

Smart Factories

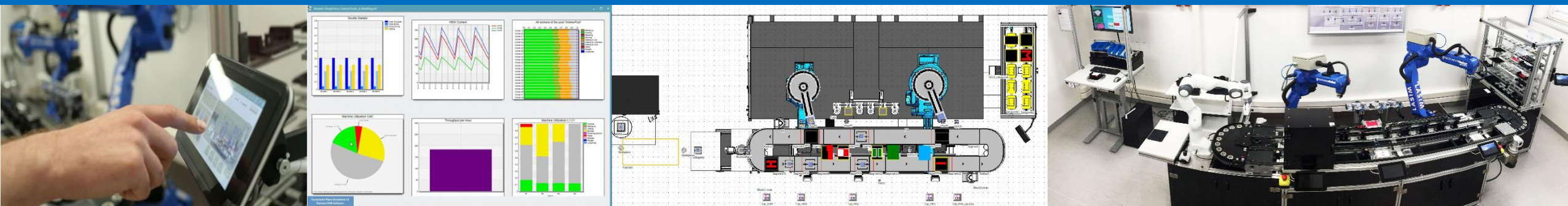
Prof. Dr. Niko Herakovič
Asst. Prof. Dr. Marko Šimic

Lectures: 30 h

Exercises (Tutorials and Lab): 30 h

Self-learning, independent work: 65 h

Overall: 125 h (5 ECTS)



What Is Industry 4.0 and Smart Manufacturing?

The course Smart factories – basic information and Agenda

Programme

Introduction to Industry 4.0

Definition of smart factory concepts

Disciplines, systems and technologies for I 4.0

Key approaches to smart factory development

Referential architectural models of smart factories

Smart factory concepts

The concept of distributed systems

Top-down approach when implementing solutions of I 4.0

Bottom-up approach in implementing solutions of I 4.0

The concept of digital twins (DT) of manufacturing processes of a smart factory

Five-dimensional modelling of a DT and its key technologies

Control of a smart production with a digital twin

Digital twins (DT) and new technologies

The course Smart factories – basic information and Agenda

Learning outcomes

- Knows and understands: the content and mission of a smart factory compared to traditional factories.
- The acquired knowledge is used by the student to draft and design processes in smart factories and to integrate them into the whole concept of a smart factory, to make effective use of I 4.0 technologies in a smart factory, and to produce digital twins of processes and the entire smart factory, as well as to control the whole system.
- To learn about key technologies of I 4.0 and the concept of distributed systems.
- Knows and understands how to use of tools to evaluate the status of digitization of a traditional factory and computer-aided tools for drafting an efficient smart factory for various purposes.
- Recognize of the usefulness of I 4.0 technologies in a smart factory.
- Knows and understands how to use simulation tools for building a digital twin of a smart factory with different subprocesses.

Challenges - Growing customer demands and the number of product variants



Bicycles in modern era

- Over **63 different bicycles** from just *one* manufacturer, available ...
 - in different **frame sizes**,
 - in different **colours**,
 - with different **forks**,
 - with different **gearshifts**,
 - with different **handlebars**,
 - with different **cranks**,
 - etc.

➔ **A huge amount of product variants must be handled!**

Standard based cylinder DSBC, ISO 15552



Theoretical variance DSBC:

195,360 combinations

plus SA (special applications) and EWK

Source: FESTO

RAPIDITY / SPEED



1.82 s

*Max Verstappen,
Red Bull*

What is the world record at the F1 wheel exchange?

T. Ohno: “Shortening lead time by eliminating waste”

VA: Cutting, Sewing,
Welding, Stapling,
Gluing,...

Exp: Sit on one kg of
incoming material and
observe what happens....

Focus on traditional
improvements:

Reduce cycle
time, Work
harder, Add
people, Add
equipment....

NVA: Transporting, Storing,
WIP, Walking, Waiting,
Overproduction,
Overprocessing,
Reworks, Scrapping,
Ignoring ideas,
Repeating mistakes,
Wrong product, place,
quantity, Uncoordinated
activities, Checking, Tool
changes, Urgent actions,
Firefighting, ...

VA 5 to 10 %

NVA:
Waste!

> 90%

Eliminating waste is
the focus for a
lean deployment!

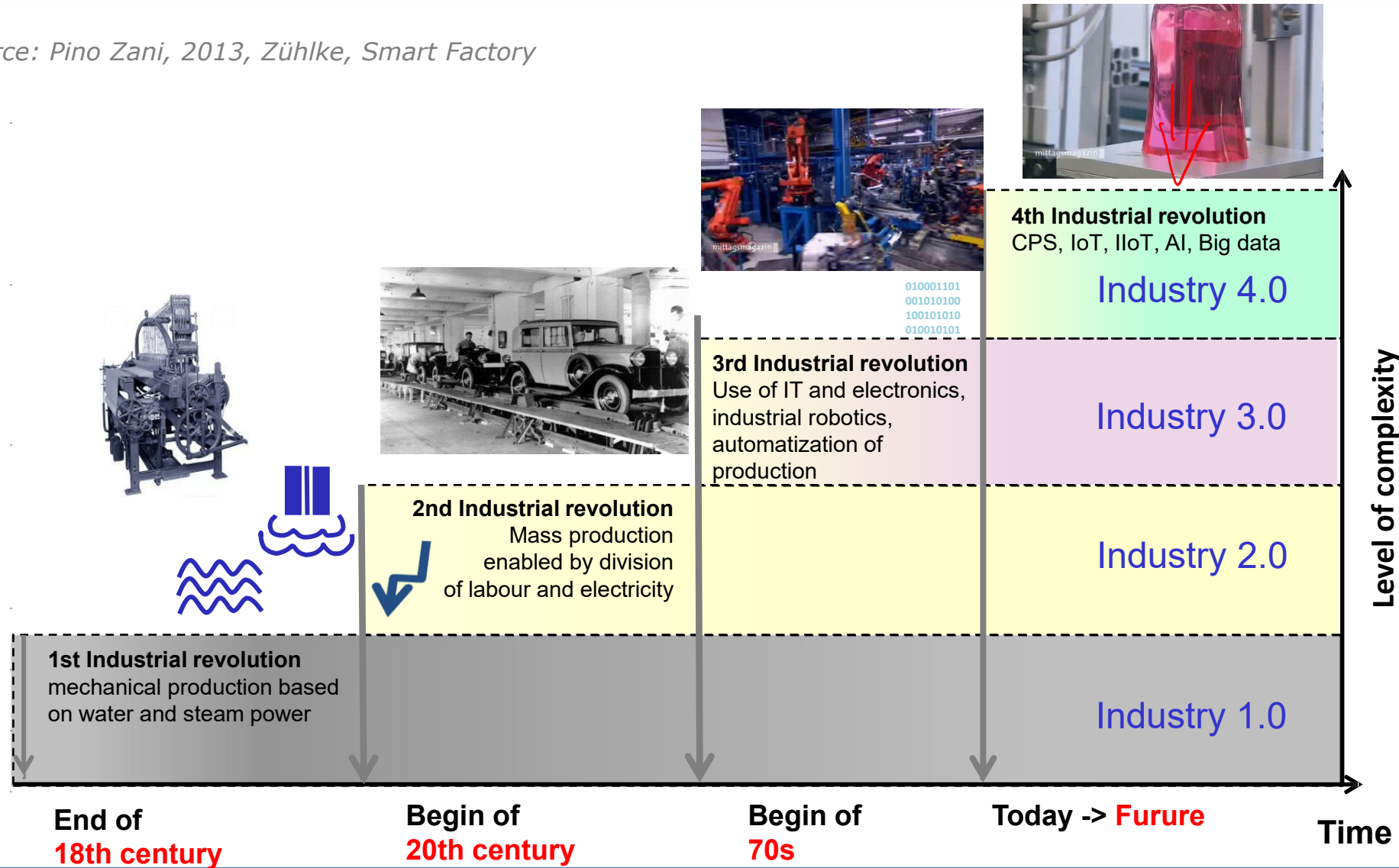
Introduction to I4.0 (4th Industrial Revolution)

