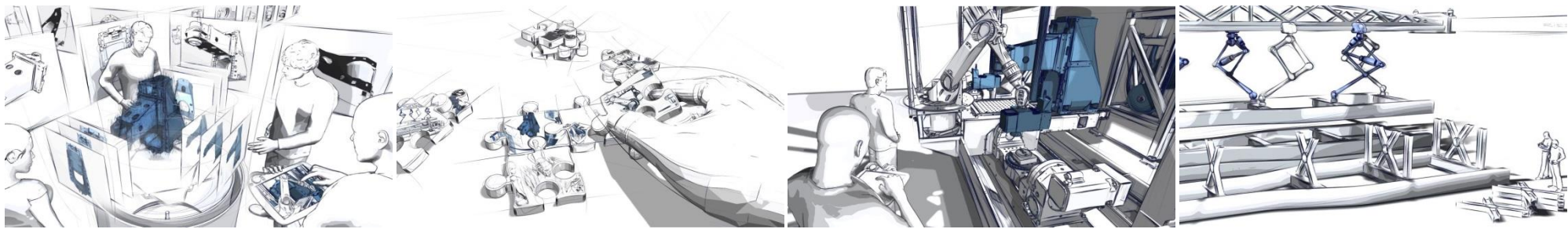# Industrie 4.0
The Aachen Approach

Axel Demmer
Fraunhofer Institute for Production Technology IPT, Aachen (GER)
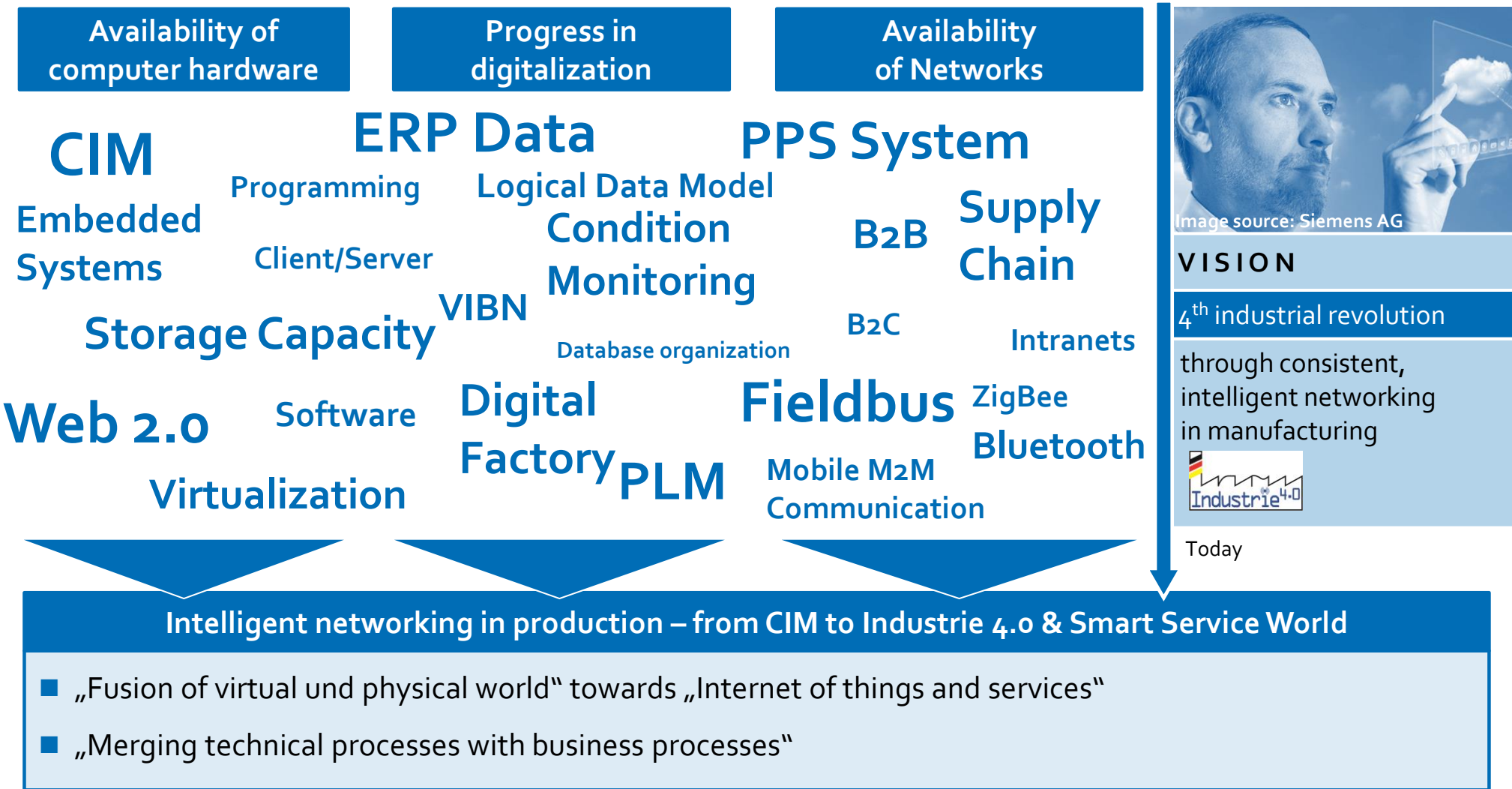
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WZL RWTH AACHEN

