection, predictive maintenance, assistance systems (→ Machine Learning)
- **Regulation:** EU Data Act (applies since 12 Sep 2025) · Cyber Resilience Act (reporting obligations from 11 Sep 2026, fully from 11 Dec 2027) · Machinery Regulation (EU) 2023/1230 (from 20 Jan 2027) · AI Act (phased since 2025)



Thank you for your attention!

“I’ve optimised all processes. Now do me a favour – sit here and don’t touch anything!”



Kahoot: create.kahoot.it
QuestBase self-test (Ch. 01): [Multiple Choice](#) · [Open questions](#)

- Self-test: QuestBase quiz chapter 01

Multiple choice

15 questions

PIN

5801-4064-9400



Open quiz

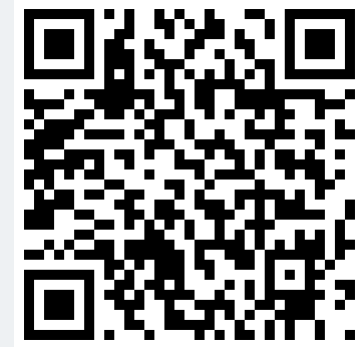
<https://quiz.questbase.com/#/5801-4064-9400>

Open questions

7 questions

PIN

1761-8921-7900



Open quiz

<https://quiz.questbase.com/#/1761-8921-7900>

Scan the QR code, click the link or enter the PIN at quiz.questbase.com.

www.ravensburg.dhbw.de