The term »Revolution« determines rapid and radical changes

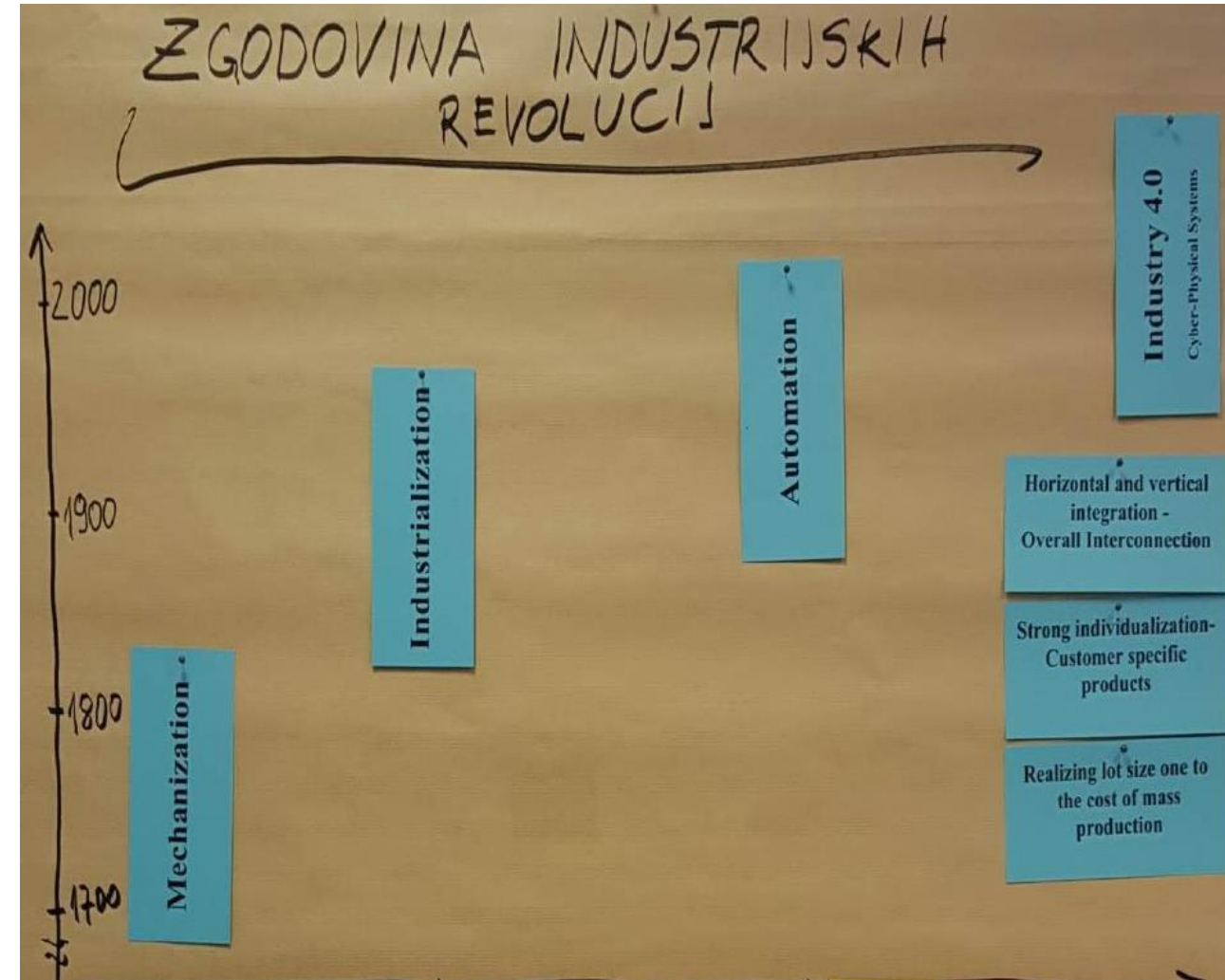
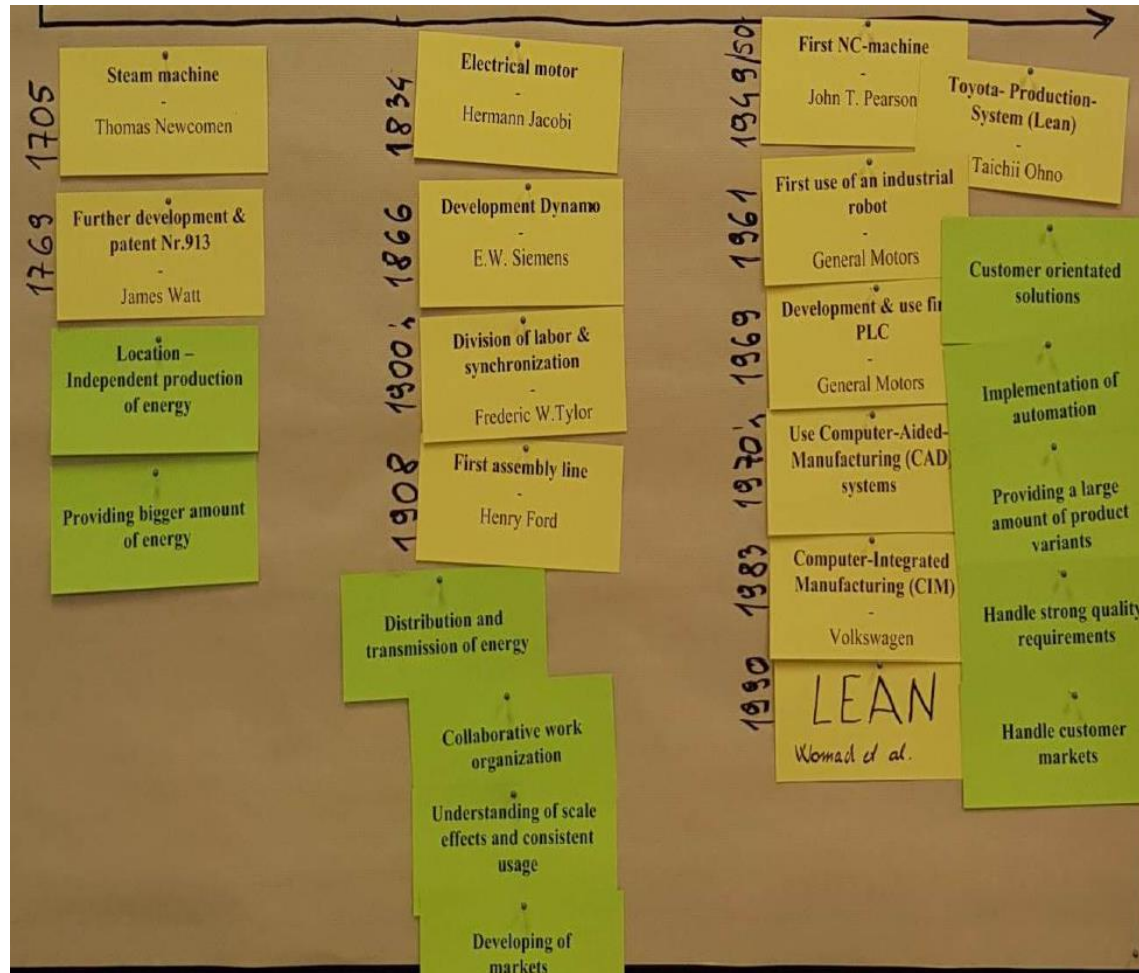
Industrial revolution is defined as the major rapid changes and transition in manufacturing and industrial processes with new innovative technologies.

From Industry 1.0 to Industry 4.0: Towards 4th Industrial Revolution

Source: Pino Zani, 2013, Zühlke, Smart Factory

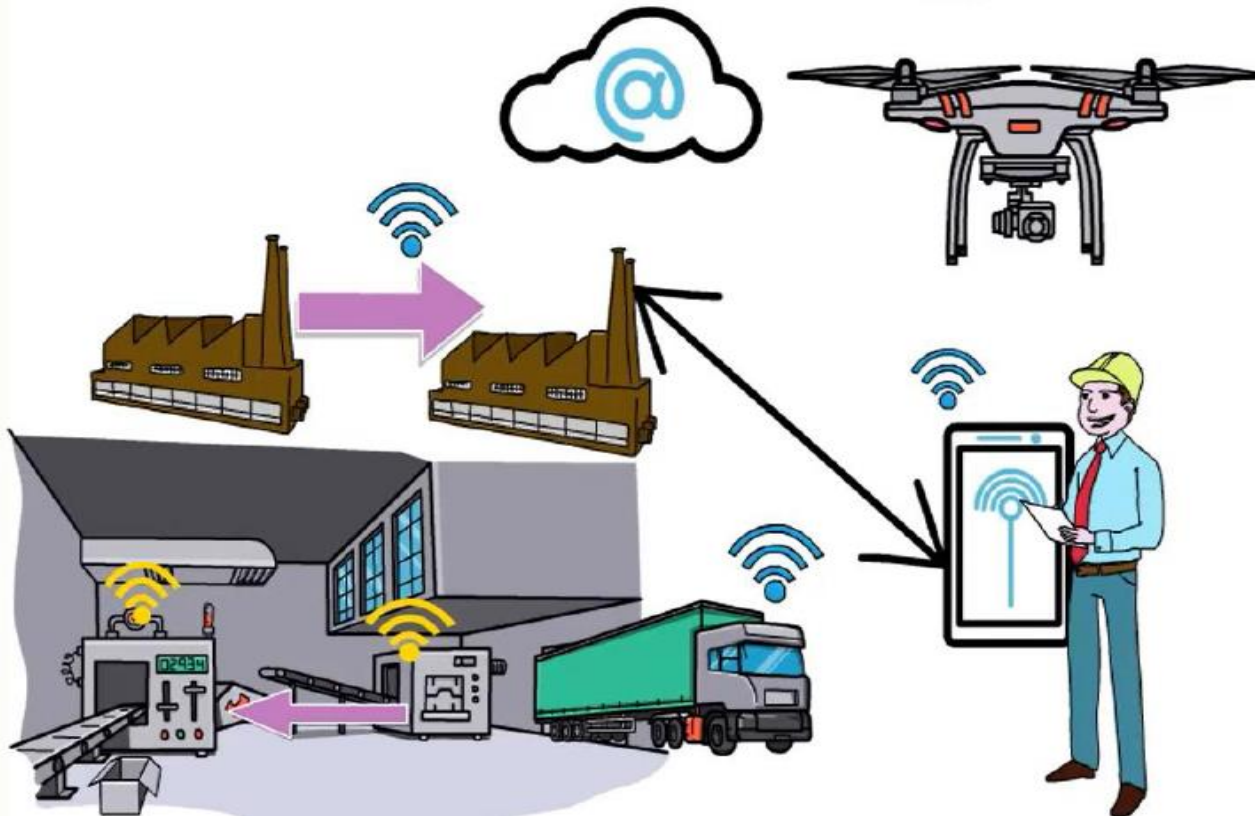


Industry revolution – short overview, essential message



WHAT IS INDUSTRY 4.0?