Paradigm shifts lead to the announced „fourth industrial (r)evolution"

1712: Steam engine

1st industrial revolution

by introducing mechanical manufacturing facilities

End of 18th century

Industrialization

1913: Assembly-line production

2nd industrial revolution

by introducing mass production based on the division of labor (Fordism, Taylorism)

Begin of 20th century

Rationalization

1969: PLC   1973: Six-axis robots

3rd industrial revolution

by applying electronics and IT to extended production automation

Begin of the 1970's

Computerization/ automation

1985:   Breakthrough of CIM

Integration of production

Integration concepts regarding information processing in manufacturing companies unifies production planning and control supported by CAD/CAM/CAQ

Begin of the 1980's

Integration concept inspired by business informatics

Development during the last decades – Requirements for Industrie 4.0

Availability of computer hardware	Progress in digitalization	Availability of Networks

CIM

ERP Data

PPS System

Programming

Logical Data Model

Embedded Systems

Client/Server

Condition Monitoring

B2B

Supply Chain

VIBN

Storage Capacity

Database organization

B2C

Intranets

Web 2.0

Software

Digital Factory

Fieldbus

ZigBee

Bluetooth

Virtualization

PLM

Mobile M2M Communication

Image source: Siemens AG

V I S I O N

4th industrial revolution

through consistent, intelligent networking in manufacturing

Industrie4.0

Today

Intelligent networking in production – from CIM to Industrie 4.0 & Smart Service World

- „Fusion of virtual und physical world" towards „Internet of things and services"
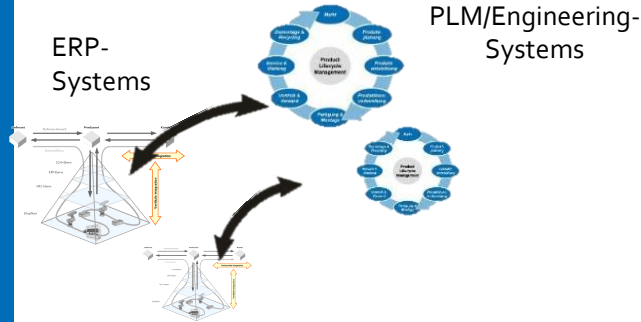- „Merging technical processes with business processes"

