Industry 4.0 – Chances and Challenges of the Digital Transformation

Dietmar Theis
Technical University Munich - Germany

dietmar.theis@tum.de

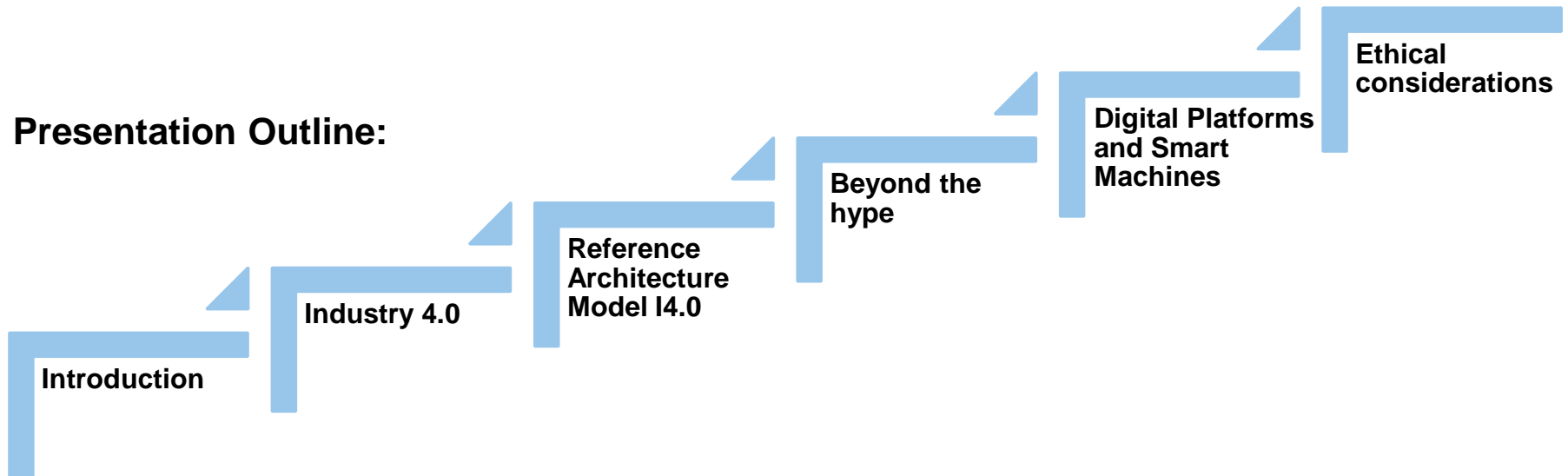# >44 zettabytes

of data in 2020; >35 % in Cloud

~ 15% of 212 bln assets connected

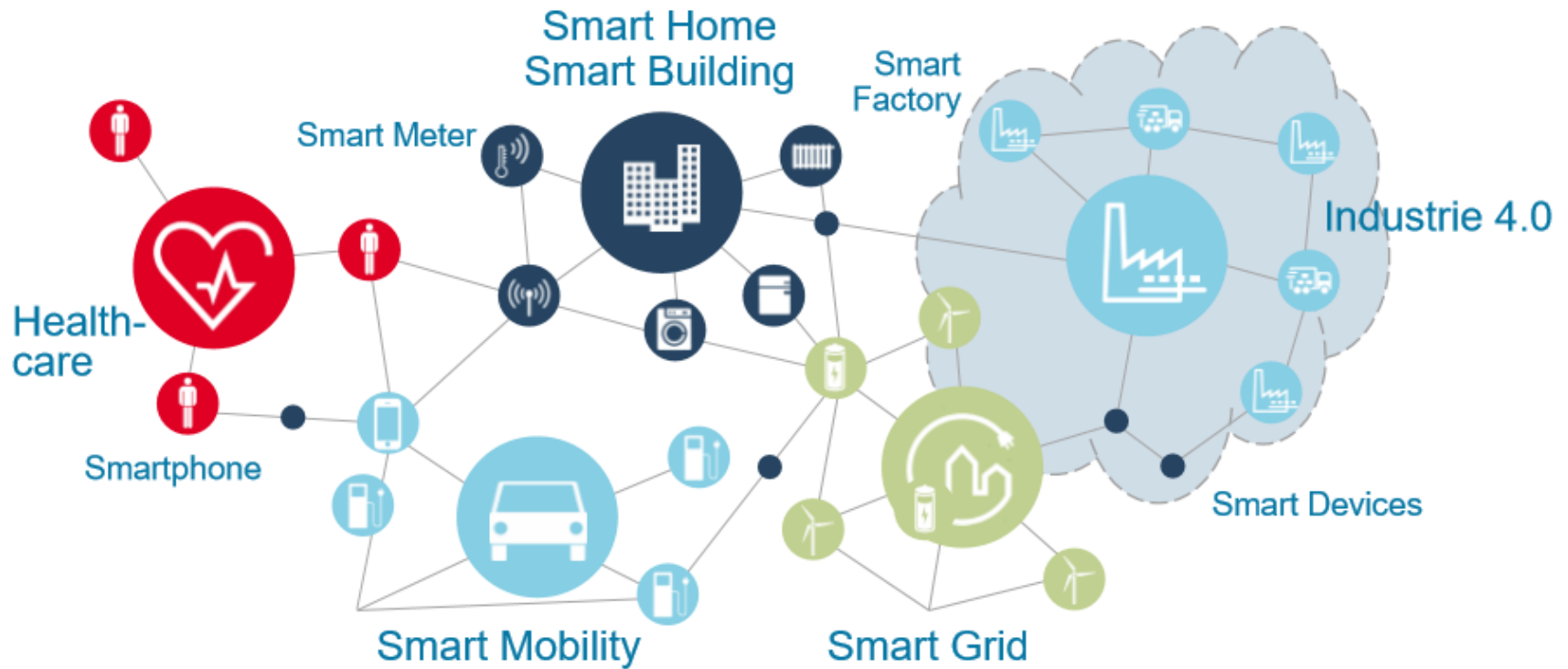**4.4 zettabytes** of data in 2013; >5% in Cloud

~ 7% of 187 bln assets connected

44	000	000	000	000	000	000	000
ZETTA	EXA	PETA	TERA	GIGA	MEGA	KILO	BYTE

Industry 4.0 – Chances and Challenges of the Digital Transformation

Presentation Outline:

Introduction

Industry 4.0

Reference Architecture Model I4.0

Beyond the hype

Digital Platforms and Smart Machines

Ethical considerations

Internet of Things and Services and Industry 4.0

Grafik © Bosch Rexroth AG

Key processes – focal topics in industrial production

PDM – Product Data Management
SCM – Supply Chain Management
CRM – Customer Relation Management
ERP – Enterprise Resource Planning
MES – Manufacturing Execution System
CAI – Computer Aided Instruction
PLM – Product Lifecycle Management
QMS – Quality Management System

Technical processes
Commercial processes

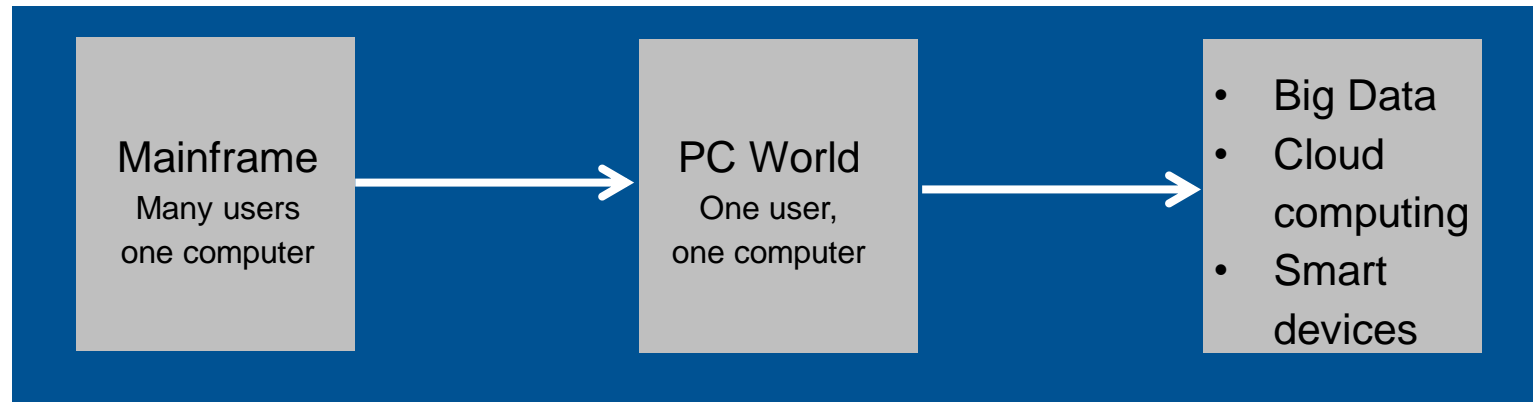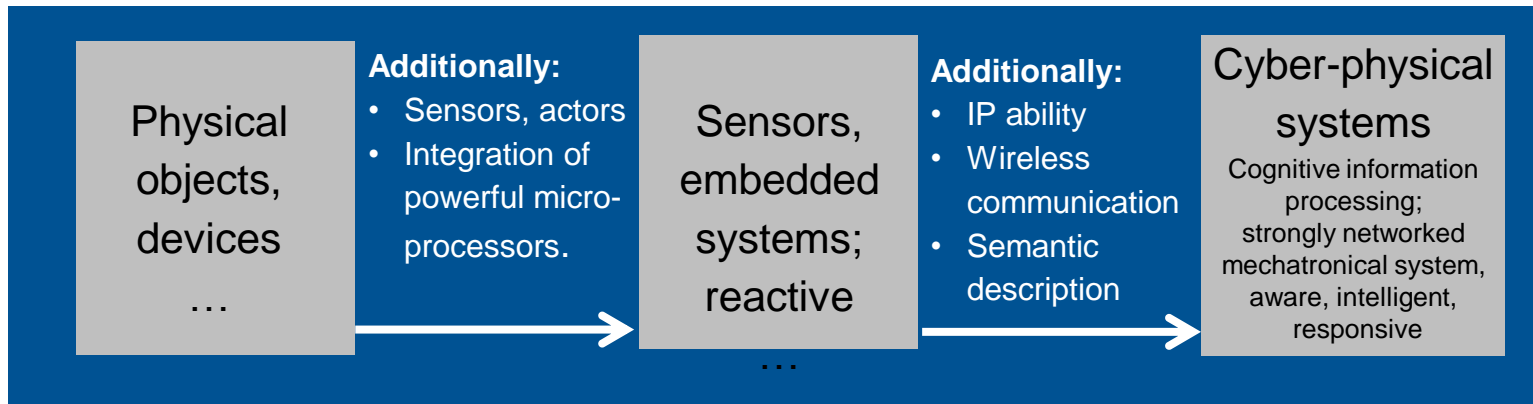The lifecycle idea is basic for Industry 4.0 !
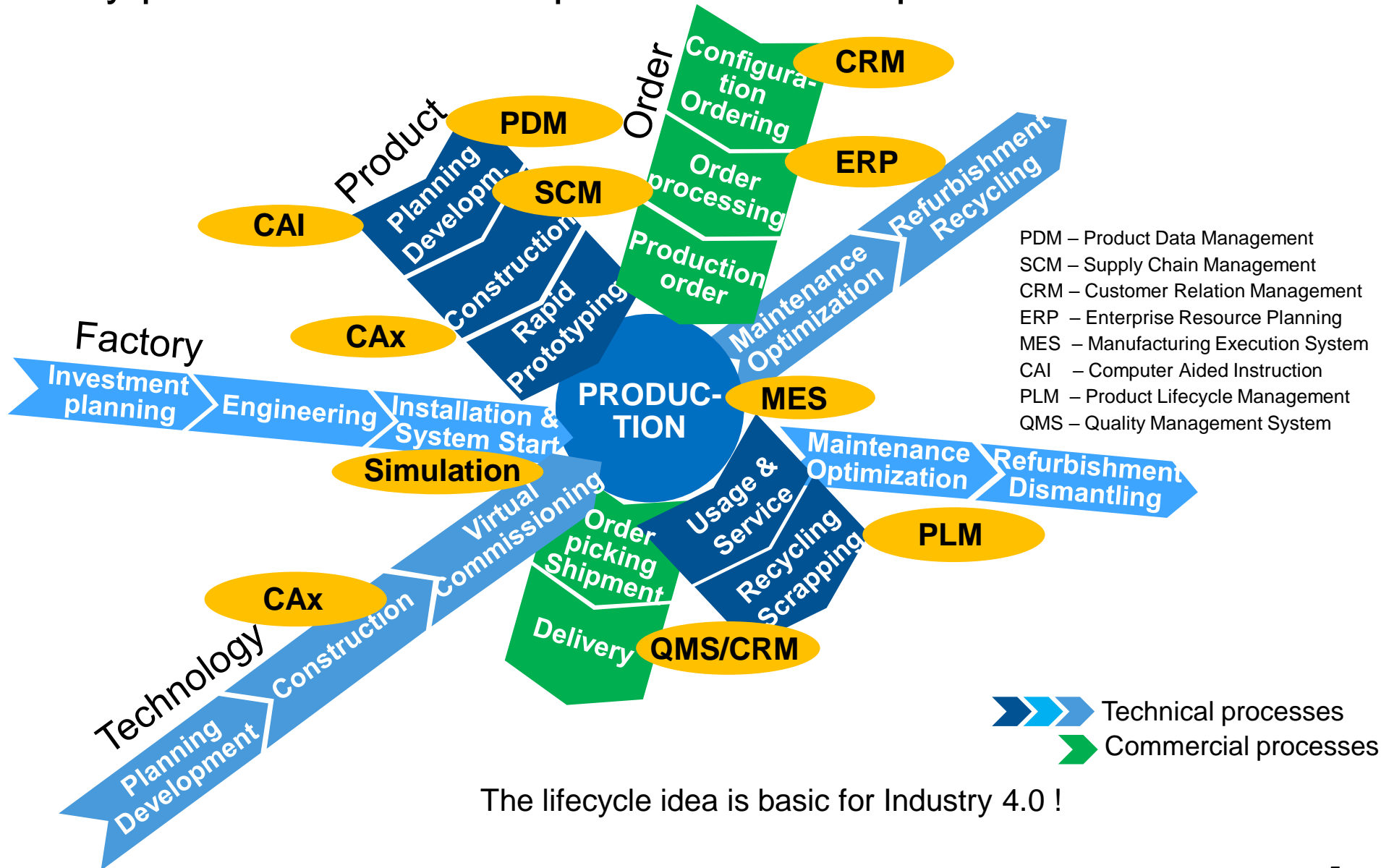
Definition: Industry 4.0…

…is a new step in the organization and control of the value chain along the life cycle of products. The life cycle is increasingly determined by individual customer requirements and extends from the original idea, the research and development phase, the final delivery to the customer up to product recycling and includes all services involved.