"Industry 4.0 is a new phase in the Industrial Revolution that introduce intelligent networking of machines and processes for industry with the help of information and communication technology"



It connects
physical world
with
digital world



Technology In Short

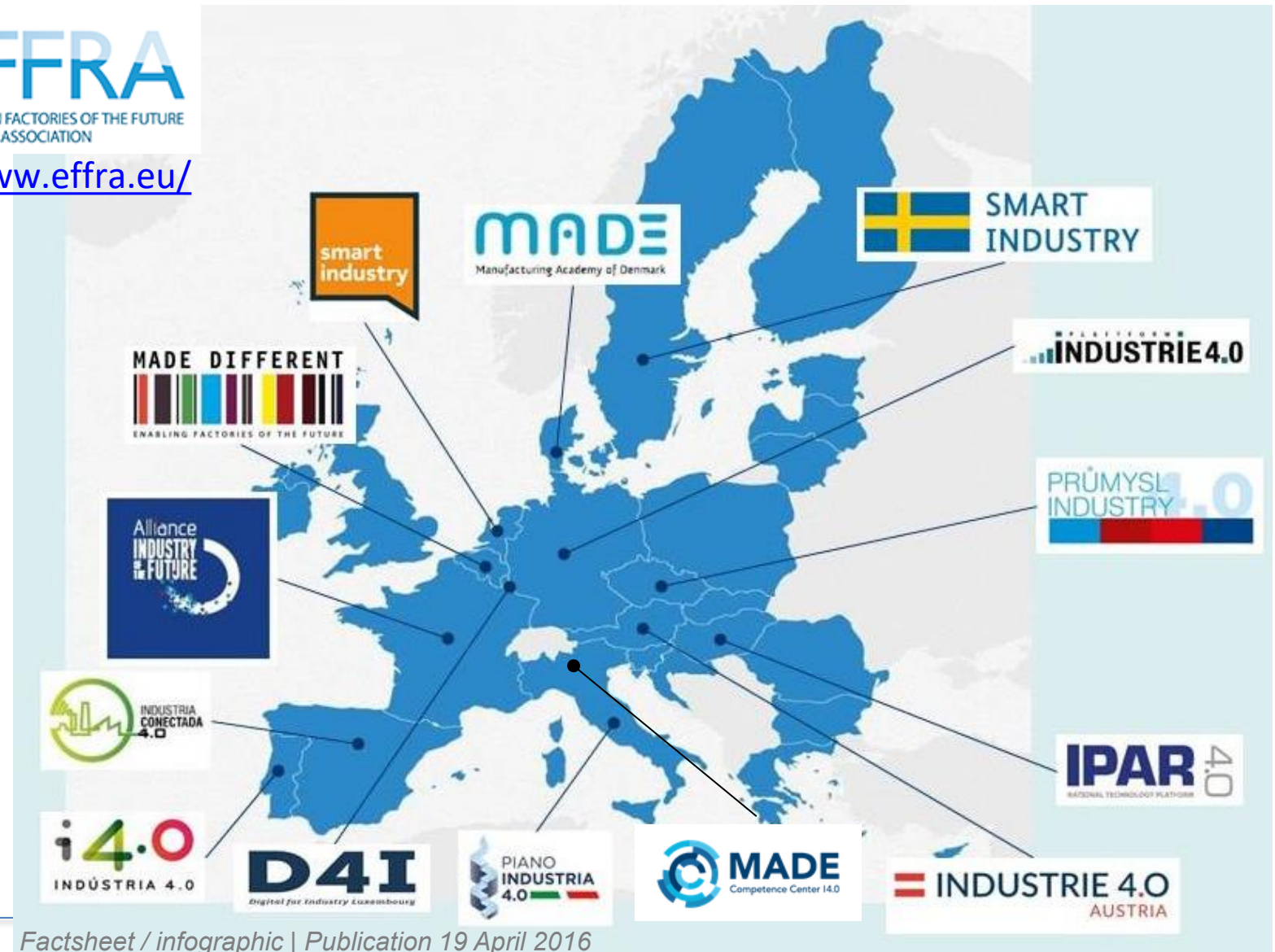
EU frameworks and competence centres



<https://www.effra.eu/>



SRIP Factories of the Future



Factsheet / infographic | Publication 19 April 2016

Some goals in the companies we are pursuing...

- ☐ Increasing the efficiency, availability and reliability of production, logistics processes, etc.)
- ☐ Increasing productivity and competitiveness (OEE, ...)
- ☐ Shortening of throughput times and delivery times (time to market)
- ☐ Reduction of stocks and inventory
- ☐ Minimizing errors, distractions and discards (waste)
- ☐ Individualization of products, flexibility, agility,...
- ☐ Reducing energy consumption, less carbon footprint...

Do these goals change in I 4.0?

NO !!!

Different approaches to solve the challenges...

- ❑ Supply Chain Management (SCM)
- ❑ Total Quality Management (TQM)
- ❑ Time Based Competition (TBC)
- ❑ Business Process Reengineering (BPR)
- ❑ Theory of Constraints (TOC)
- ❑ Quick Response Manufacturing (QRM)
- ❑ Lean, Lean Thinking
- ❑ Agile Manufacturing (AgileM)
- ❑ Digitalization (digital LEAN, I4.0 Technologies, Smart Factory...)

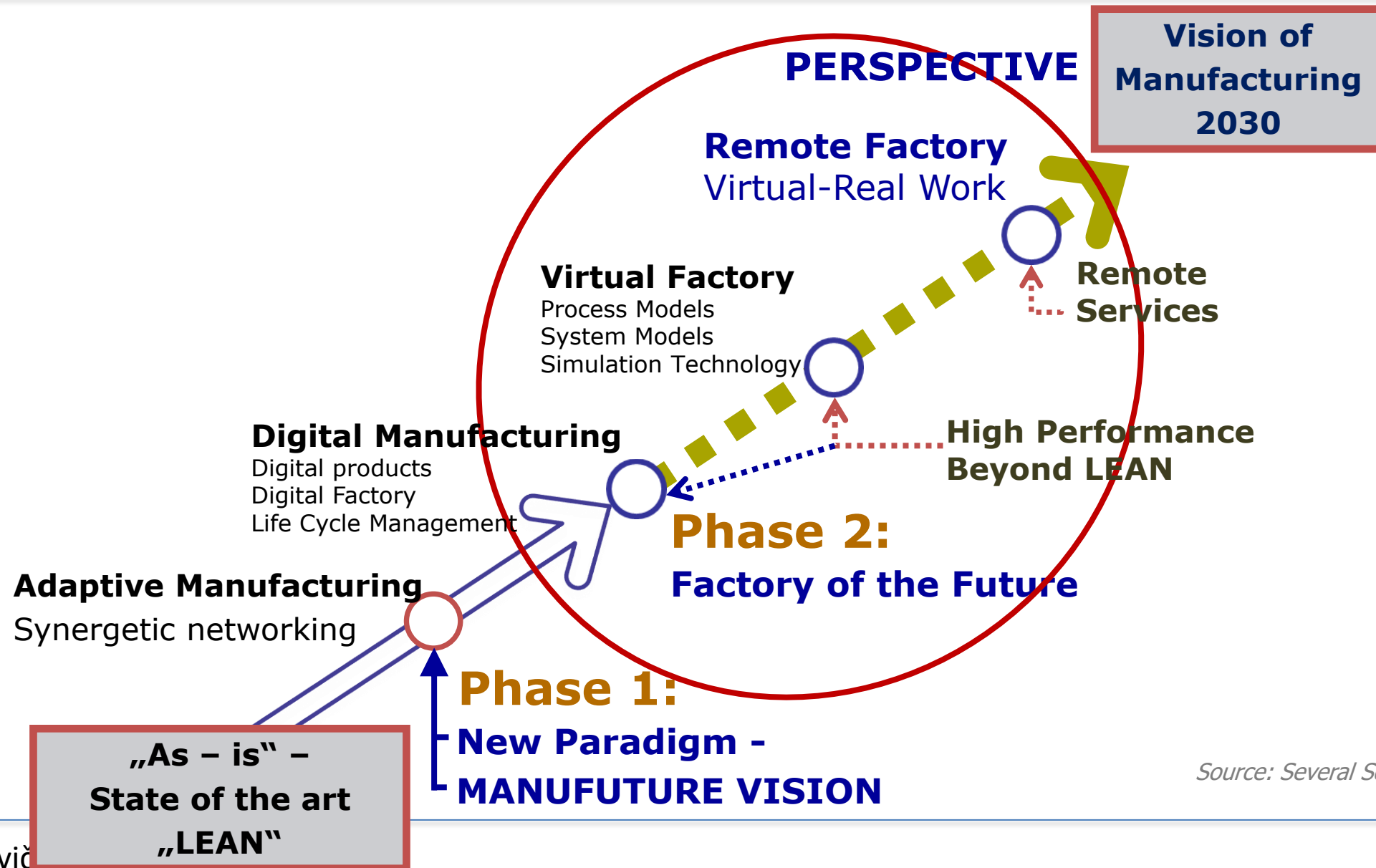
The tools and approaches to strengthen the competence of enterprises

- Integration of the Internet of Things (IoT) into the production process.
- IoT enables communication between individual objects (machines, devices, products, etc.) with the help of technologies such as RFID, various sensors, machine vision, actuators, etc.
- CPS (Cyber-Physical Systems) - the integration of virtual and physical processes.
- Embedded computers and networks control physical processes and at the same time affect one another.