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Industrie 4.0 makes global network complexity manageable and enables the realization of economies of scale and scope
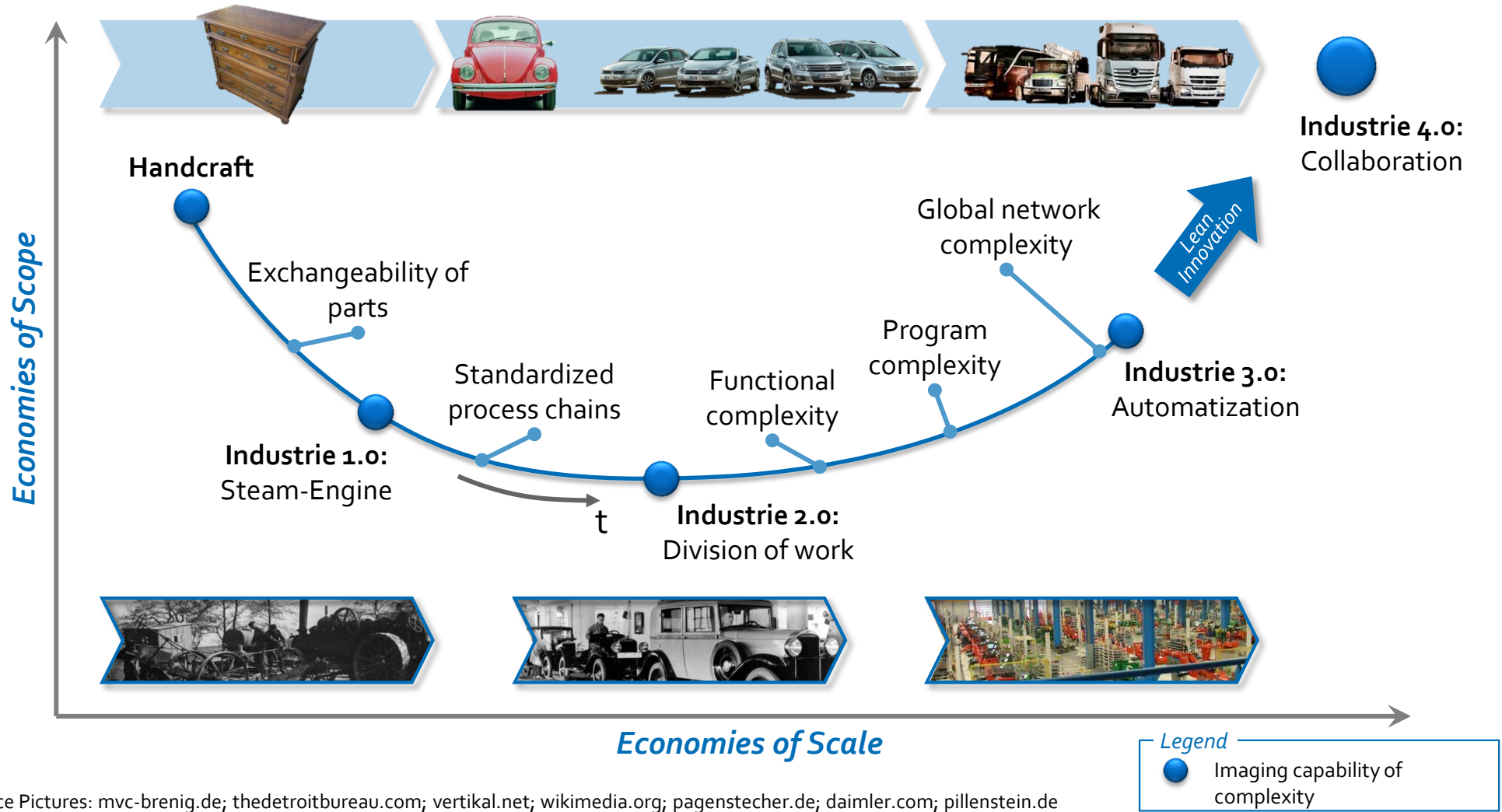
Handcraft

Exchangeability of parts

Industrie 1.0: Steam-Engine

Standardized process chains

t

Industrie 2.0: Division of work

Functional complexity

Program complexity

Global network complexity

Lean Innovation

Industrie 3.0: Automatization

Industrie 4.0: Collaboration

Economies of Scope

Economies of Scale

Legend
Imaging capability of complexity

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Industrie 4.0 –
The Aachen Approach

Single Source of Truth

ERP-Systems

PLM/Engineering-Systems

IT-Globalisation

Local data storage

- Big Data
- Assessing and Storage in the cloud
- Data mining, safety, security
- High Speed Computing

Cooperation

- Business Communities
- Social Communities

Automation

- Cognitive System

- Adaptation by sensors
- Intuitivity, reliability
- IT-Openness
- Cost-efficiency
- Robustness