…encompasses a confluence of trends and technologies like the dramatic increase in com-putational power and connectivity, new forms of human-machine interaction and improvements in transferring digital instructions to the physical world. Robotics is part of the Industry 4.0 picture.
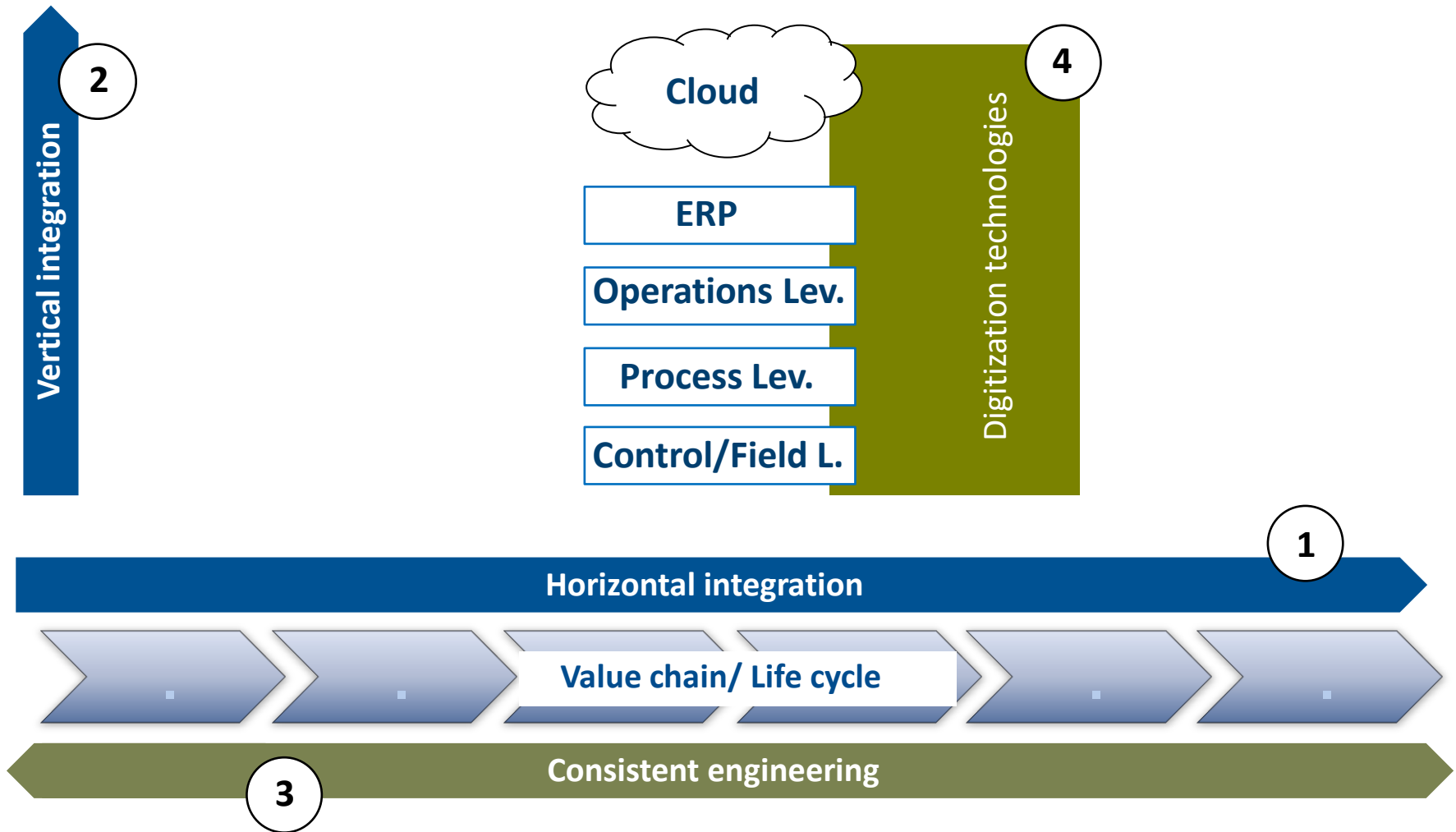
While Industry 3.0 focused on the automation of single machines and processes, Industry 4.0 focuses on the end-to end digitization of all physical assets and integration into digital ecosystems with value chain partners.
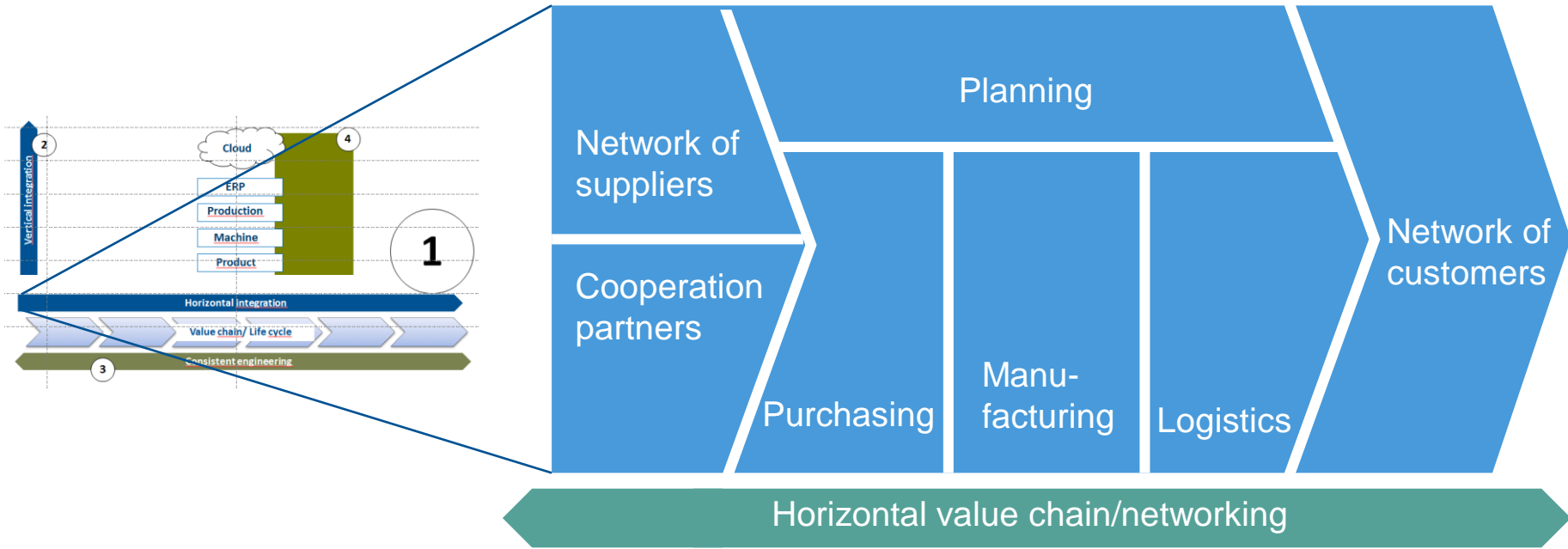
Moving towards a cyber-physical system

Physical objects, devices …

Additionally:
- Sensors, actors
- Integration of powerful micro-processors.

Sensors, embedded systems; reactive …

Additionally:
- IP ability
- Wireless communication
- Semantic description

Cyber-physical systems
Cognitive information processing; strongly networked mechatronical system, aware, intelligent, responsive

Mainframe
Many users one computer

PC World
One user, one computer

- Big Data
- Cloud computing
- Smart devices

Source : Stuttgart University, Automation Technology and Software Systems

7

Four features constituting Industry 4.0

2 Vertical integration

Cloud

ERP

Operations Lev.

Process Lev.

Control/Field L.

4 Digitization technologies

1 Horizontal integration

Value chain/ Life cycle

3 Consistent engineering

1. Horizontal integration over value adding network

- Designing value adding networks along (worldwide) value chains
- Integration of business processes stretching beyond the internal operations
- Cyber-physical systems communication increases flexibility, collection of data enables consistent transparency and new control parameters optimize production
- New business models for producers and service providers will emerge

2. Vertical integration and networked manufacturing system
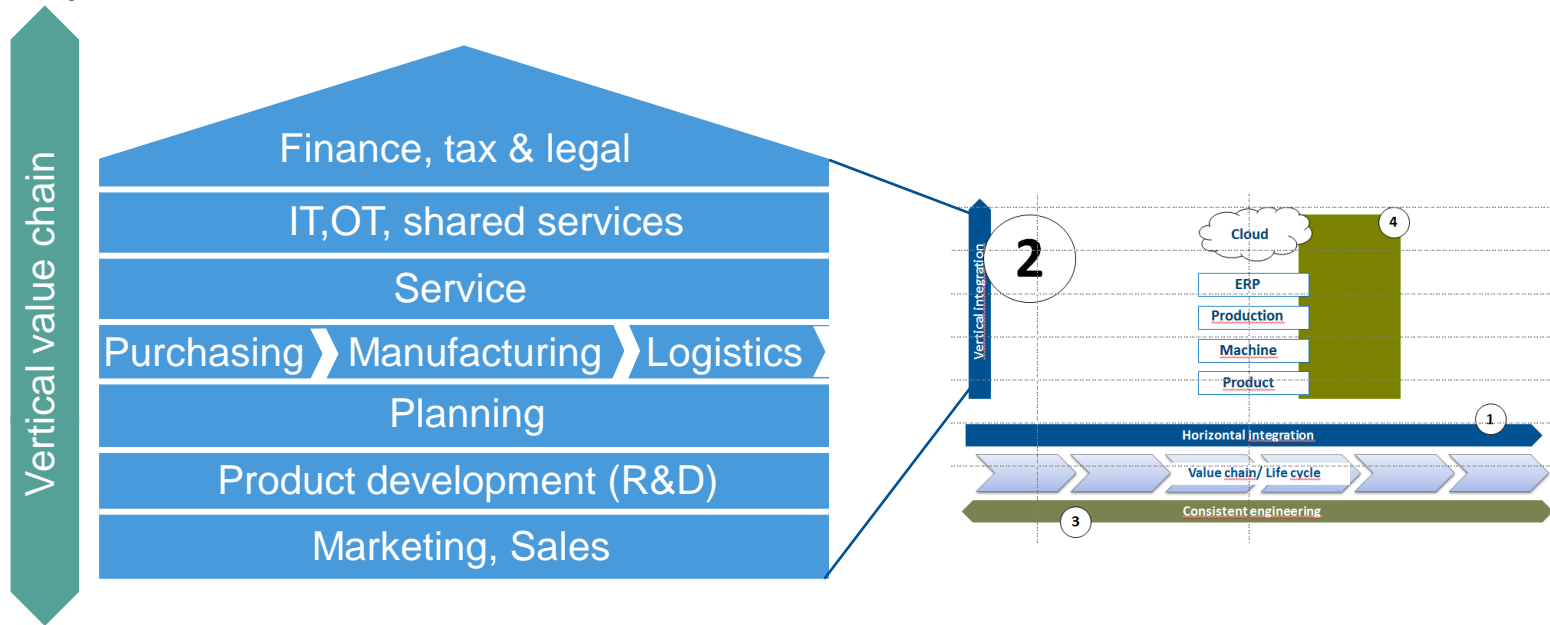
- **Interoperability** — machines, devices, sensors and people that connect and communicate with one another. Semantic data analysis enables continuous optimization of product - or machine - related process parameters

- All data about operations processes, **process efficiency** and quality management, as well as operations planning are available in **real-time**. Self-learning and -controlling systems react highly flexible to disruptions and changes

- Experience and data analysis enable optimized **predictive maintenance**

- Knowledge of models and flexible production systems enable **individualized production**

Adapted from PwC

3. Consistent engineering along the entire life cycle

- By contextualizing all available information a virtual digital copy of the physical world is generated (products and processes) based on sensor data, simulations and descriptive/planning models (Cyber Physical Production Systems – CPPS).

- The generated digital copy („twin") of a product is used over the entire life cycle

- This integration of the real and the digital/virtual worlds requires well defined common semantics

- The virtual product leads to new business models

4. Digitization Technologies

Four technology clusters enable the digitization of the manufacturing sector in Industry 4.0

Data, computational power, & connectivity

Big data/ open data (significantly reduced costs of computation, storage, sensors), **Cloud technology** (centralization of data and virtualization of storage) **Internet of Things / M2M** (interoperability, wireless connectivity).