Concequences for companies...

- Companies face difficulties when identifying and implementing scenarios of Industry 4.0.
- We have to know what to do in general and what to do first (the sequence of activities) to achieve major effect.

The Evolution of Industrial research – Perspectives of Future Production

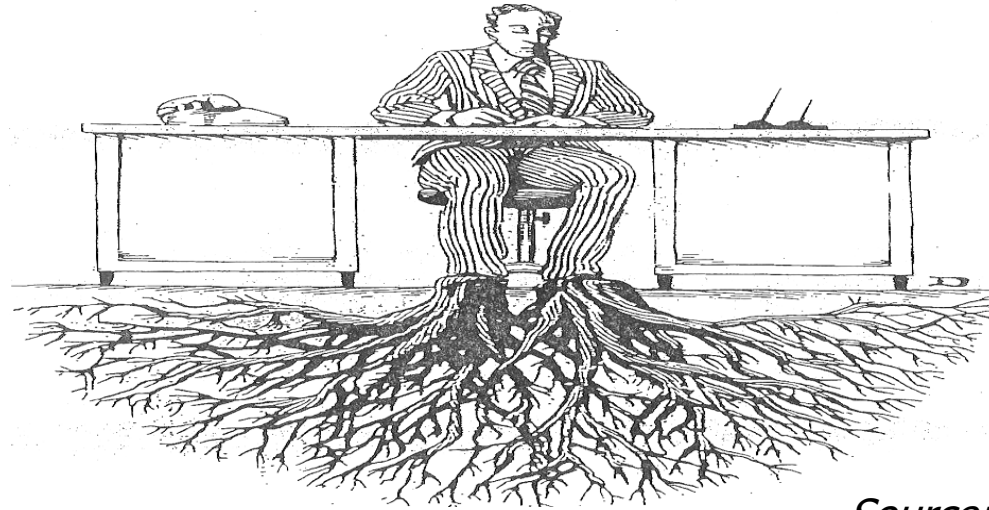


Source: Several Sources, 2015

Industry 4.0 and jobs

- ✓ Industry 4.0 is an industrial ecosystem, which requires, among other things, a change in the role of people in the industrial value chain.
- ✓ The good news is that when introducing a new company paradigm, it is crucial that workers develop new skills and introduce new tools to be able to deploy Industry 4.0 in the right way.
- ✓ Despite some weaknesses, the risks that Industry 4.0 brings, gives us the opportunity to keep creating value in the industry in Europe, even where it was not possible to do so.

Changing of people is ...



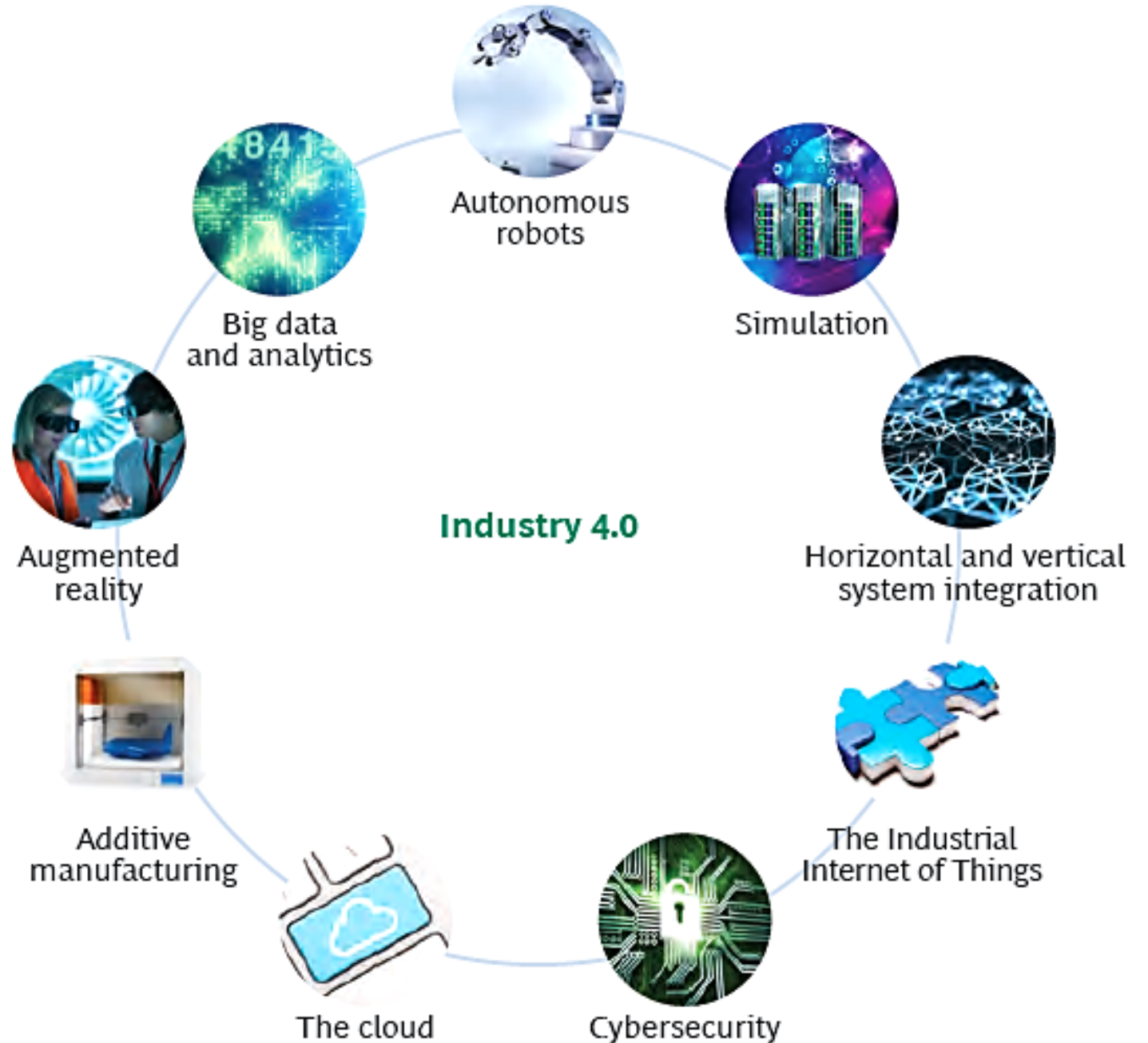
Source: Bob Dahm/inx

German proverb

"It is not the great who will eat the small, but the quick who will eat the slow"