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Industrie 4.0 –
The Aachen Approach

cyber

Single Source of Truth

ERP-Systems

PLM/Engineering-Systems

IT-Globalisation

- Big Data
- Assessing and Storage in the cloud
- Data mining, safety, security
- High Speed Computing

Local data storage

4th Industrial revolution

Collaboration Productivity
- Human/Human
- Human/Machine
- Machine/Machine

Cooperation

- Business Communities
- Social Communities

Automation

- Adaptation by sensors
- Intuitivity, reliability
- IT-Openness
- Cost-efficiency
- Robustness

- Cognitive System

physical

software

hardware

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Virtualization and Cross-Linking

Globalization and Complexity
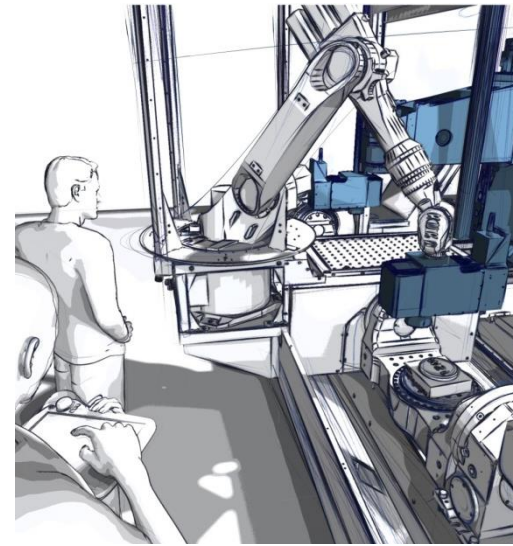
Digital Production
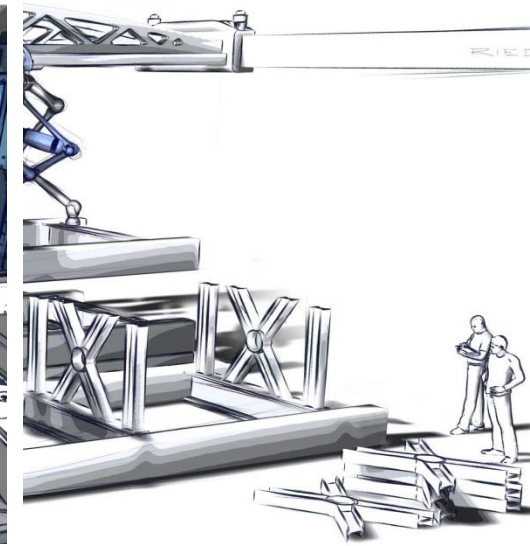
Cyber Physical Production Systems

Industrie 4.0 –
Virtualization and Cross-linking

Industrie 4.0

Real world

Virtual world

Fusion

Internet of Things

Business processes

Technical processes

Order
Order
Order
Performance
Invoicing

Resource
Track and
Control
Physical
Final Post Processing

Semantics, System understanding

Virtualization

Cross-linking

Finite-Element-Models

Data Models

CAx-Chains

PLM/PDM

Clouds

State Models

Analytical Models

Mobile Devices

Ubiquitous Computing

Image sources: Daimler, Chiron, WZL

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Cyber-Physical-Systems (CPS) are systems with embedded software, integrated for example in:
- equipment,
- buildings,
- transportation means,
- medical processes
- logistic processes
- or **Production Systems (CPPS)**
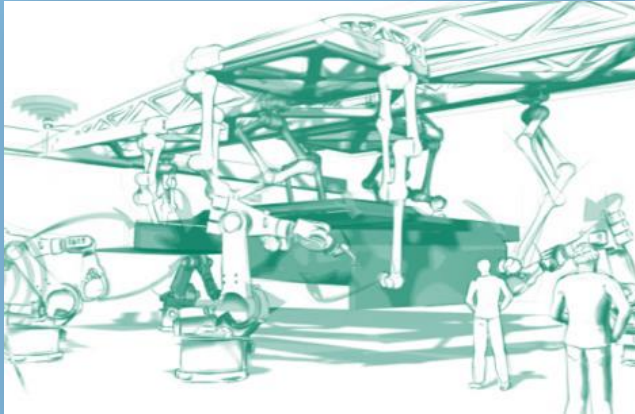
Cyber-Physical Production Systeme (CPPS) …

- ◼ …**gather data** with production-integrated sensors and metrology systems **in real-time,**

- ◼ …**record** and analyse data for the **creation of models,**

- ◼ …**interact actively** with actors of the physical and digital world as well as with **human**

- ◼ …are connected via digital **communication interfaces** with theirselves and with the **Internet of Things**.