Analytics & intelligence

Digitization and automation of knowledge work (breakthrough advances in AI and machine learning) **Advanced analytics** (improved algorithms and exponential increase in available data).
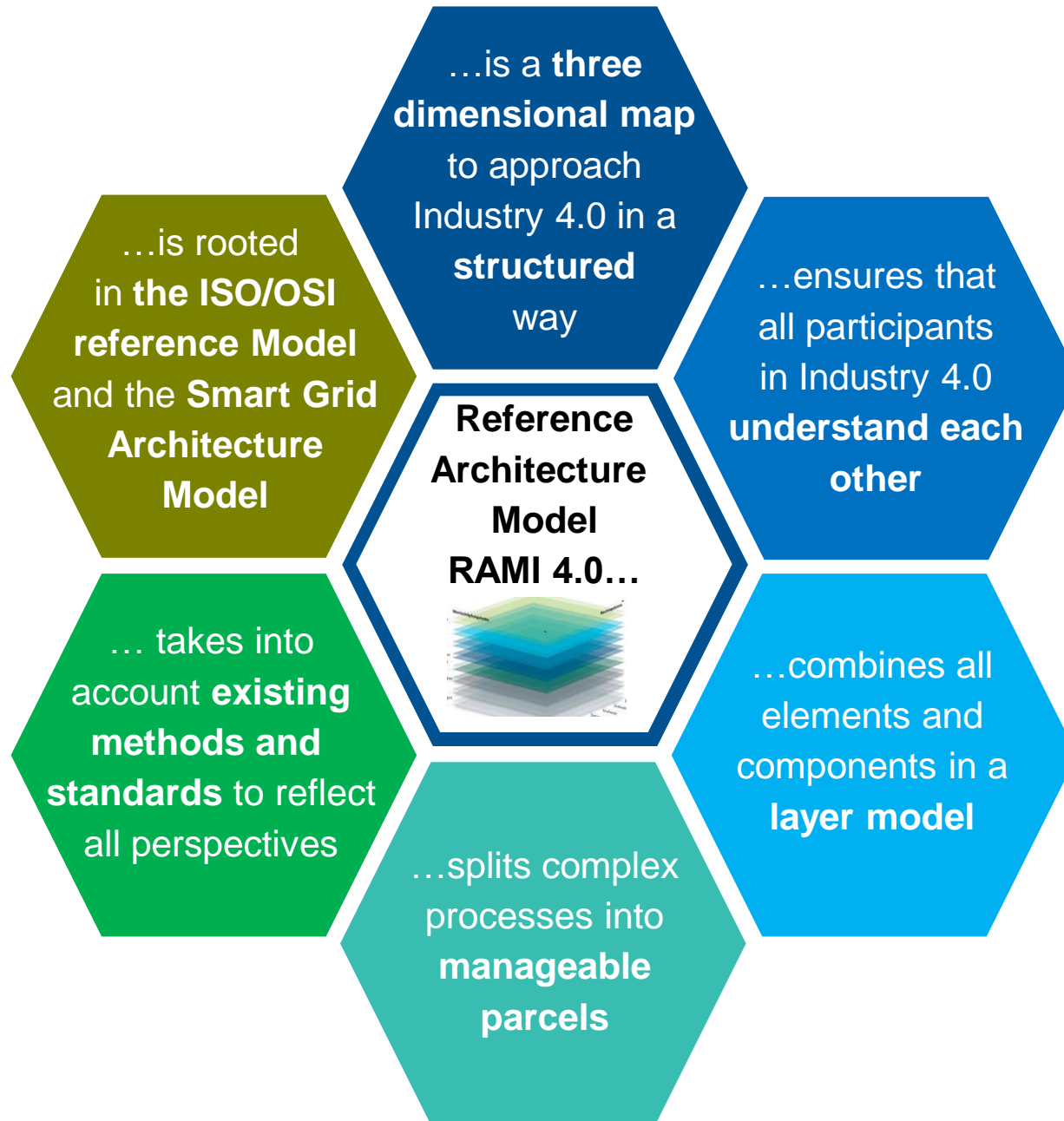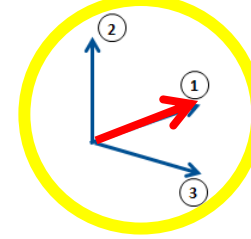
Digital-to-physical conversion

Combination of decreasing costs, new materials, advances in precision and quality : **Smart sensors**; **Additive manufacturing/**3D-printing; **Energy storage** and harvesting.
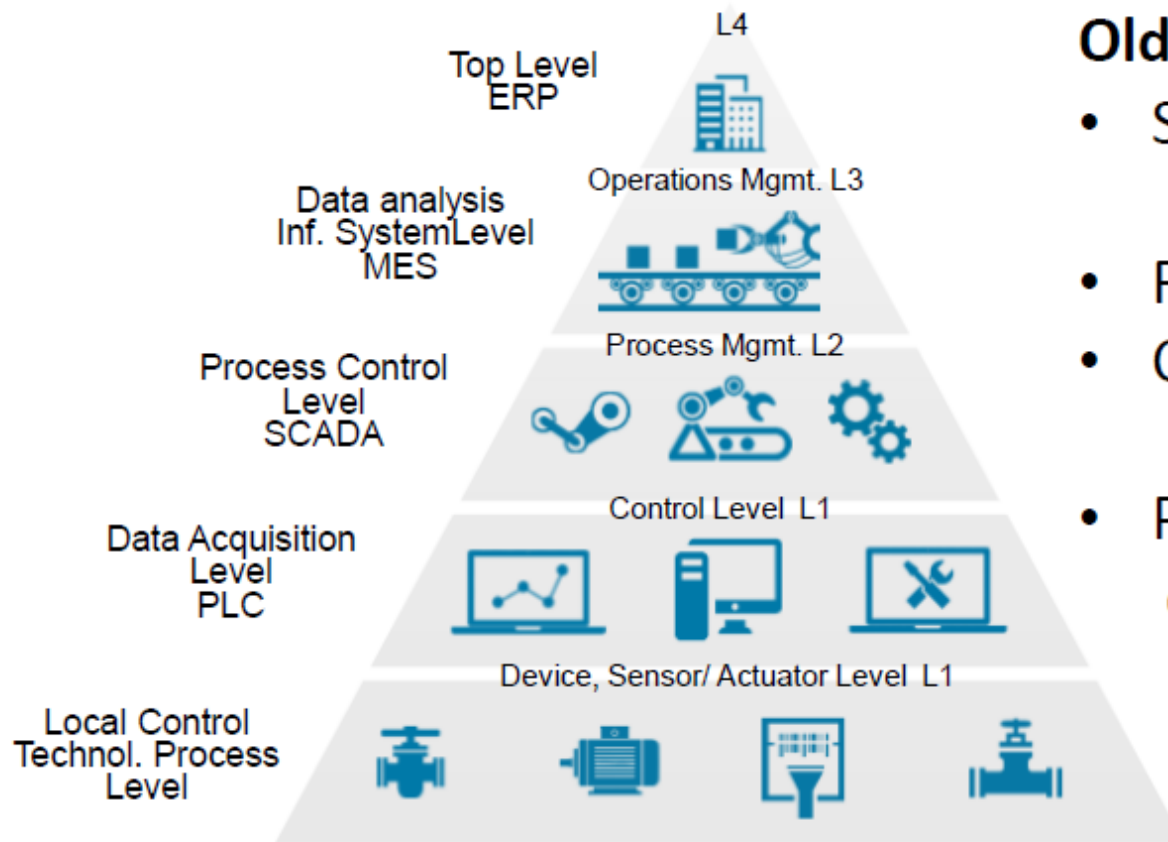
Human-machine interaction

Advanced human-machine **interface;** **Virtual** and augmented **reality / wearables;** Advanced robotics/**human-robot collaboration.**

…is a **three dimensional map** to approach Industry 4.0 in a **structured** way

…is rooted in **the ISO/OSI reference Model** and the **Smart Grid Architecture Model**

…ensures that all participants in Industry 4.0 **understand each other**

Reference Architecture Model RAMI 4.0…

… takes into account **existing methods and standards** to reflect all perspectives

…combines all elements and components in a **layer model**

…splits complex processes into **manageable parcels**

Architecture Axis 1
## Inspired by the Automation Pyramid

Old World – Industry 3.0

- Structure determined by hardware
- Features tied to hardware
- Communication only between hierarchy levels
- Product not integral part of process

Pyramid levels (left labels):
- Top Level — ERP / L4
- Data analysis Inf. SystemLevel MES / Operations Mgmt. L3
- Process Control Level SCADA / Process Mgmt. L2
- Data Acquisition Level PLC / Control Level L1
- Local Control Technol. Process Level / Device, Sensor/ Actuator Level L1

Product

ERP – Enterprise Resource Planning
MES – Manufacturing Execution System
SCADA – Supervisory Control And Data Acq.
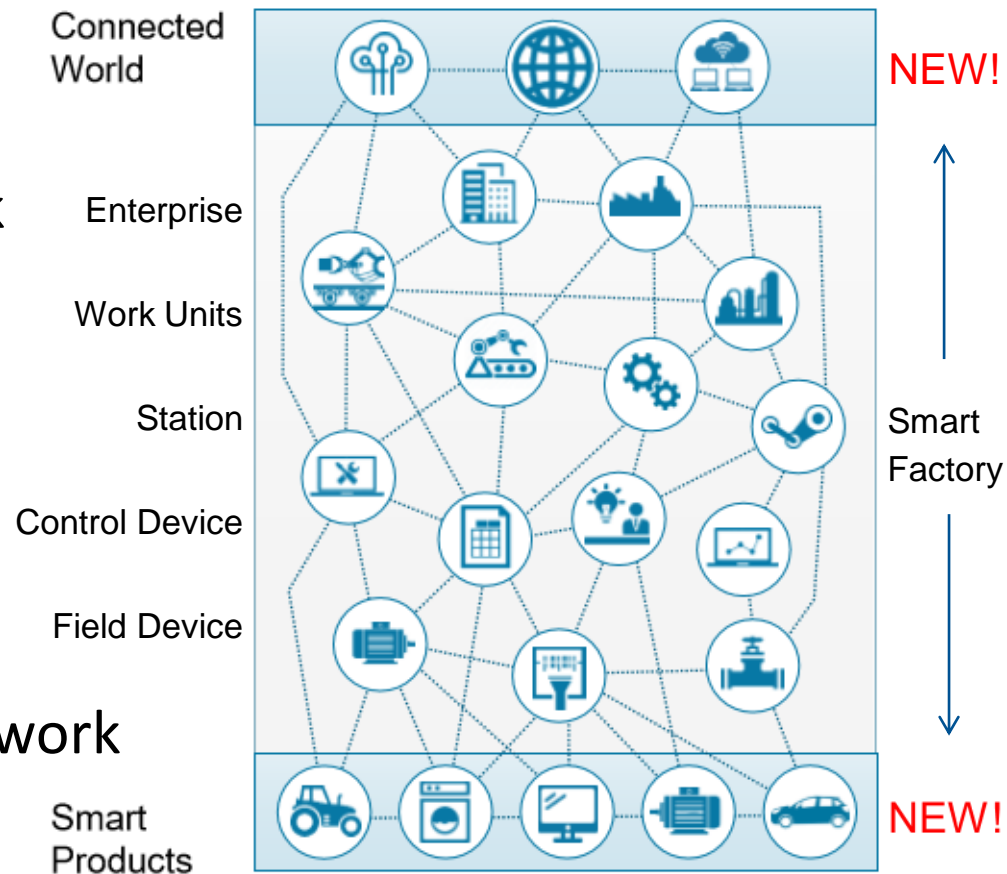PLC – Programmable Logic Controller
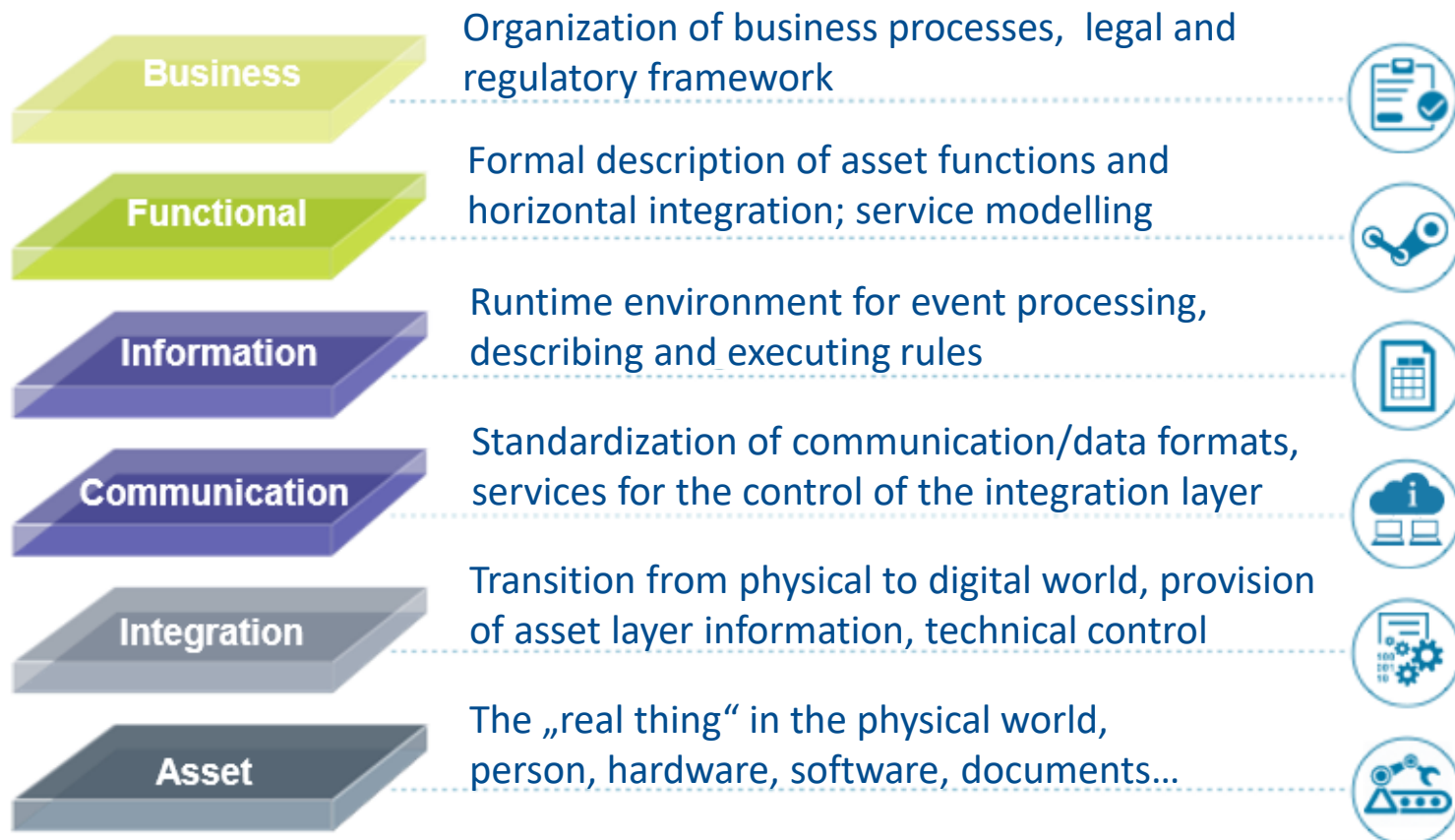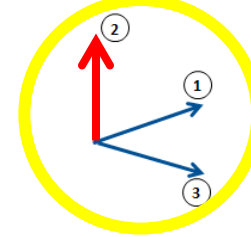
Adapted from Plattform Industrie 4.0
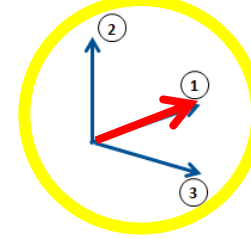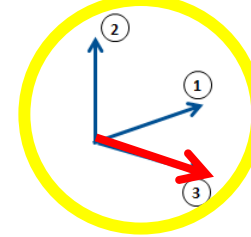
Architecture Axis 1 – Production Stages