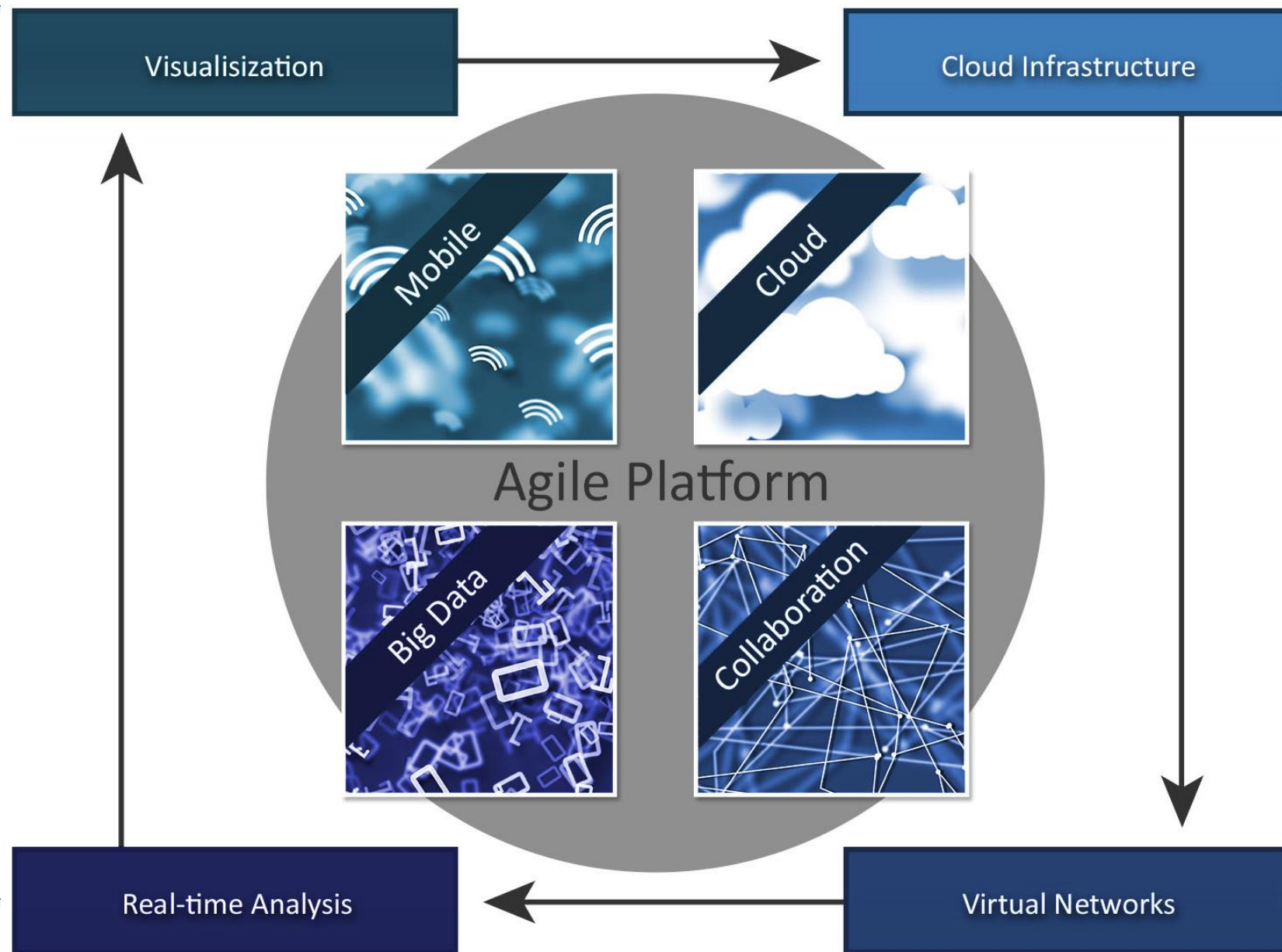
Heinz Peter Halek

Nine main pillars of technologies for I 4.0



Source: BCG

Components of Industry 4.0



Source: Goodarz, Axxessio GmbH

The second component of Industry 4.0: CLOUD

- » Around 70% of adult Internet users in the USA use personal services of CLOUD
- » Cloud will replace PCs
- » **SECURITY???**



Source: Goodarz, Axxessio GmbH

The third component of I 4.0: Cooperation and Virtual networks

- ❑ Transformation of cooperation
 - » Cyber-physical production systems

- ❑ The connection between virtual and real world
 - » Processes
 - » Embedded systems
 - » Software components, integrated into machines
 - » Robots do not receive commands from the central computer but from the product

Source: Goodarz, Axxessio GmbH

The third component of I 4.0: Cooperation and Virtual networks

❑ How it works?

- » Through RFID (Radio-Frequency-Identification)
- » NFC (Near-Field-Communication)
- » QR (Quick-Response-Code)

❑ Benefits of Smart Factory Technology:

- » Components can be provided by different manufacturers
- » All components communicate using the same language
- » Production starts only when the command comes in
- » The buyer is always informed about the development
- » A precise number of products in the production process

Source: Goodarz, Axxessio GmbH

The third component of I 4.0: Cooperation and Virtual networks

❑ Challenges:

- » Moving from a centralized to a decentralized production control system – even better to distributed control system
- » Security (DATA, Information, Systems etc.)

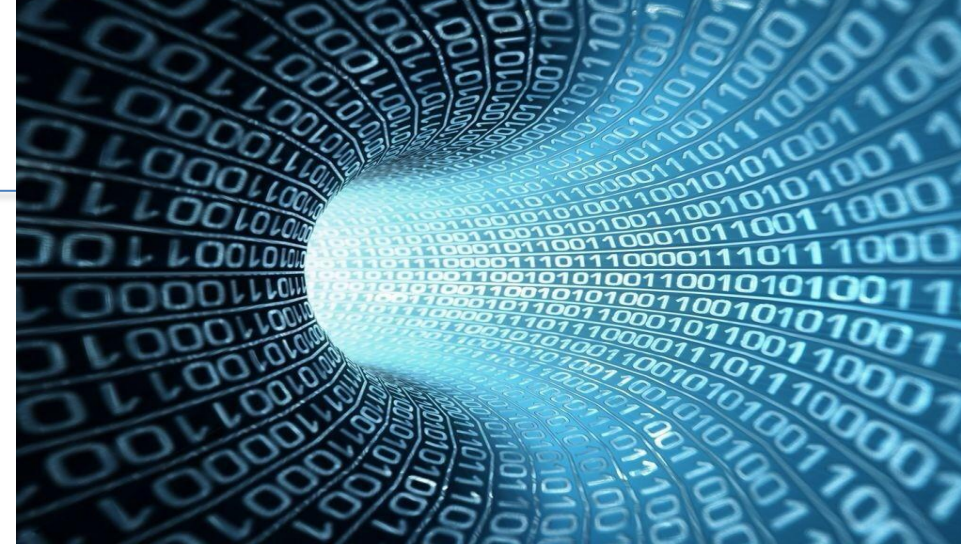
❑ How the revolution will start or is starting?

»Without „Big Bang“

Source: Goodarz, Axxessio GmbH

The fourth component of I 4.0 – Big DATA

- » **Data is generated everywhere**
- » According to information from IBM
2.5 – 3 exabytov / day
1 exabyte = **1.000.000.000.000.000.000** bytes
- » 90% of all data was produced in last TWO years.

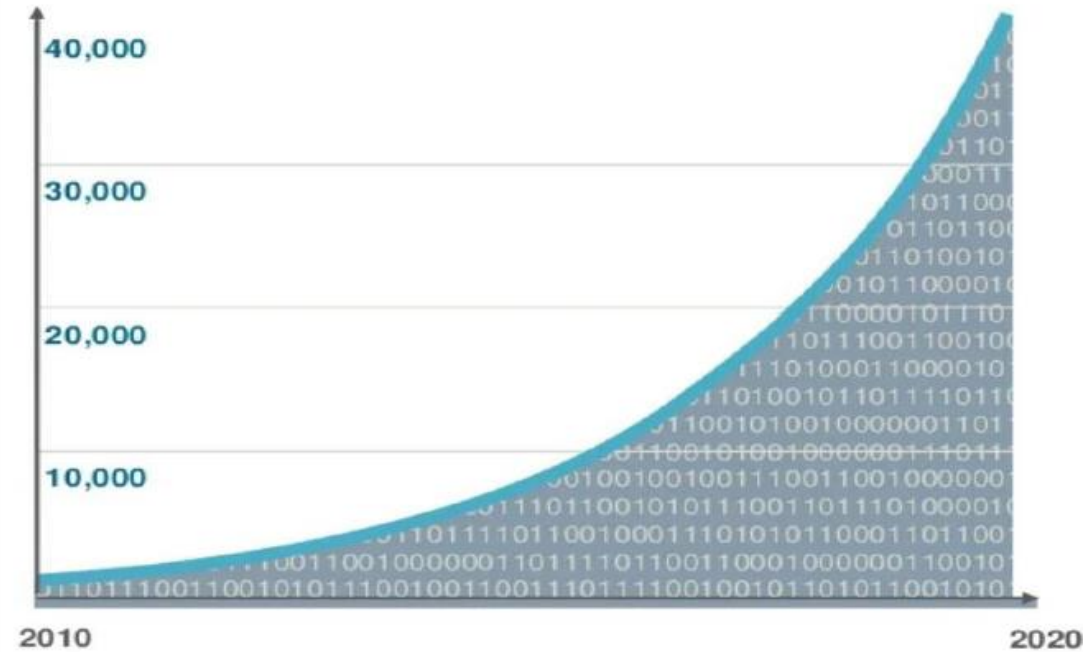


Source: Goodarz, Axxessio GmbH

The fourth component of I 4.0 – Big DATA and analytics



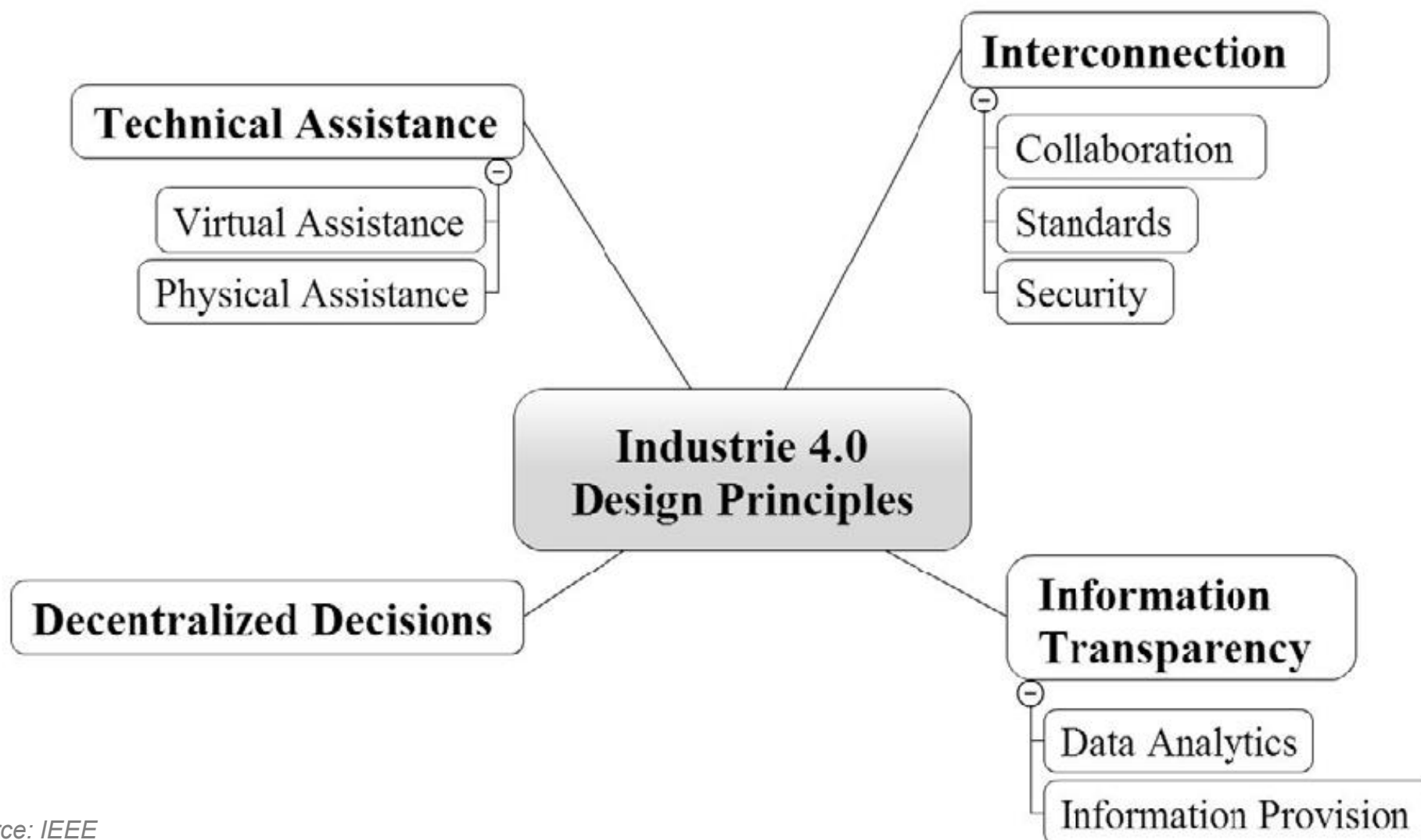
- *Data created only in 2000 was more than in 25 million years*
- *Many different sources (robots, automation software, even unfinished products)*
- *Must for real-time decision making*