A Cyber-Physical-System (CPS) is the smallest element of an intelligent object in the architecture of Industrie 4.0

Expectations of Manufacturing Companies towards Industrie 4.0
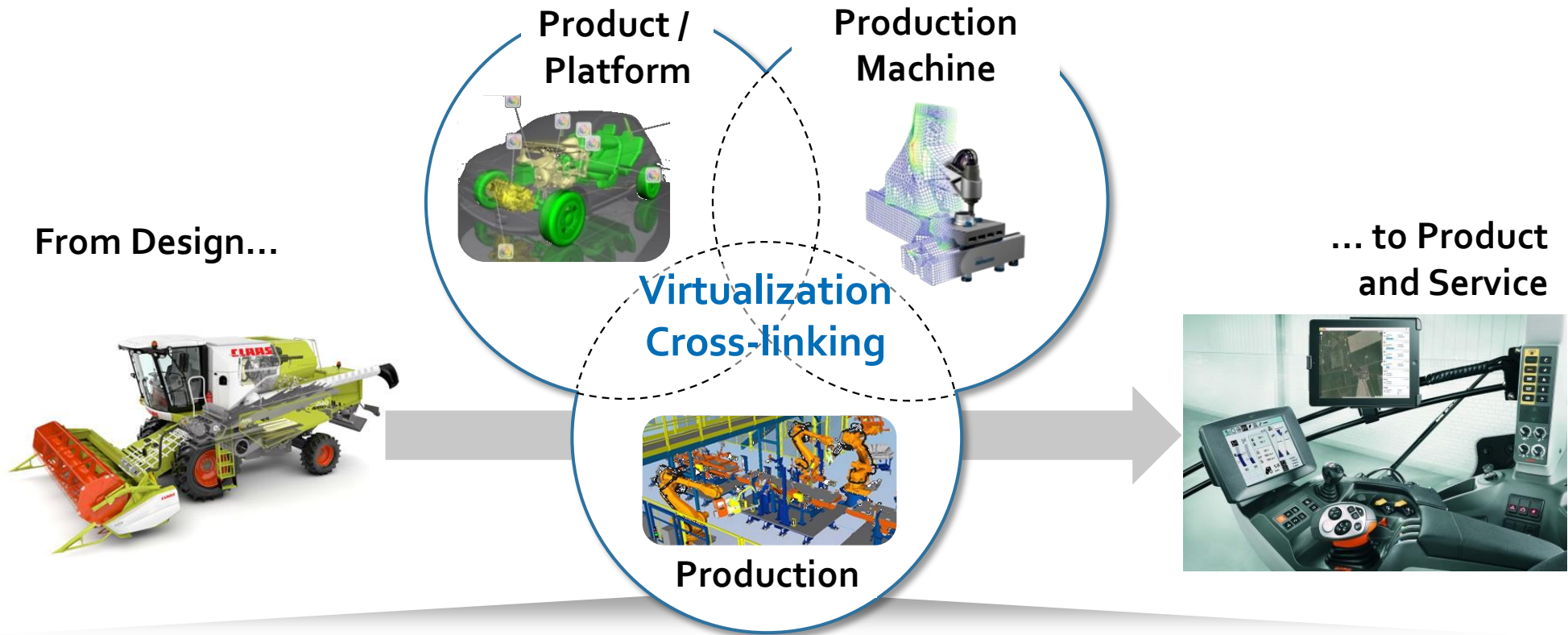
Product / Platform

Production Machine

From Design...