New World – Industry 4.0

- Flexible plants and machines
- Roles distributed in a network
- All participants are inter-
  connected even across
  hierarchy levels
- Communication takes place
  between all participants
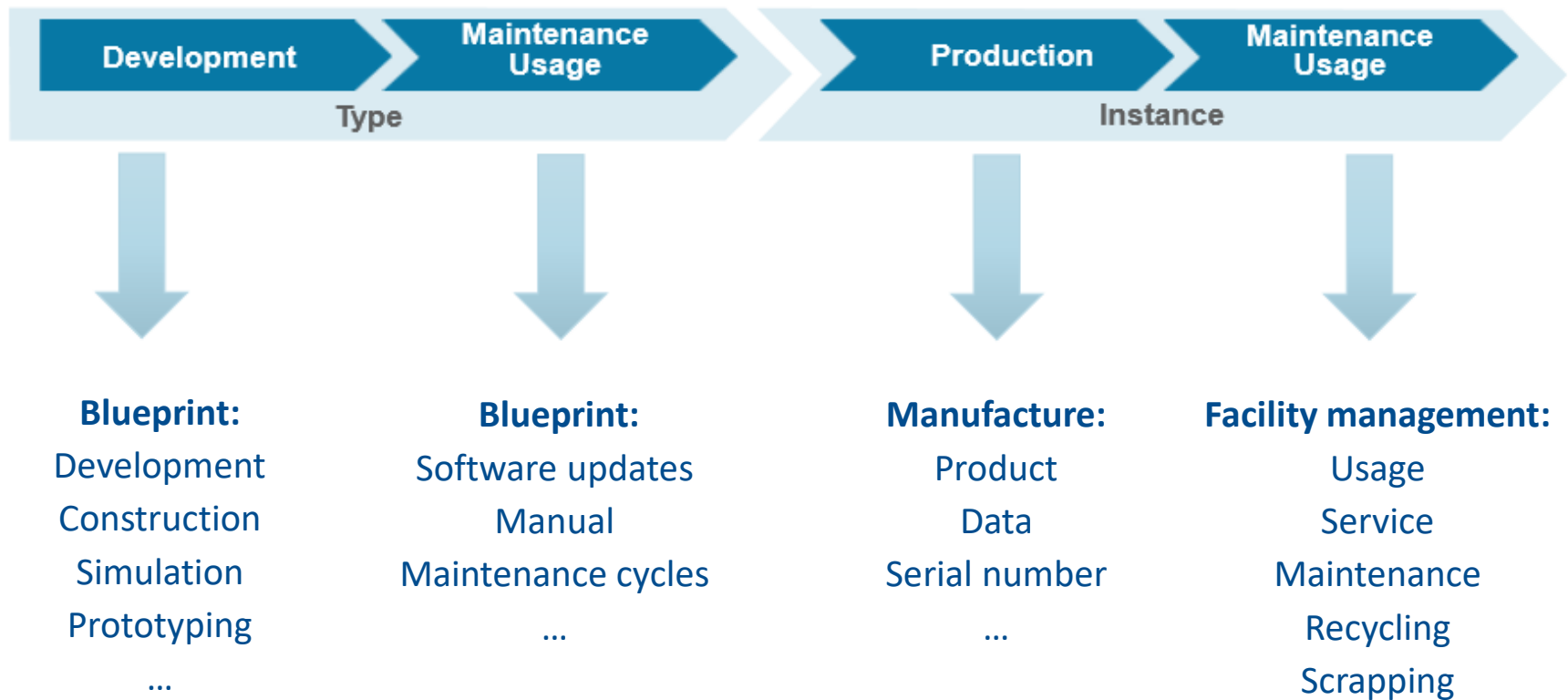- The product is part of the network

Architecture Axis 2 – RAMI IT 4.0 layers

Business — Organization of business processes, legal and regulatory framework

Functional — Formal description of asset functions and horizontal integration; service modelling

Information — Runtime environment for event processing, describing and executing rules

Communication — Standardization of communication/data formats, services for the control of the integration layer

Integration — Transition from physical to digital world, provision of asset layer information, technical control

Asset — The „real thing" in the physical world, person, hardware, software, documents…

Architecture Axis 3 – Product lifecycle

The Product: from the first idea down to the scrap yard

Development	Maintenance Usage		Production	Maintenance Usage
	Type			Instance

Blueprint:
Development
Construction
Simulation
Prototyping
…

Blueprint:
Software updates
Manual
Maintenance cycles
…

Manufacture:
Product
Data
Serial number
…

Facility management:
Usage
Service
Maintenance
Recycling
Scrapping
…

The Architectural Model of Industry 4.0


Adapted from Plattform Industrie 4.0
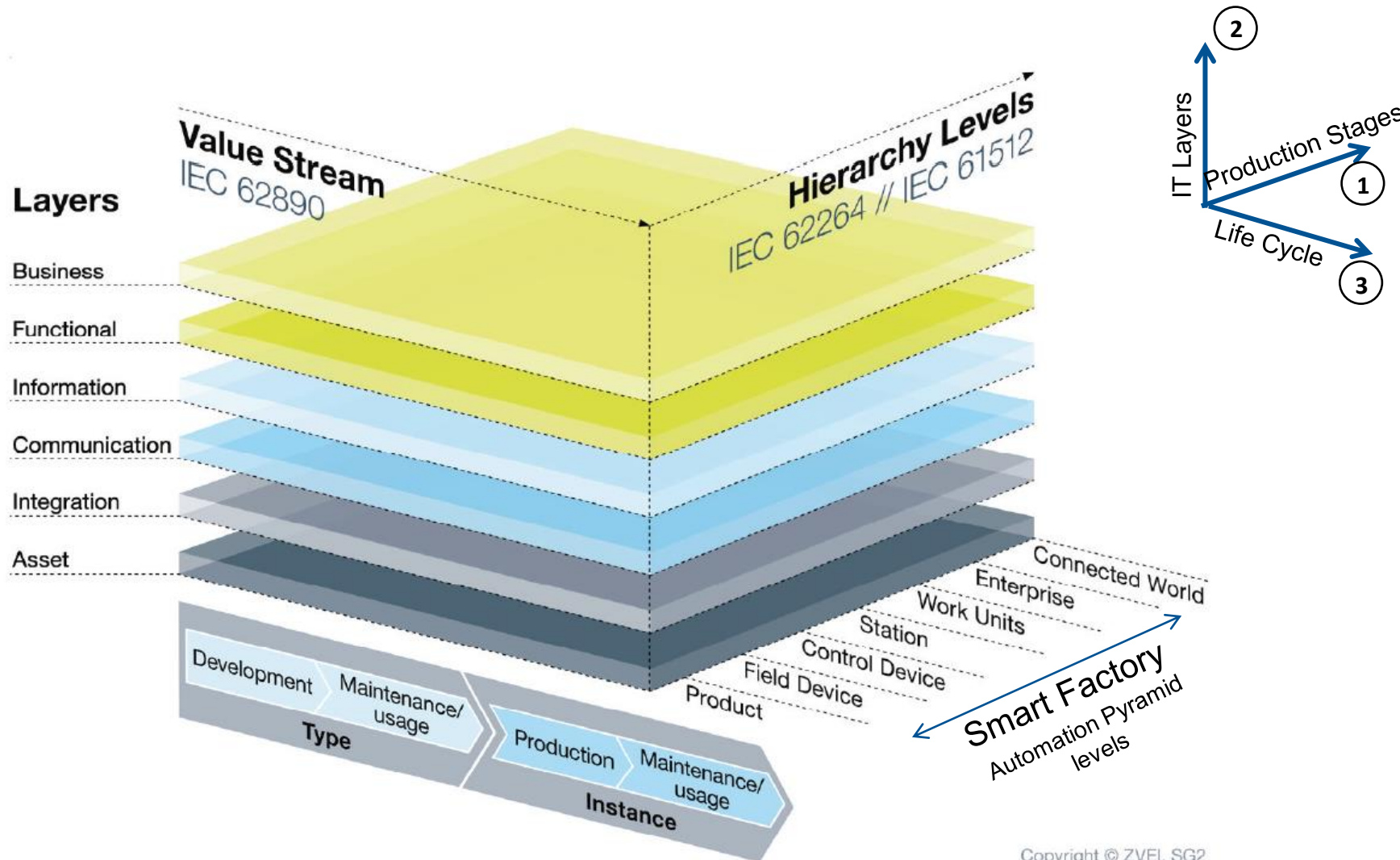
Who translates between assets? The administration shell…
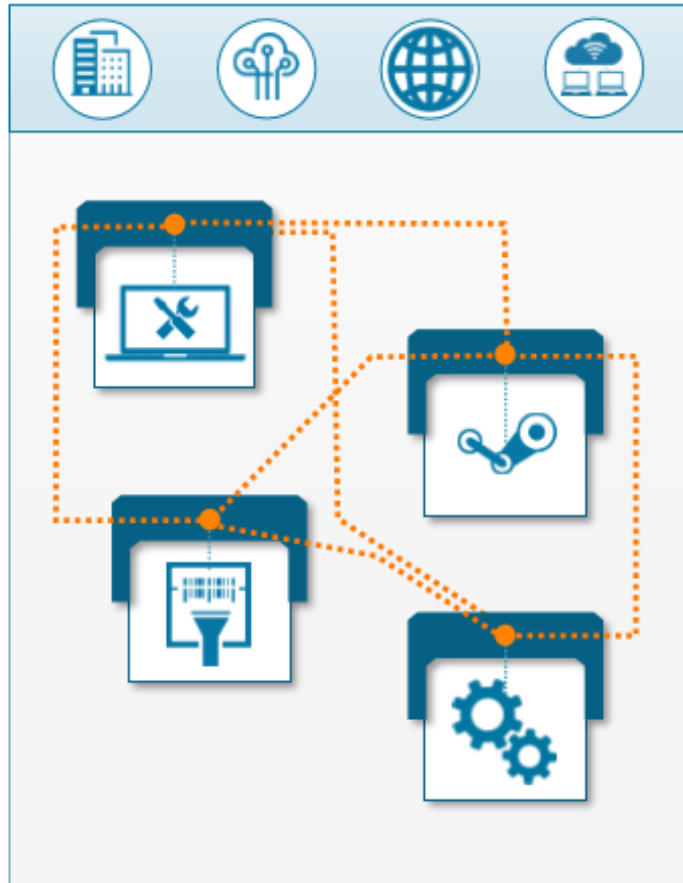
- …is the interface between **I** 4.0 communication and the physical object.
- …is the data store of all information about the asset.
- …is the standardized communication interface in the network.
- …is the virtual image of the physical asset describing its properties
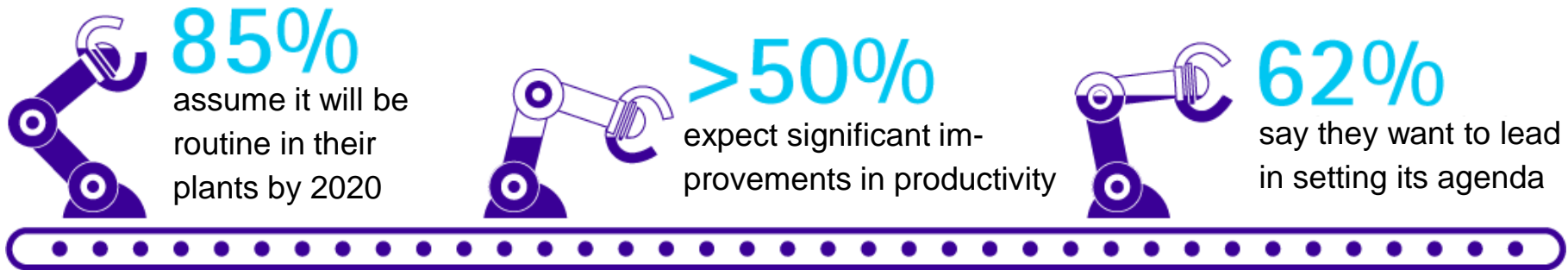
The Industry 4.0 component
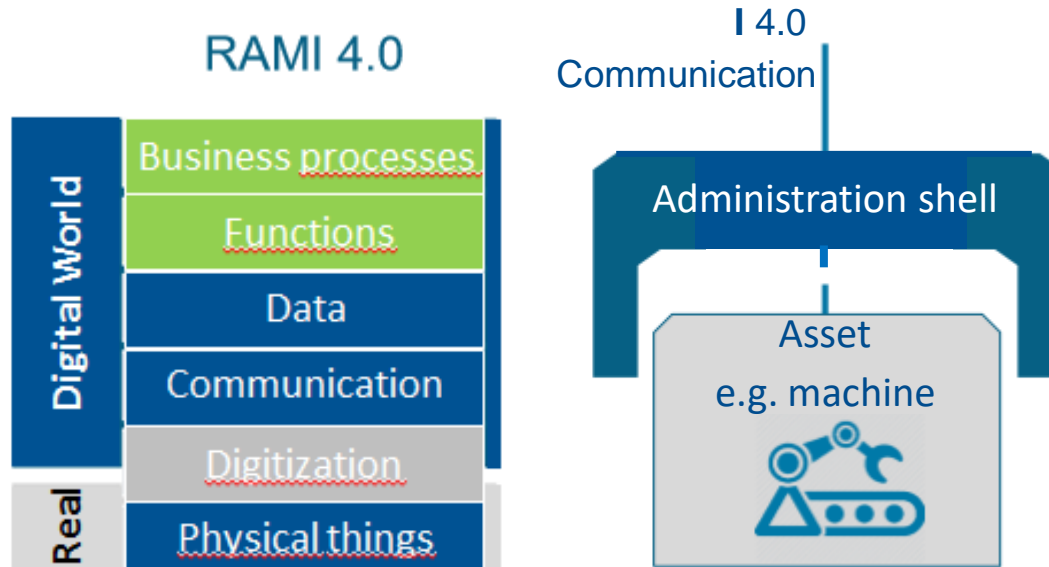
- Every asset has its **own administration shell;** together they constitute an **I 4.0 component** that is clearly identifiable world-wide.

- The administration shell is the **digital share** providing all **status** plus **life cycle data**.

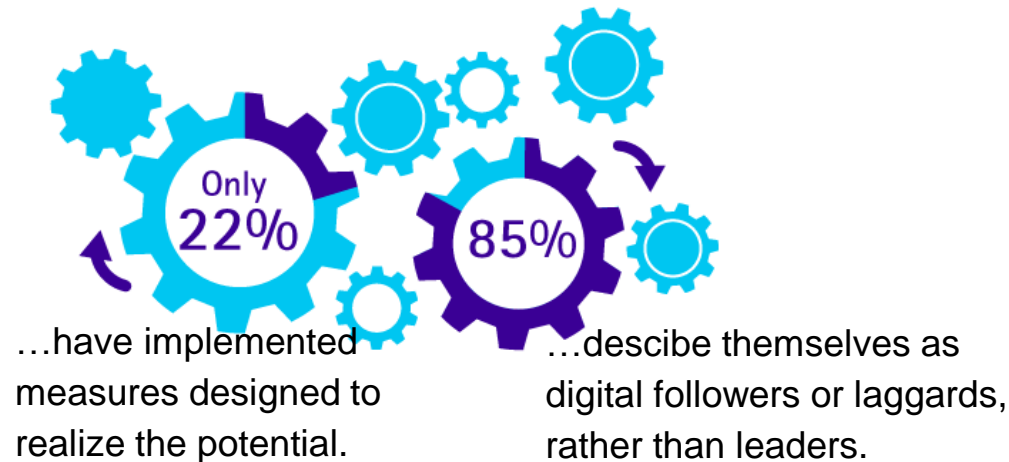- The **asset** is the **real share**.