50fold

Increase of data
from 2010 to 2020

Four main principles of introducing of Industry 4.0 – „How to do“ principles



Source: IEEE

What will be for the factory of the future very important?

- Software and smart algorithms (AI) for data analysis in real time, provides data in a comprehensible form or format and which will work easily and safely.
- Workers with different skills, open to new technologies and adaptable to rapid changes. In spite of all the progress, man will still be a decisive factor that will properly interpret the events, react and appropriately decide quickly.
- Highly skilled workers with multiple competencies and abilities to reasonably analyse various information for meaningful future use.

Steps of production companies in active transformation towards the Smart Factory

1. Identification of key areas for improvements:

- flexibility,
- speed,
- productivity,
- quality.

What do we want to achieve?

2. Consideration about the use of nine pillars of technologies of I 4.0 in a way, that the improvements of the above mentioned fields will be possible.

3. Avoid the situations when we could stack at the level of incremental approaches --> consider basic changes by using 9 (and more) pillars of I 4.0 technologies.

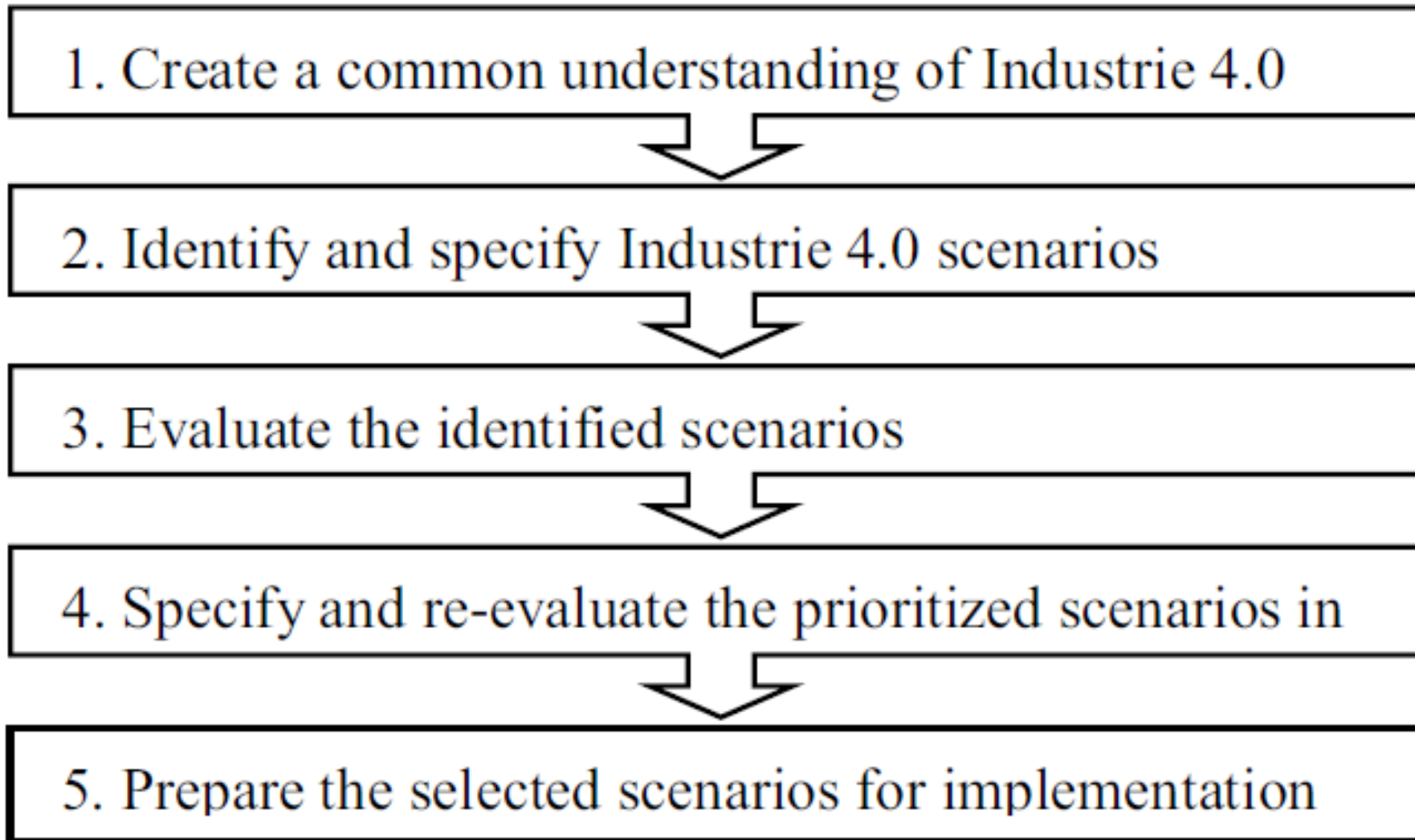
Steps of production companies in active transformation towards the Smart Factory

4. Analysis of the long-term impact of the deployment of new I4.0 technologies on the workforce and the introduction of strategic planning for the workforce.
5. Adjusting of workers to new roles, recruiting new, capable workers, and introducing additional training to acquire additional IT skills which will be needed.

Other necessary measures

1. Development of knowledge for the use of new technologies in order to achieve the highest impact.
2. Participation in the design of new technological standardization.
3. Development of the vision of the long-term evolution of the industry and the preparation of our own strategy.
4. Upgrading of the appropriate technological infrastructure, which will enable data transfer in real time.
5. Adaptation of trainings.

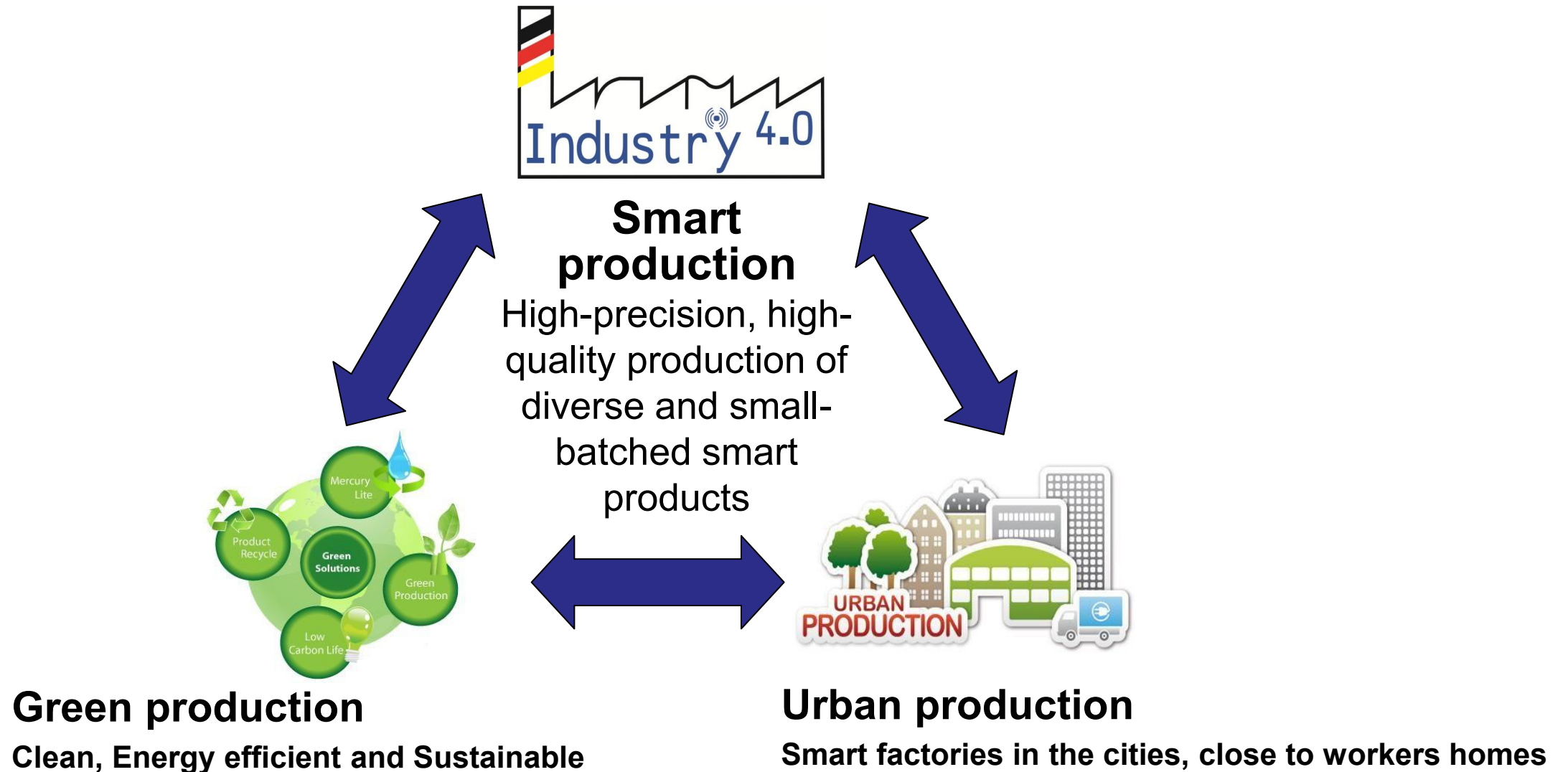
Plan of the implementation of the I 4.0 project in the company