Virtualization
Cross-linking

Production

... to Product and Service

First Time Right

Continuous optimization of machining processes

Efficiency down to production batch size 1

Image Sources: CLAAS, CLAAS/Deutsche Telekom, Siemens PLM, WZL

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Overall objectives

First Time Right	Continuous optimization of machining processes	Efficiency down to production batch size 1
Virtualization of product, production means and production	Cross-linking of manufacturing resources and information	Production control with virtual technologies
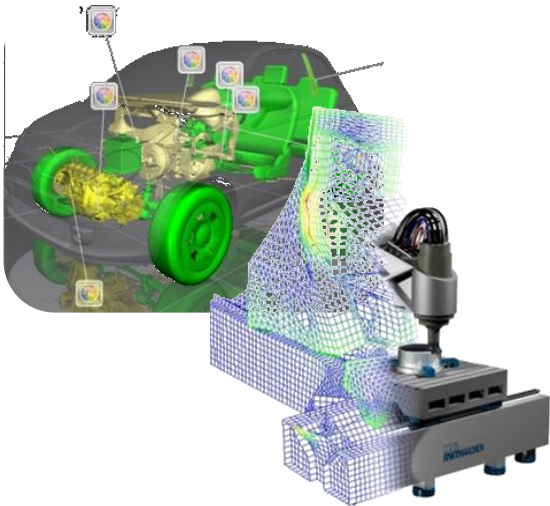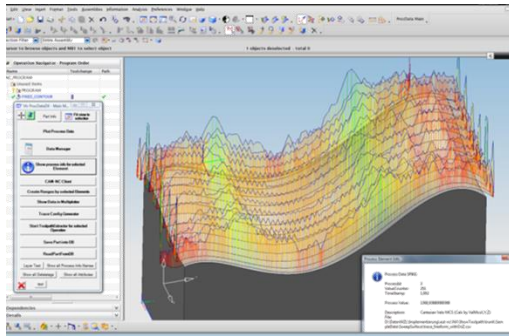
Image Sources: Siemens PLM, Index-Werke, WZL

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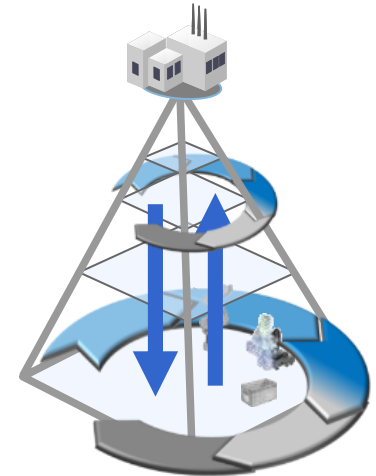
Virtual Prototypes in Vehicle Development

Crash

Operational Stability
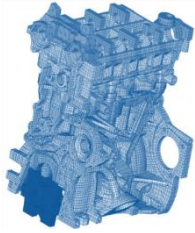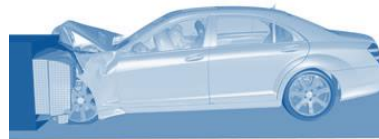
Flow
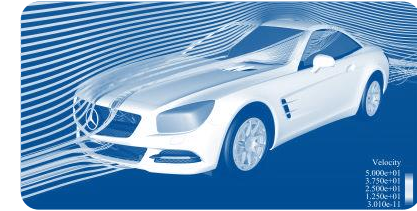
Energy / Climate

Drive Unit

Acoustics (NVH)

Velocity
5.000e+01
3.750e+01
2.500e+01
1.250e+01
3.010e-11

Each saved real prototype saves development months and costs

Image Sources: Magna/Steyer, Daimler, IAV

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Deficits in Cross-linking lead to increased deviations between digital Planning Models and real Production

Production planning

Information loss

NC program, workbook

```
% NCPROG
N10 G90
N20 G00 X50 Y100 Z100
N30 Z10
N40 G01 Z1 F2400
```

Input data

Information loss

Production

Insufficient cross-linking between reality and virtuality

Deficit

Unreliable planning resulting from deviations of models and input data

Exemplary solution strategies

Consideration of uncertainty induced by input data

Feedback of real production data within their context

Image Sources: WZL, Siemens, Index-Werke

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Individualized, flexible Production requires intelligent, model-based production control
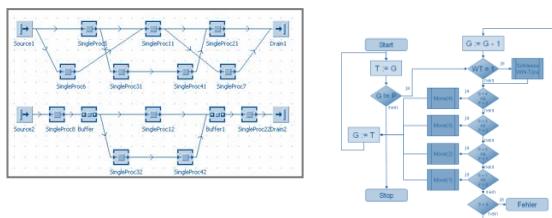
Conventional Production Control