Every object needs its own administration shell enabling the integration into Industry 4.0

Industry 4.0 beyond the hype

A number of management consulting firms have carried out surveys on Industry 4.0 acceptance. E.g. *Accenture* reports that in 2016 most manufacturers are recognizing benefits:

85% assume it will be routine in their plants by 2020

>50% expect significant improvements in productivity

62% say they want to lead in setting its agenda

But…

Only 22% …have implemented measures designed to realize the potential.

85% …descibe themselves as digital followers or laggards, rather than leaders.

Manufacturers need to overcome major implementation barriers

Concerns about cybersecurity in particular when implementing horizontal integration from disparate sources

Lack of necessary talent, e.g. data scientists, people with interdisciplinary skills, machine-coordination and maintenance experts, identification of new job profiles

Difficulty in coordinating actions across different organizational units in vertical integration and **envisioning the full promise** of Industry 4.0

Implementation of a governance structure that clearly defines roles, reponsibilities and ownerships; full support of senior leaders
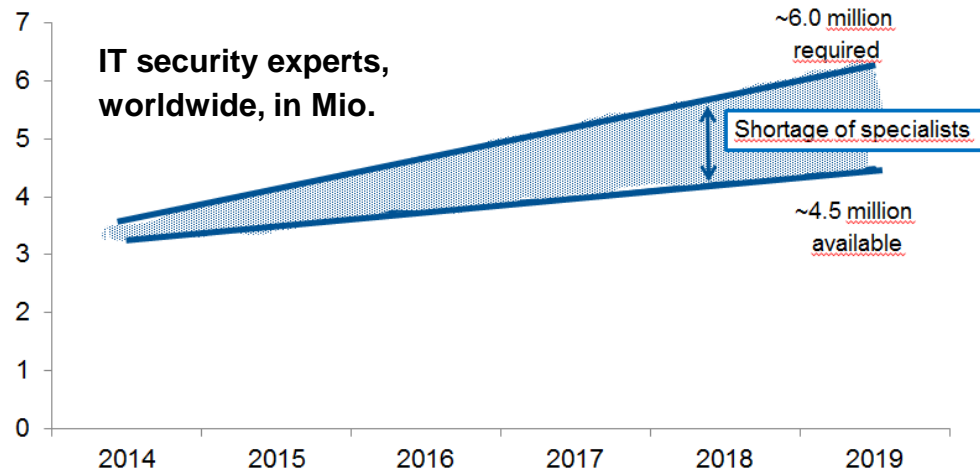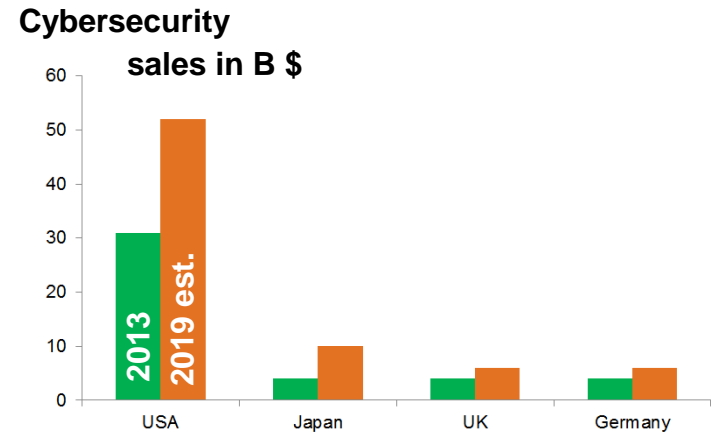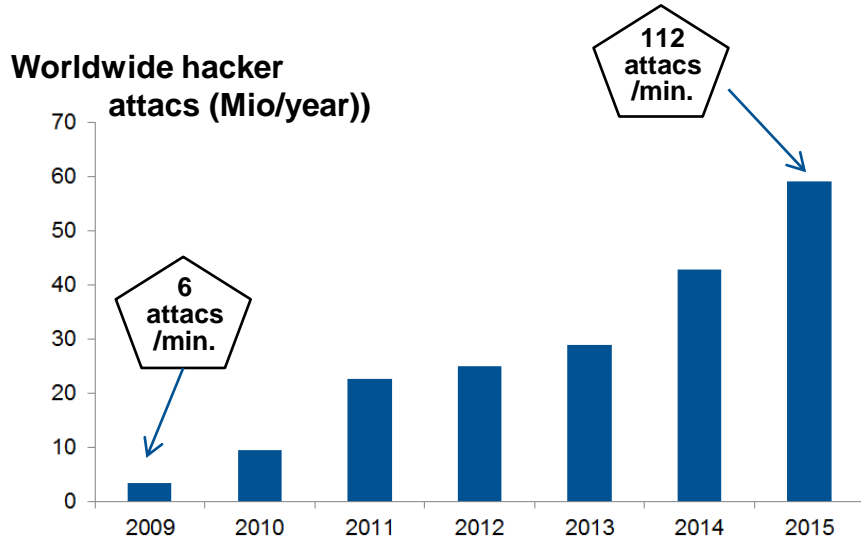
Lack of courage to push through radical transformation, e.g. harnessing analytics capabilities and extending seamless connectivity to a wider ecosystem

Lack of a clear business case justifying investments in the legacy IT architecture, in boosting data and systems security, and in R&D

Cybersecurity challenge

Security is not just about technology but also about standards, regulations, ethics, social contracts.

Worldwide hacker attacs (Mio/year))

112 attacs /min.

6 attacs /min.

Cybersecurity sales in B $

2013
2019 est.

USA   Japan   UK   Germany

IT security experts, worldwide, in Mio.

~6.0 million required

Shortage of specialists

~4.5 million available

2014   2015   2016   2017   2018   2019

Source: Handelsblatt

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Effects of digitalization by context of activities

Digitalization → Platform economy

Technical dimensions of digitalization | **Business** dimensions of digitalization

Technical dimensions of digitalization

Physical | **Virtual**

Process level

Smart Factory
Networked Production (real time data exchange btw. plants and machines, cyber-physical systems)

Smart Operations
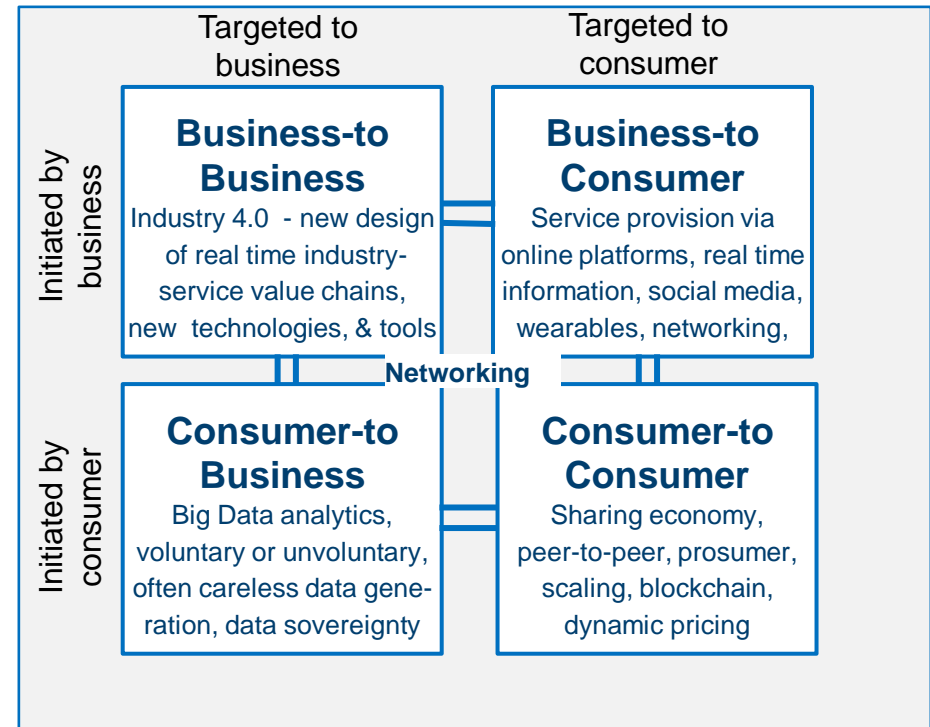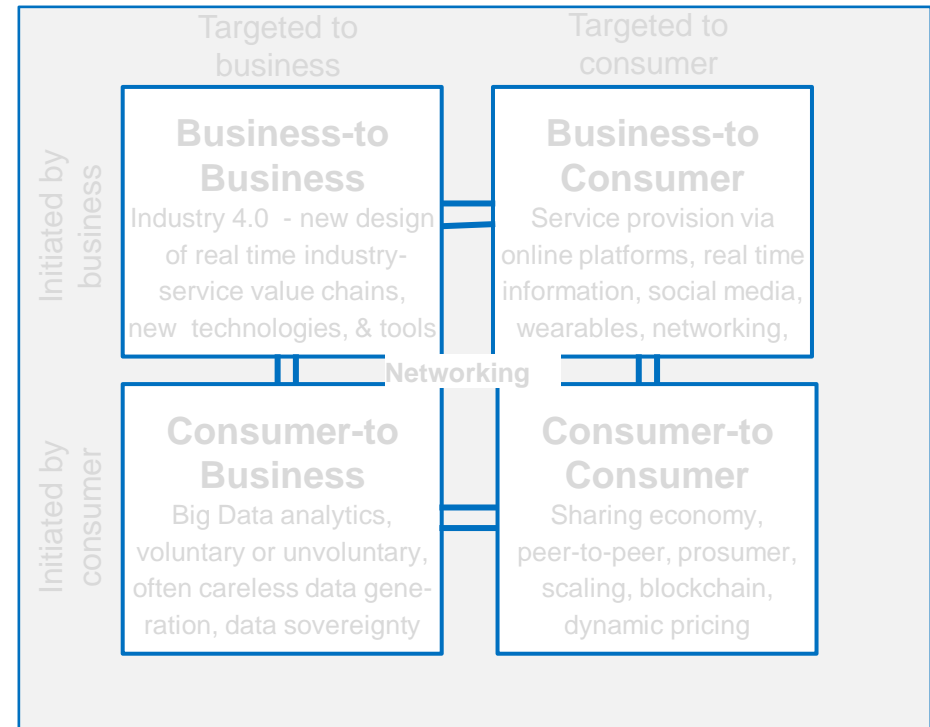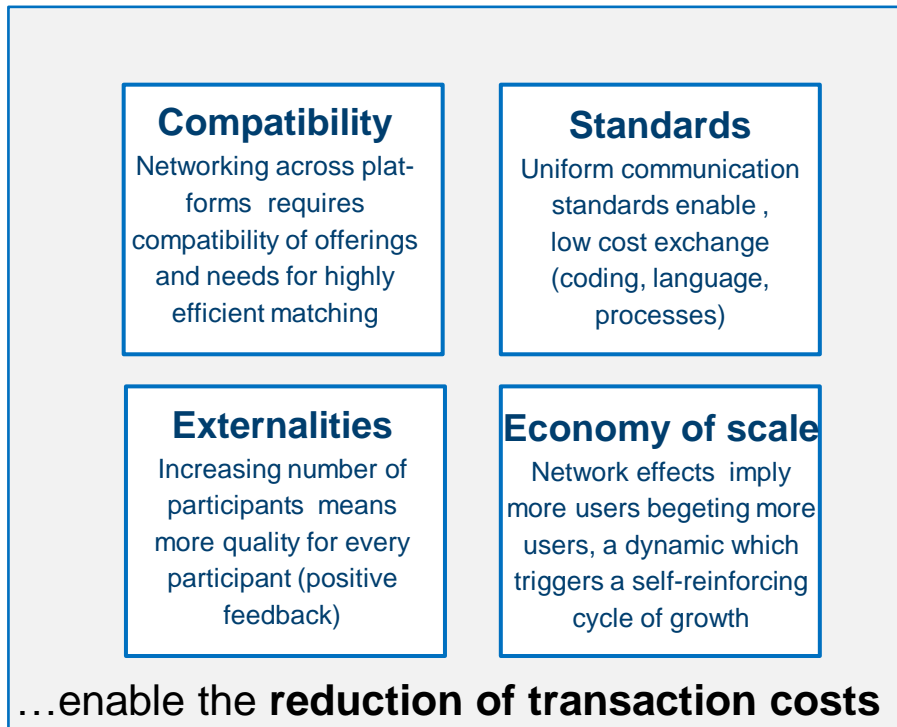Virtualized processes & controls (software and data management for efficiency improvement)

Networking

Product level

Smart Products
Networked products on manufacturer-customer level (components and terminal devices)

Smart Services
Data-based &networked services (apps and on-line shops ; predictive maintenance)

Business dimensions of digitalization

Targeted to business | Targeted to consumer

Initiated by business

Business-to Business
Industry 4.0 - new design of real time industry-service value chains, new technologies, & tools

Business-to Consumer
Service provision via online platforms, real time information, social media, wearables, networking,

Networking

Initiated by consumer

Consumer-to Business
Big Data analytics, voluntary or unvoluntary, often careless data gene-ration, data sovereignty

Consumer-to Consumer
Sharing economy, peer-to-peer, prosumer, scaling, blockchain, dynamic pricing