What can slow down the deployment of Industry 4.0?

- A serious problem – the advantage of the USA in the IT field (the most innovative IT companies are in the USA) → for now, the only way to overcome this problem is cooperation with US IT companies → here the problem of data security and trust (CyberSecurity) appears.
- Lack of "Smart" people.
- Significant inertial forces that, internationally speaking, keep traditional production stable as much as possible with only incremental improvements towards Industry 4.0

Industry 4.0: Smart, Green and Urban production

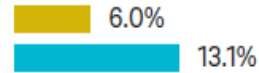


Forecast effects of industry 4.0

ROCE



PROFITABILITY



OVERALL PLANT UTILIZATION



ASSET TURNOVER (sales/capital employed)



MACHINE PARC



STAFF



Today Industrie 4.0

Source: Roland Berger

Three "enablers" of the factory of the future

- Strategy and leadership
- Adequate IT infrastructure
 - The IT infrastructure must enable connectivity throughout the value chain
 - It must ensure data security
- Skills and competencies of workers

Source: WZL, RWTH Aachen, 2017

Competences of workers in the factory of the future

- **Technical competences** - greater emphasis on competences in the fields of ICT, electronics, mechatronics, cyber systems (feedback-loop control)
- **Social competences** (ability to learn, teamwork, responsibility, ability to solve problems).
- **Education and qualifications** (hands-on workshops, personnel department)
- **Technology-supported learning** (working at the workplace with appropriate self-learning programs on mobile devices - not learning via PPT presentations in the classroom)

Source: WZL, RWTH Aachen, 2017

SMART FACTORY

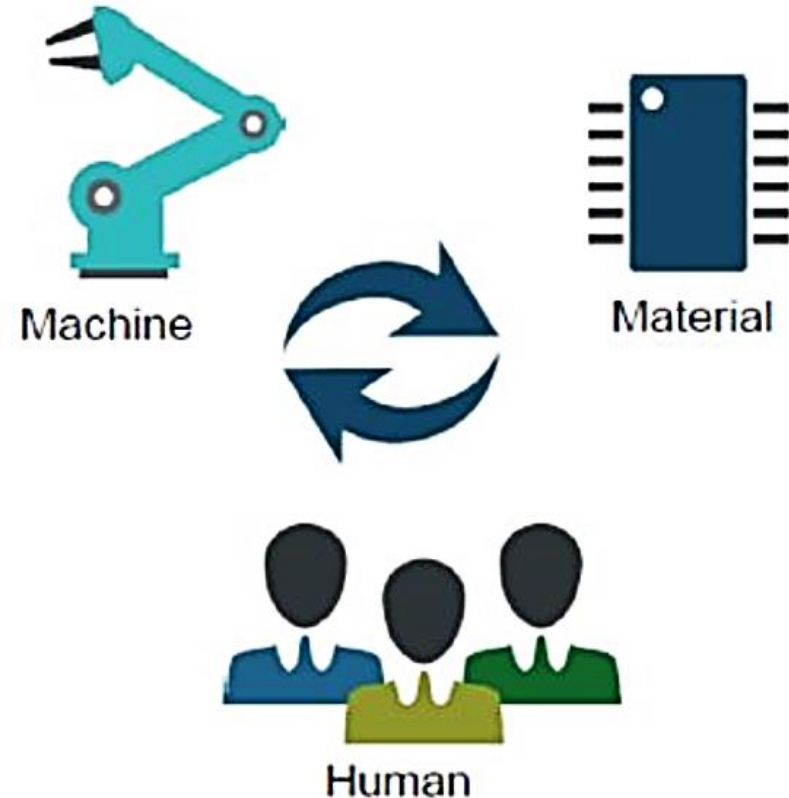
Smart factory - definition

Smart Factory IS NOT:

- ◆ Just Automation and Robotics
- ◆ Just Predictive Analytics
- ◆ Just Isolated Best Practices

Smart Factory IS:

- ✓ A Continuous Journey
- ✓ About Baseline Solutions
- ✓ About Standardization and Innovation
- ✓ About enabling a Behavioral & Cultural Change
- ✓ A structured System
- ✓ About Connecting EVERYTHING
- ✓ Part of EMS 2.0 (Electronic Manufacturing System)

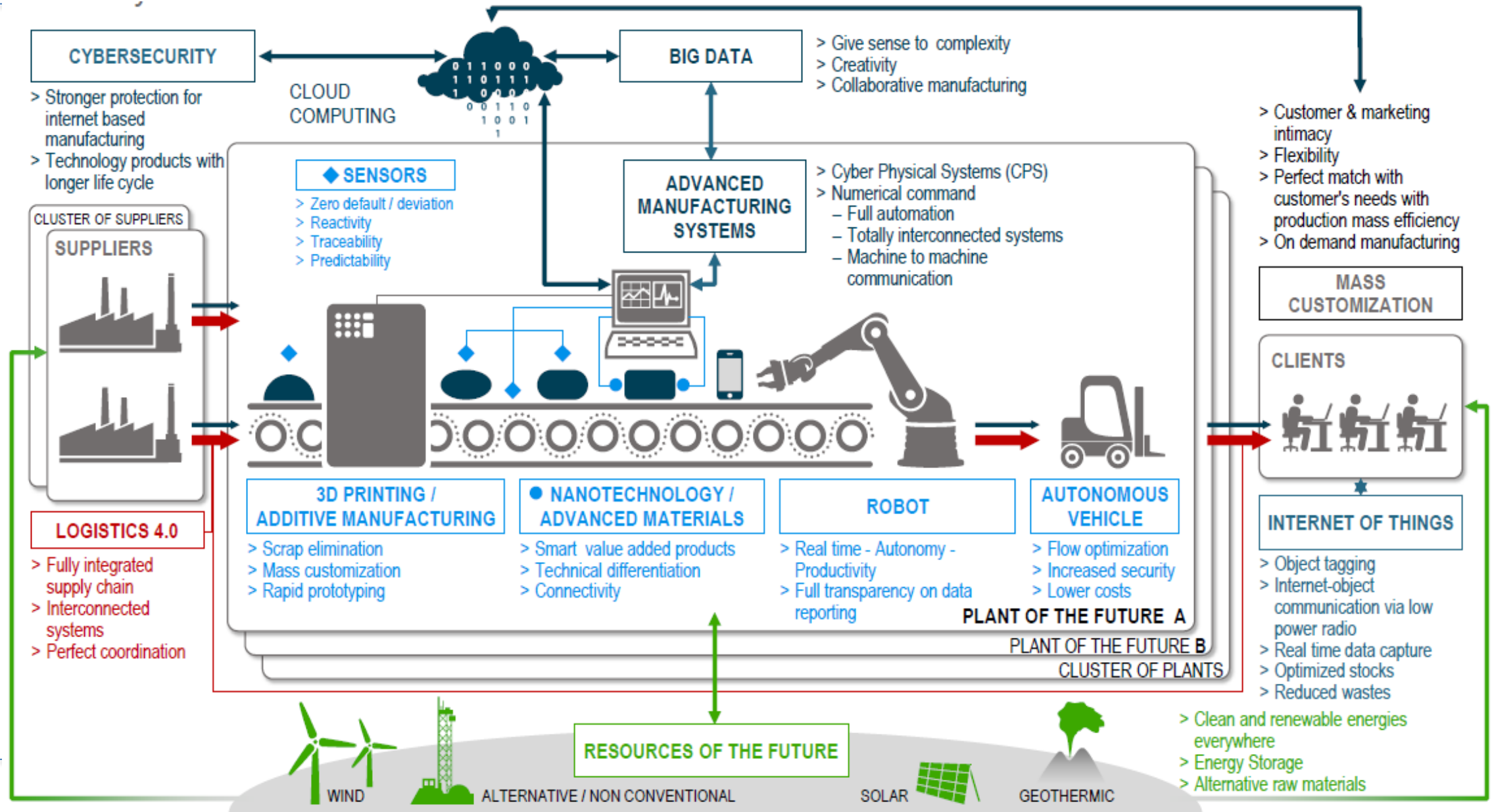


Source: EOS, EMS Operations Services

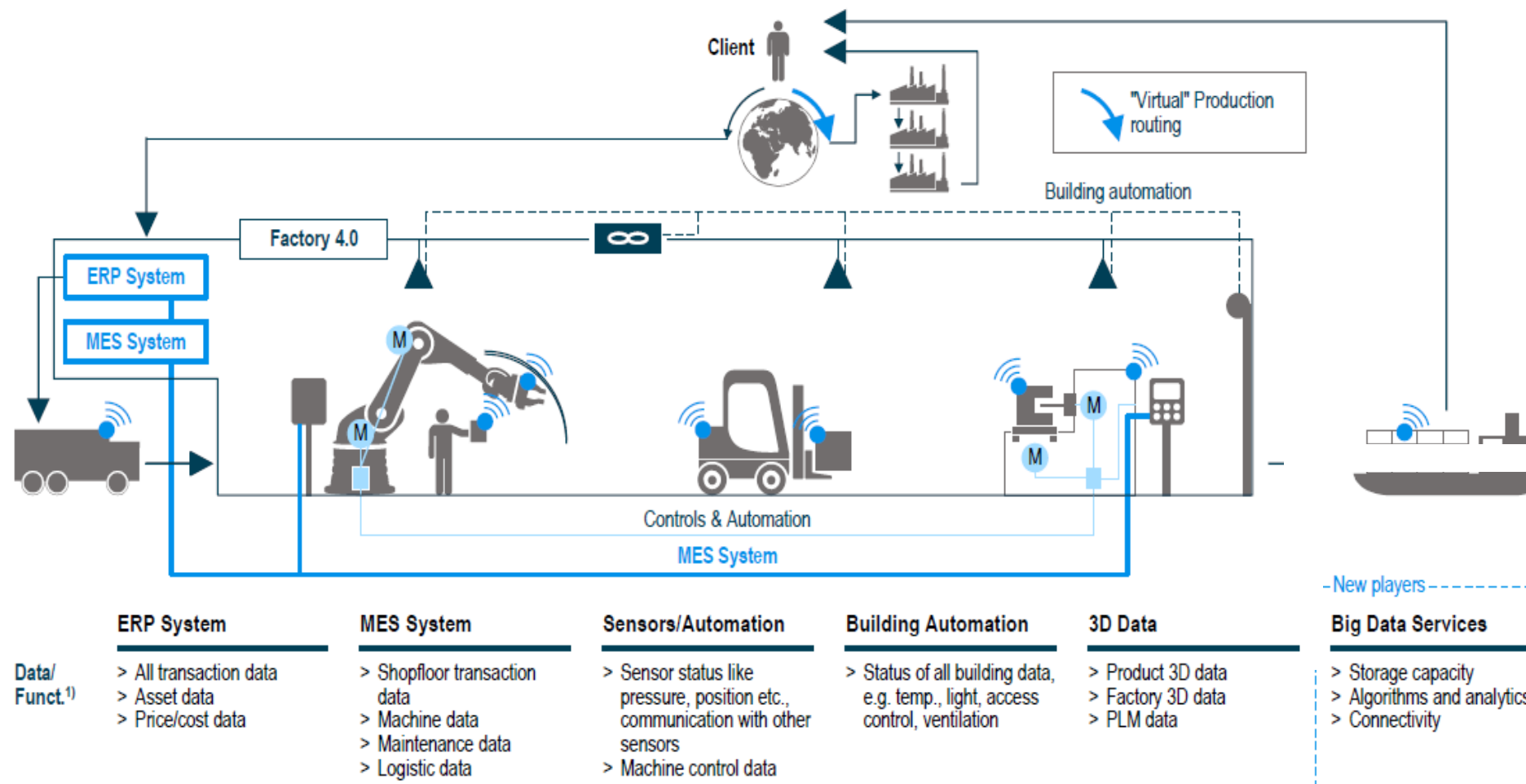
Smart factory



Smart manufacturing ecosystem



The backbone of the Smart Factory will be the **data, digital twins, real-time communication – M2M communication, fast IoT → 5G network**

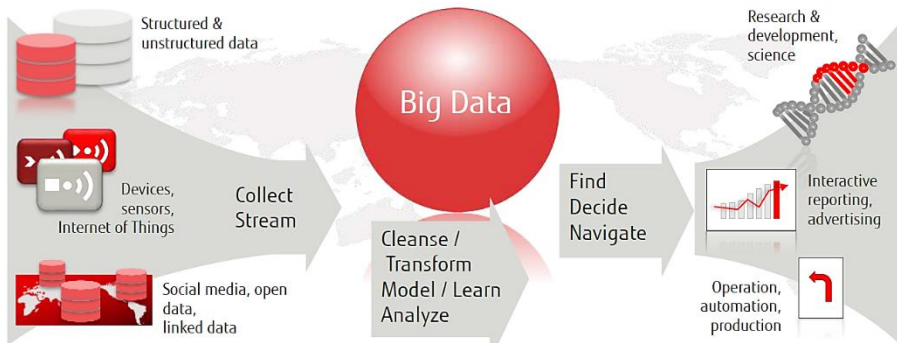


The essence of the Smart Factory vision

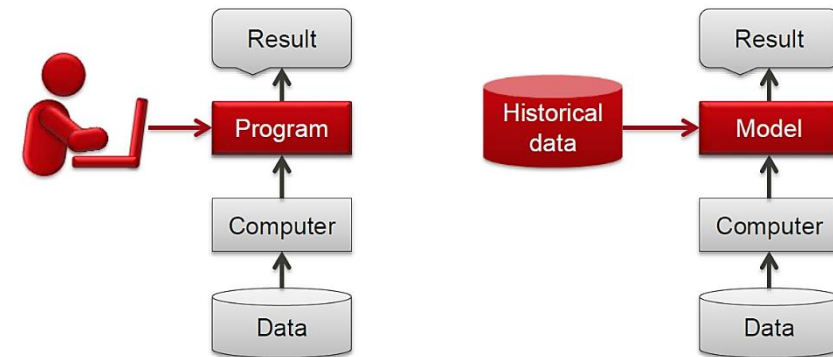
- It is a factory that helps people and machines-devices to perform tasks with the help of systems that work in the background.
- These systems perform their tasks on the basis of information obtained from the physical (process parameters) and virtual world (simulation models, decision agents, documents in electronic form, etc.).
- Based on the IoE (Internet of Everything - IoT + IoP), the smart factory enables the connection of people, things and data → a new way of organizing and managing industrial processes.

Challenges of Smart value chains

Big data in Smart factory



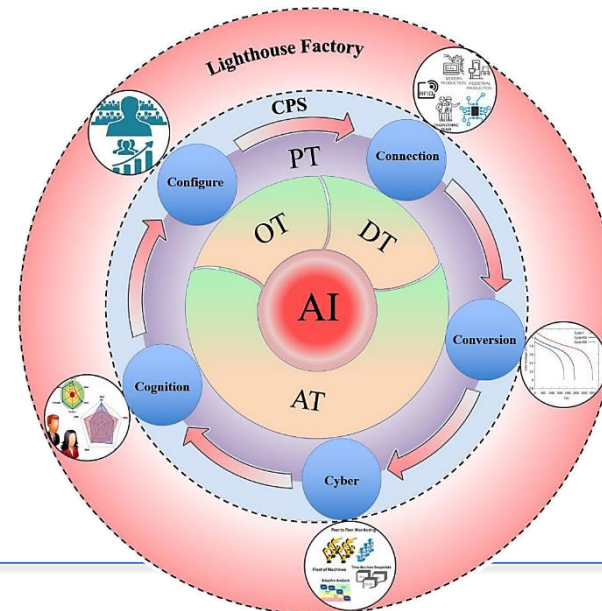
Machine learning instead of programming



Smart factory with integrated AI.

Lighthouse factories worldwide:

Foxconn Shenzhen, Bosch Automation, BMW, Tata Steel, Procter & Gamble, Rold



Source: FUJITSU

Source: Jay Lee, Jaskaran Singh, Moslem Azamfar, Industrial Artificial Intelligence

Seven steps towards the Smart Factory

1. Bring people who know what I4.0 technologies enable for a common table - an interdisciplinary team.
2. Find a common language - due to a lot of terms, technologies, areas, etc. the "Babylonian linguistic confusion" can arise. Therefore, we need to focus on the actual problems which we want to solve and leave out the technological or business jargon.
3. Define business objectives - do not get lost in technological details. Eg: What can we do to make our customer more satisfied? Does more flexibility help us to sell? etc.
4. Define the ideal business goal. Eg: Shorter lead time from product design to delivery!

Seven steps towards the Smart Factory

5. Estimate the costs and benefits and develop an investment plan!
6. Defining technologies that can enable us to achieve our goal according to the estimated costs and benefits - using steps 1 to 5, we can usually solve a large part of the task, and at the same time identify the technologies and areas, which are missing.
7. Implementation and continual improvements.

Smart manufacturing of the future

- Increasing the flexibility of systems and machines.
- Modular, flexible automation concepts.
- Ideal use of production resources.
- Short flow times:
 - from input materials to delivery,
 - from order to machine.
- Energy-optimized production.

SOLUTION:
Integration of horizontal
value-added processes
and vertical business
processes.

Business functions and the Smart Factory concept

ERP – Enterprise Resource Planning

MES – Manufacturing Execution System

SCADA - Supervisory Control And Data System

DOUBLE LOOP MNG – Double Loop Management

PLM – Product Lifecycle Management