Effects of digitalization by context of activities

Platform economy

Digital networking : four essentials…
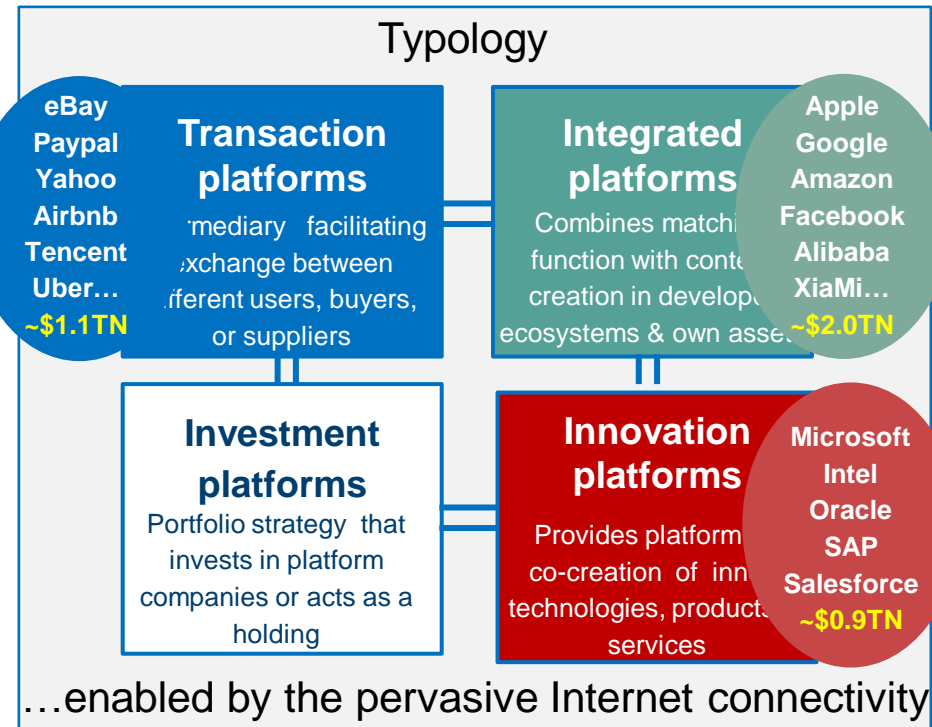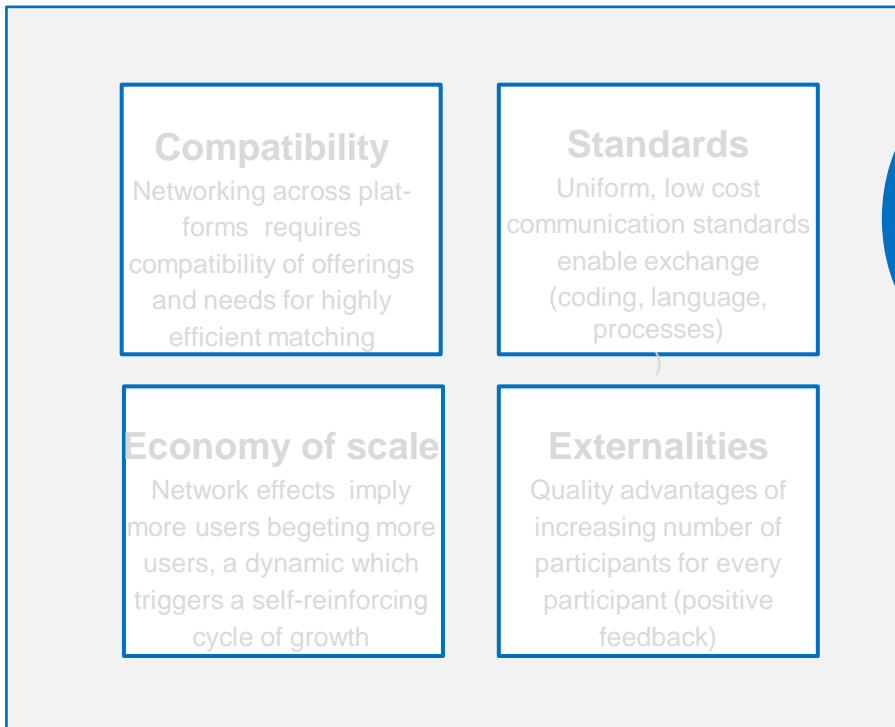
Economic dimensions of digitalization

Compatibility
Networking across plat-forms requires compatibility of offerings and needs for highly efficient matching

Standards
Uniform communication standards enable , low cost exchange (coding, language, processes)

Externalities
Increasing number of participants means more quality for every participant (positive feedback)

Economy of scale
Network effects imply more users begeting more users, a dynamic which triggers a self-reinforcing cycle of growth

…enable the **reduction of transaction costs**

Targeted to business

Targeted to consumer

Initiated by business

Initiated by consumer

Business-to Business
Industry 4.0 - new design of real time industry-service value chains, new technologies, & tools

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Platform economy

Digital networking : four central features   **Digital Platform Typology*)**

Typology

Compatibility
Networking across plat-
forms requires
compatibility of offerings
and needs for highly
efficient matching

Standards
Uniform, low cost
communication standards
enable exchange
(coding, language,
processes)
)

Economy of scale
Network effects imply
more users begeting more
users, a dynamic which
triggers a self-reinforcing
cycle of growth

Externalities
Quality advantages of
increasing number of
participants for every
participant (positive
feedback)

eBay
Paypal
Yahoo
Airbnb
Tencent
Uber…
~$1.1TN

Transaction platforms
Intermediary facilitating
exchange between
different users, buyers,
or suppliers

Integrated platforms
Combines matching
function with content
creation in developer
ecosystems & own assets

Apple
Google
Amazon
Facebook
Alibaba
XiaMi…
~$2.0TN

Investment platforms
Portfolio strategy that
invests in platform
companies or acts as a
holding

Innovation platforms
Provides platform for
co-creation of innovative
technologies, products,
services

Microsoft
Intel
Oracle
SAP
Salesforce
~$0.9TN

…enabled by the pervasive Internet connectivity

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Market Capitalization US$ B

2006		**2017**, June 17	
ExxonMobil	362.5	Apple	810.1
General Electric	348.5	Alphabet	692.8
Microsoft	279.0	Microsoft	558,9
Citigroup	362.5	Amazon	482.8
BP	225.9	Facebook	443.8
Shell	203.5	Berkshire Hathaway	411.0

■ Tech   ■ Oil/Energy   ■ Financial Services   ■ Conglomerate

Data is the new oil of the digital economy

There are concerns…and first precautions

"Before I write my name on the board, I'll need to know how you're planning to use that data."

Gradually, then suddenly…
We are at the pivot point of technological exponential change

1 2 4 8 16 32 64

Graphic: Gerd Leonhard

What appears to be happening

Technology change

Gap in business performance potential

Business production; Human performance

Rate of change

Time
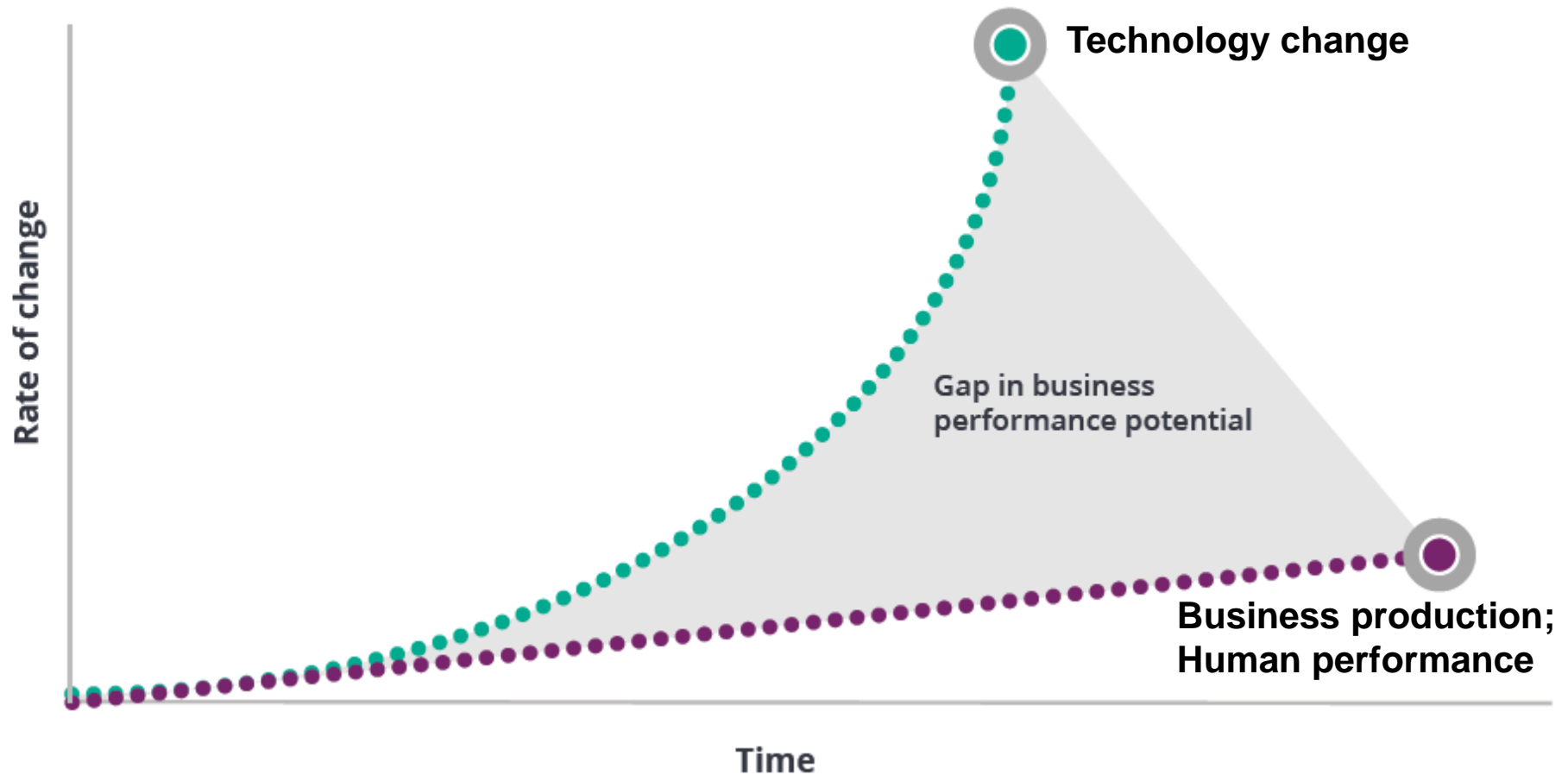
Smart machines are outperforming humans…

Predictive maintenance enables spotting problems long before wind turbines or trains fail

Smart machines are outperforming humans…

Cancer cell detection
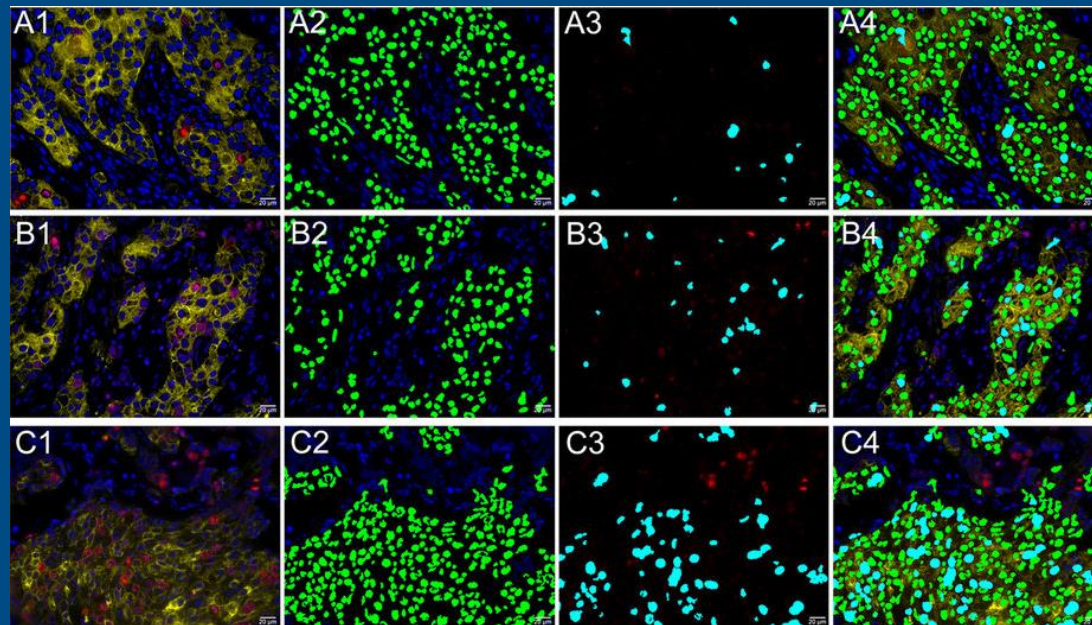
Learning software identifies more cancer cells than were known before more

Smart machines are outperforming humans…

Half of all US adults are in face recognition data bases*)

*) according to a report from Georgetown University's Center for Privacy and Technology, 2016
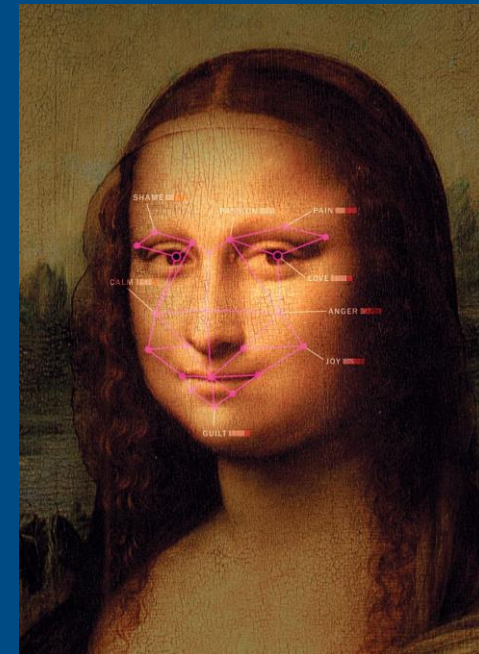
„We know how you feel!" Computers are learning to read motion and the business world can´t wait*)

*) Source: The New Yorker, 2015

Robots make life easy in the smart kitchen
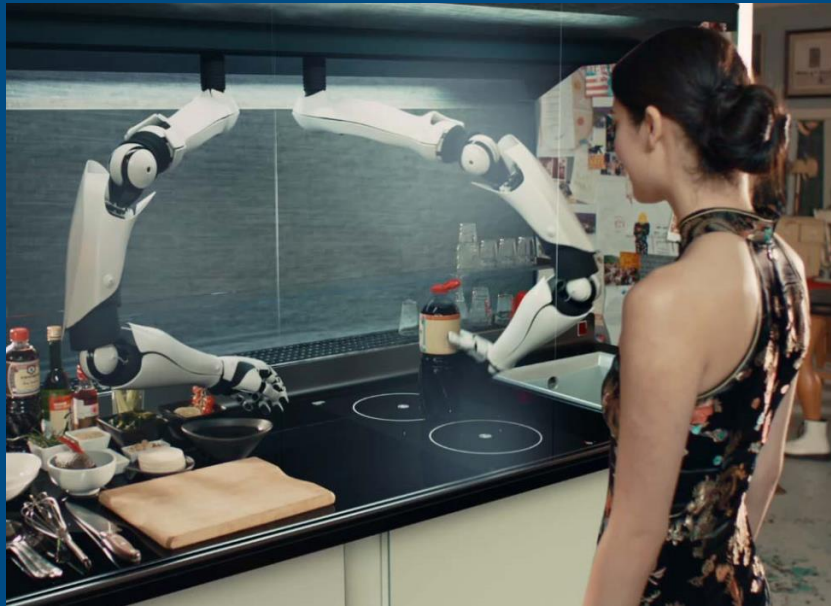
Robots make life easy in the smart kitchen, but…

Artificial intelligence expansion does not stop …
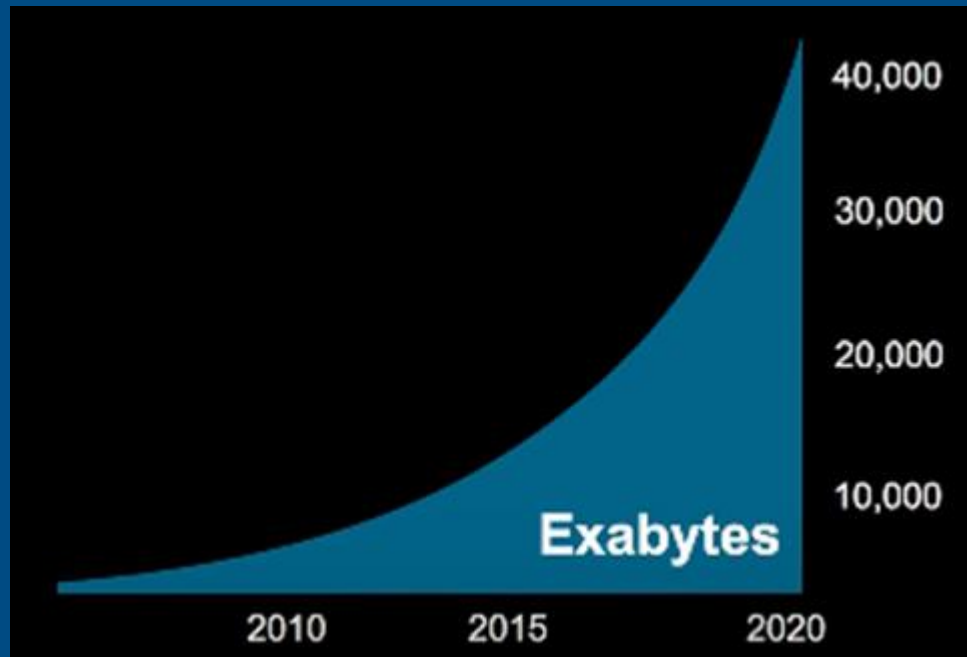
Up to the year 2000 the world has generated 2 exabytes (2 billion gigabytes) of information.

Now the world generates that much data in one day only!

In 2025 data volume in the internet will be ~130 zettabytes…

Artificial intelligence expansion does not stop …

Left Graphic: Gerd Leonhard
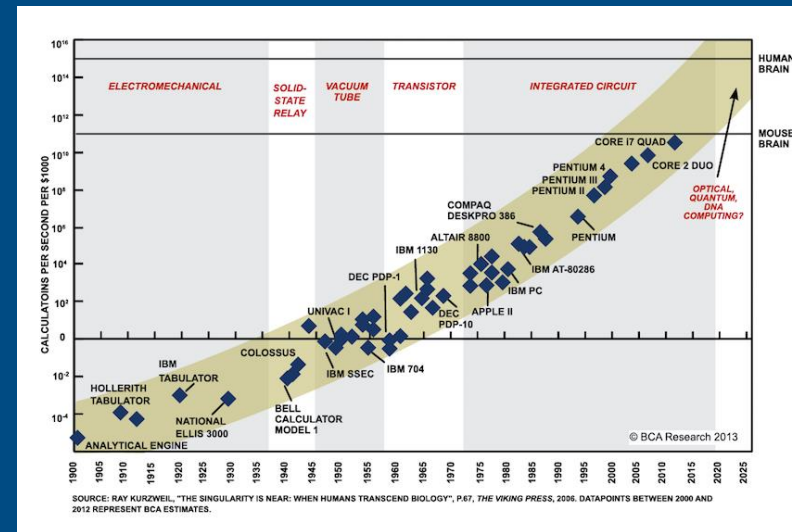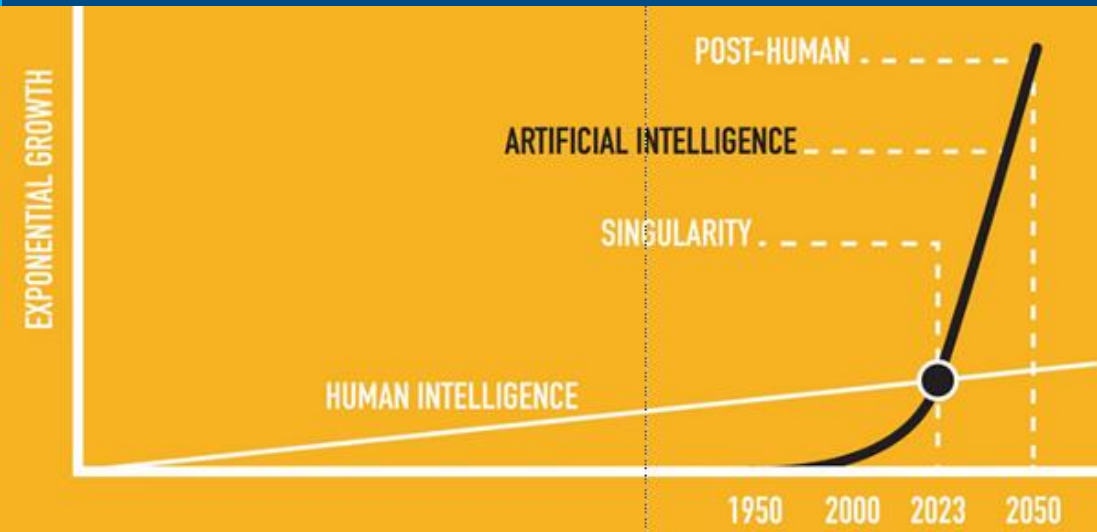
Ethics and values taking chances against digital technologies

Graphic: Gerd Leonhard

Pay Rose With Productivity… And Then It Didn´t

The Great Prosperity: 1947–79

The Great Regression: 1980–Now

Pay Rose With Productivity …

Wages and overall compensation, for production and non-supervisory workers (now about 82 percent of the private sector work force), tracked steadily upward alongside gains in productivity.

The rising value of goods and services per worker meant rising pay. But that relationship ended in the 1970s.

… And Then It Didn't

CHANGE, 1979-2009 +80%

PRODUCTIVITY

CHANGE, 1947-79 +119%

AVG. HOURLY COMPENSATION

CHANGE, 1979-2009 +8%

+100%

+72%

+7%

AVG. HOURLY WAGE

BASELINE IS 1947

'50 '60 '70 '80 '90 '00

Crowding-out by computerization of jobs…

Think

United States employment, by type of work, m

Non-routine cognitive

Routine cognitive

Routine manual

Non-routine manual
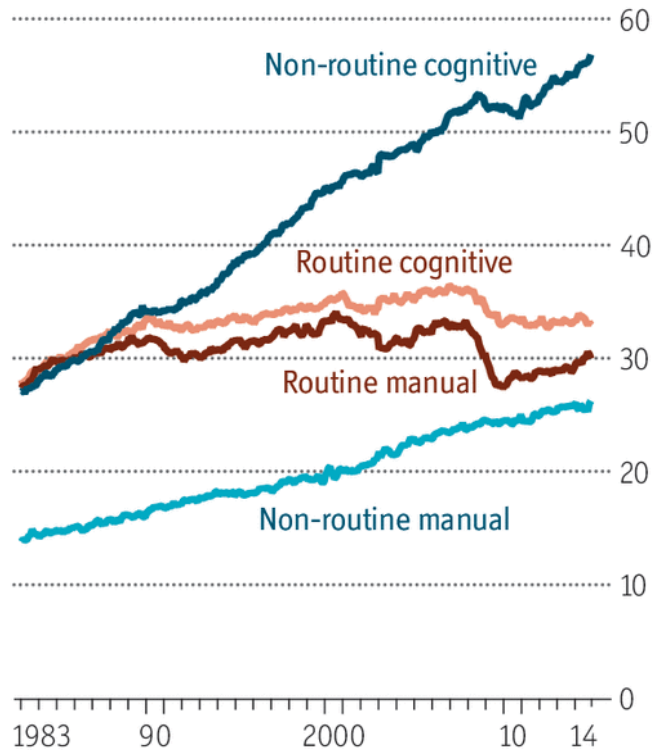
Sources: US Population Survey; Federal Reserve Bank of St. Louis

Economist.com

2022

2030

Crowding-out by computerization of jobs…

%
50
45
40
35
30
25
20
15
10
5
0

■ Change in tasks (50-70% risk) ▨ Automatable (>70% risk)

Slovak Republic, Czech Republic, Italy, Germany, Austria, Poland, Netherlands, United Kingdom, Average, United States

OECD 2016: Automation and Independent Work in a digital economy
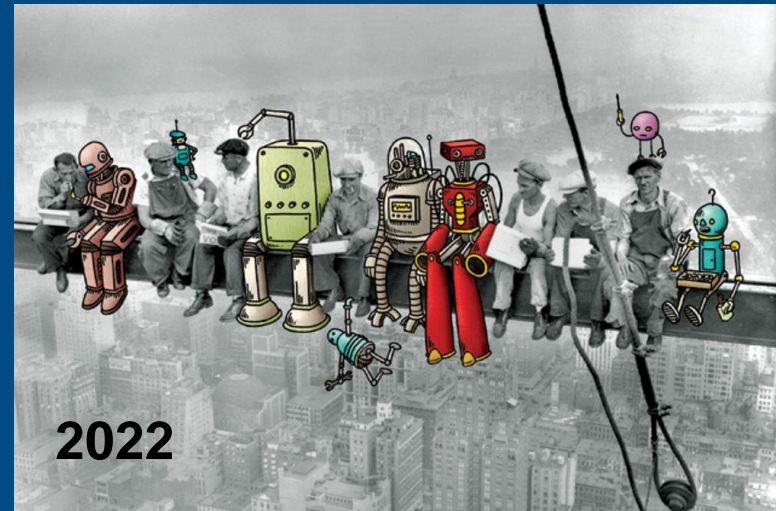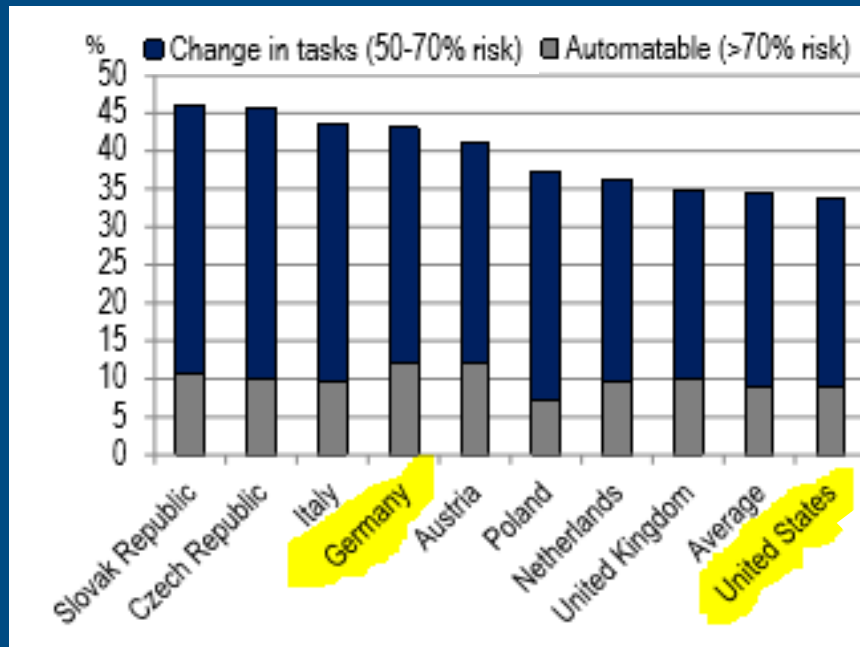
Not in danger:
- Complex tasks (perception and manipulation)
- Creative jobs (creative intelligence)
- Social competence (e.g. teacher, social worker, nurse, coach…)

In danger (automatable):
- Routine jobs in factories & offices
- Bank advisors, insurance agents
- Cleaners, bus & taxi drivers
- ~ 12 % of all jobs in Germany,
- ~ 8 % in the USA

Man-machine convergence, brain-computer interface – how far can it be taken?

Graphic: Gerd Leonhard
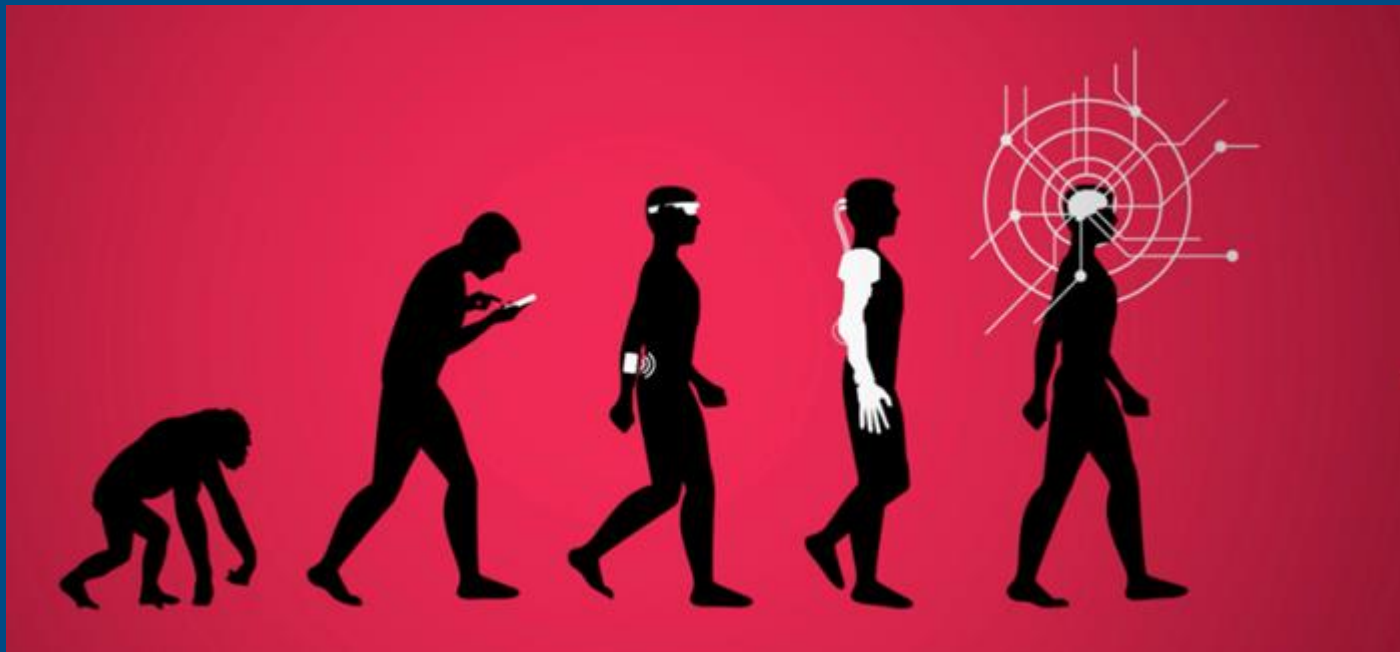
Security (and data privacy) requires some compromises in other values…
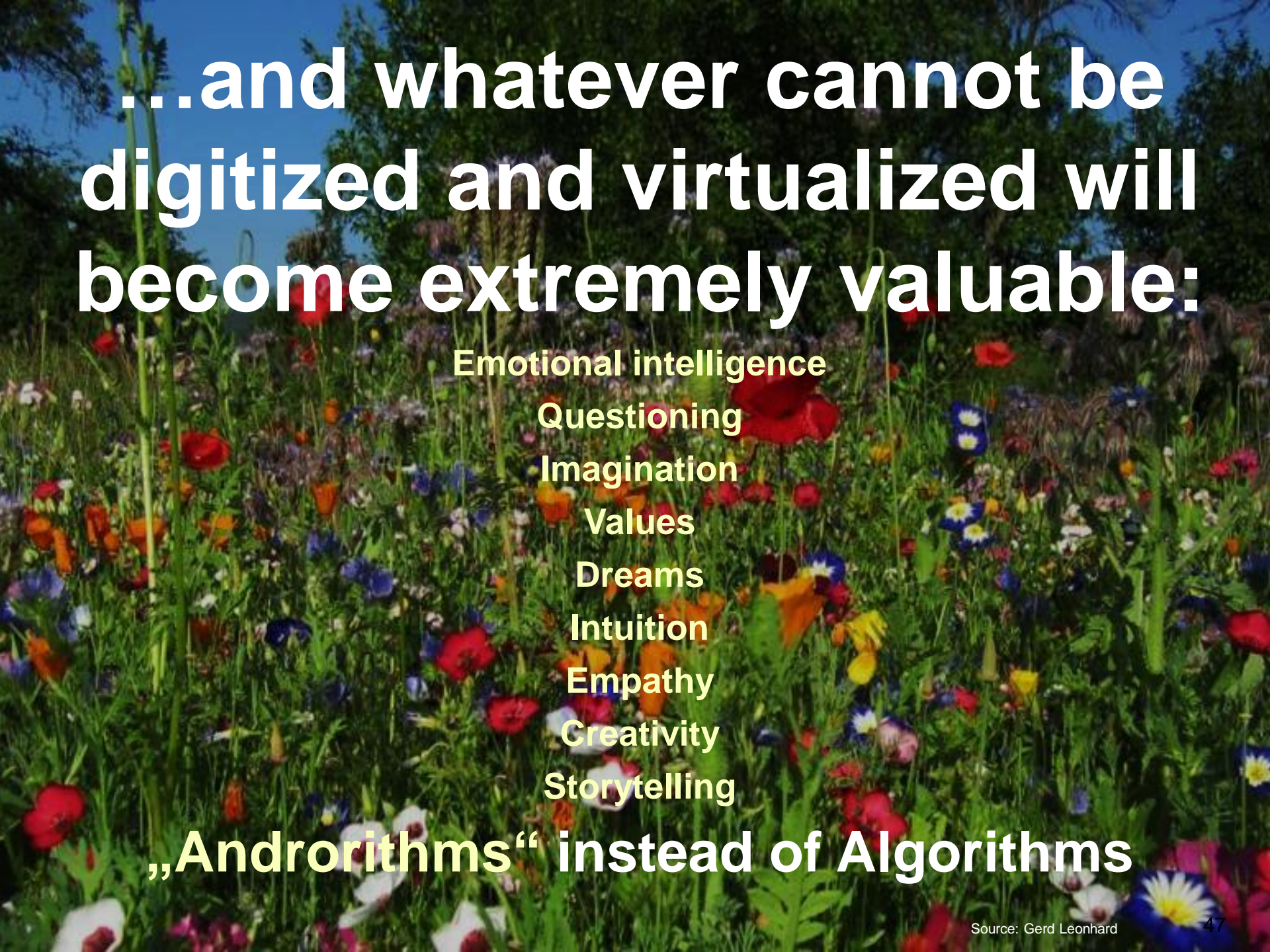

Cartoon: Clay Bennett, Christian Science Monitor
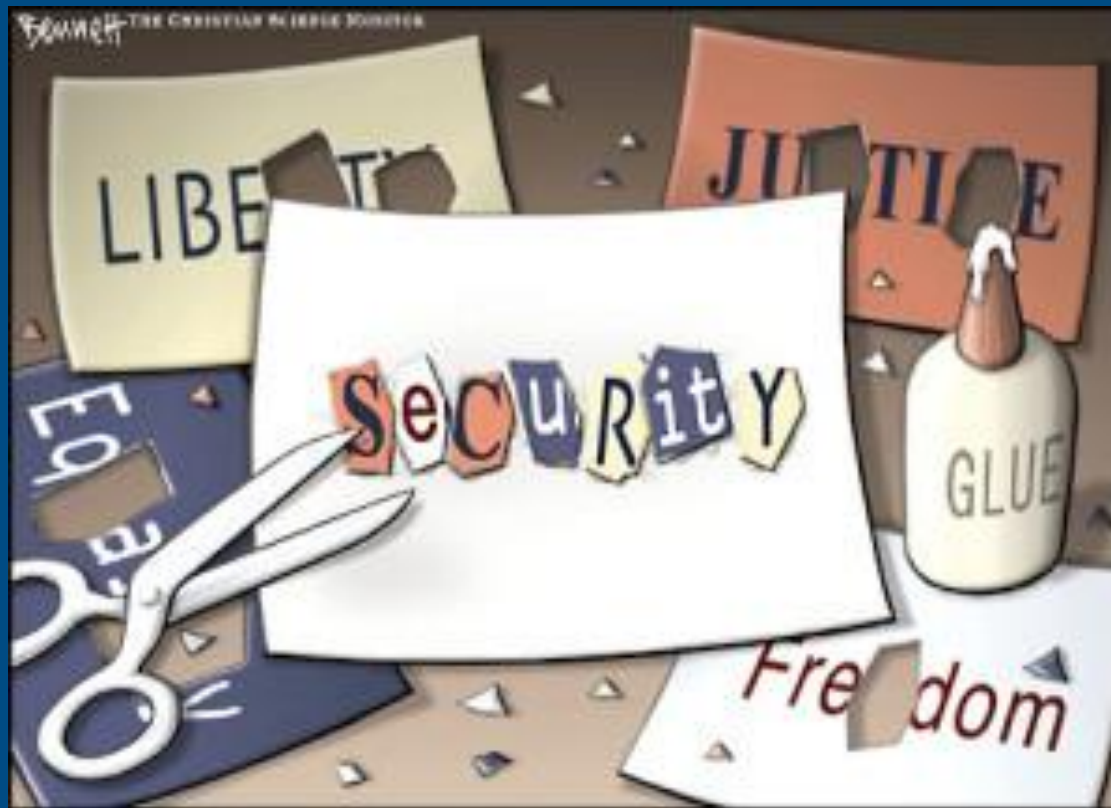
Digitization, data, exponential growth and humans

- **Smart machines change the relation of humans to the world. They are helpful and welcome, no doubt.**

- **But technology has no ethics, it never questions the meaning of any action.**

- **With increasing exponential power of smart machines the identity of humans is at stake.**

- **Personality is shaped by overcoming obstacles and in the confrontation with challenges and resistances.**

- **A world with prefabricated routes, where one is relieved from own decisions because algorithms are pretending to know preferences and desires is a counter-model to this →subjection!**

- **We must keep the ability to take a step back from our own wishes, to question, to negotiate, to develop and to self-correct them.**

- **This and other essential human values cannot be digitized.**

Anything that can be digitized will be digitized…

...and whatever cannot be digitized and virtualized will become extremely valuable:

Emotional intelligence

Questioning

Imagination

Values

Dreams

Intuition

Empathy

Creativity

Storytelling

„Androrithms" instead of Algorithms

I think, therefore I am
Descartes (1596-1650)

I care, therefore I am.
I hope, therefore I am.
I imagine, therefore I am..
I have a purpose, therefore I am.
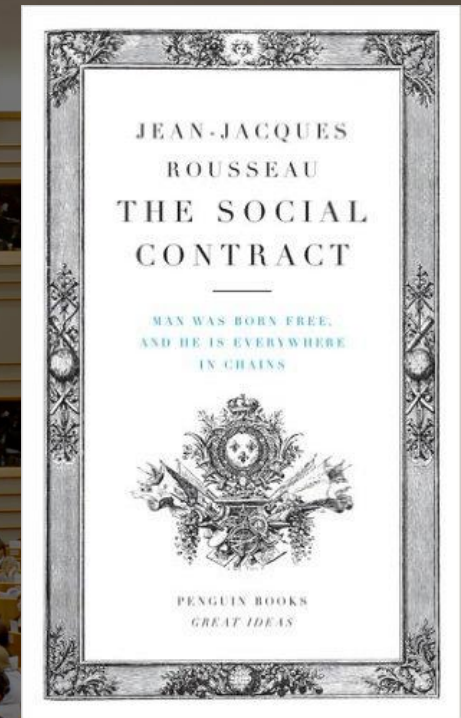**I pause and reflect,** therefore I am.

Descartes updated (21st century, digital age)

Exponential growth in digitization is calling for the protection of „androrithms" – in a new social contract for humanity
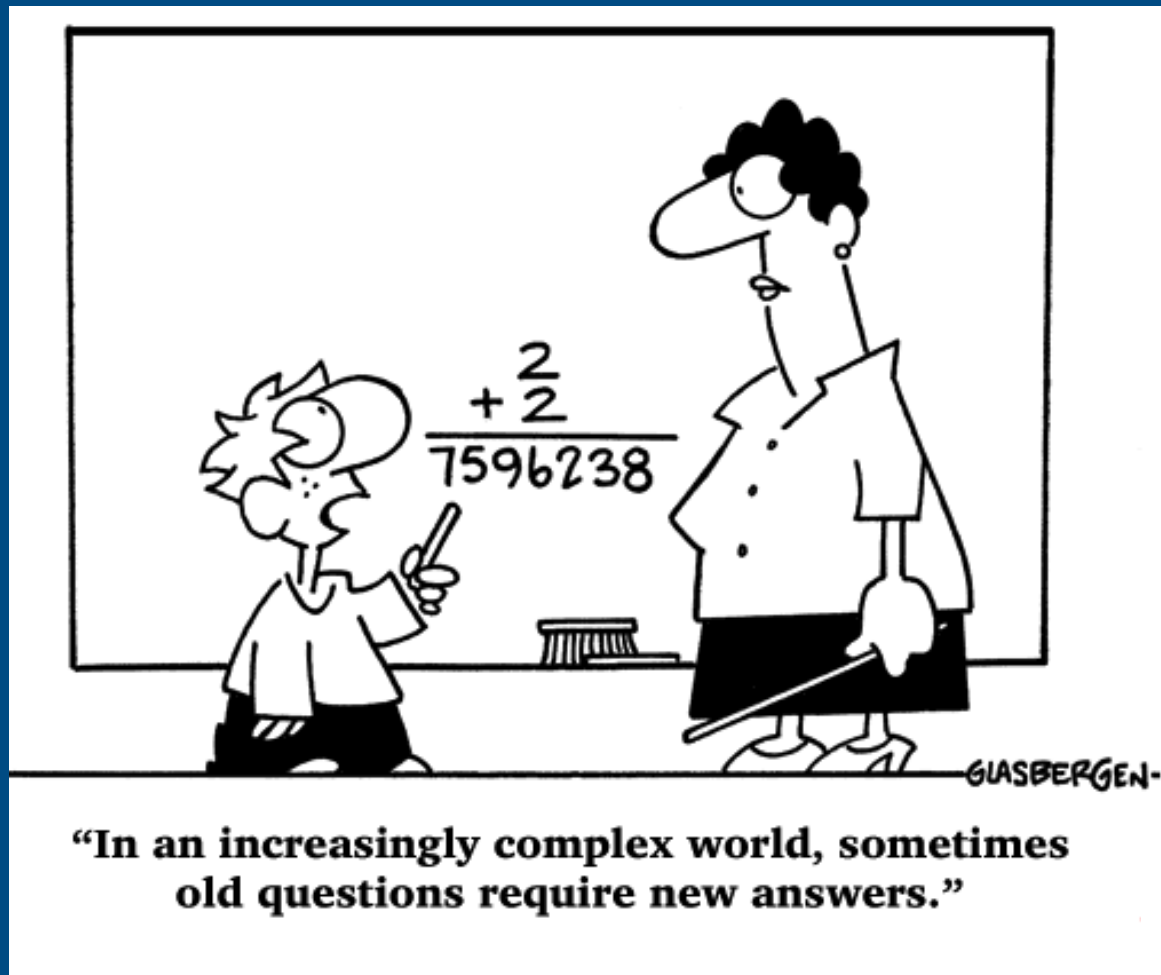
Some of the issues which need to be settled in the new contract:

- Establishing a global digital ethics counsel
- Regulation of „data oil" companies – privacy!
- A(S)I* non-proliferation agreement
- Man-machine convergence
- Intelligent machines upgrading themselves
- Future of work
- Basic income guarantees
- Automation levies…

*Artificial (Super)Intelligence

JEAN-JACQUES ROUSSEAU

THE SOCIAL CONTRACT

MAN WAS BORN FREE, AND HE IS EVERYWHERE IN CHAINS

PENGUIN BOOKS
GREAT IDEAS

1762

Thank you!
Any - old or new - questions?