Specification „how" production has to be carried out

Procedures and processes as central, stringent sequences of instruction

▼

Suitable for durable process chains in mass production

Challenge Mass Customization

| Alternative process sequences |
| Different efforts |
| Alternative process parameter |
| Multi-criteria optimization |
| Short product lifecycles |
| Mutability |

Individualized products

Intelligent, model-based Production Control

Specification „what" the target of production is

Information / objectives embedded in workpieces and production means

▼

Decentralized, semi-autonomous control units
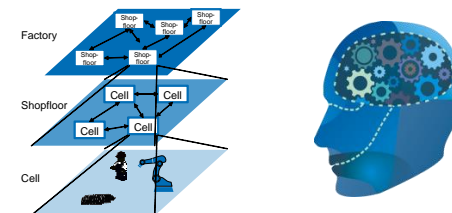
▼

Flexibility in procedure and process changes


Image Sources: Siemens, WZL

Conclusion

Virtualization
and Cross-linking

Industry 4.0 …

- … results from novel combination of existing elements

- … requires models as basis for intelligent cross-linking

- … has a great potential due to aggregated information in the right context

- … is particularly interesting because of its evolutionary steps

- … must first provide production-related solutions before it reaches industry!

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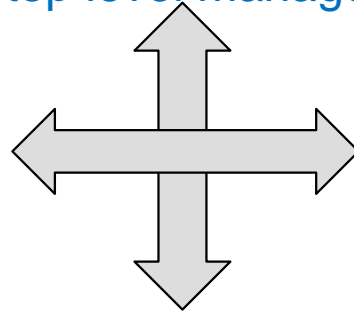# In a nutshell – Smart factory

Cyber
Physical Networks
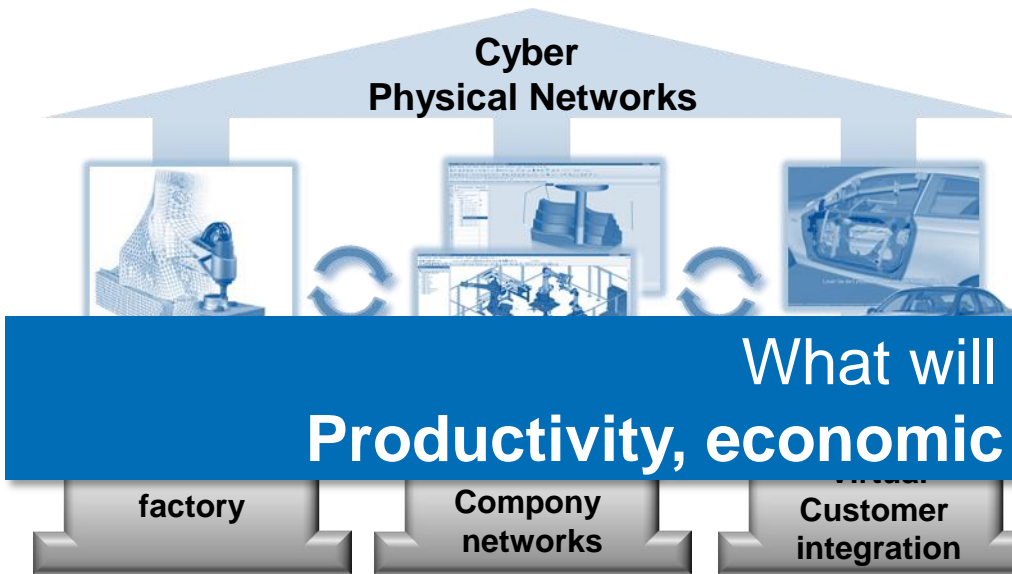
- Fusion of real and virtual environment

What will you get?
Productivity, economic efficiency, profitability

| factory | Compony networks | Virtual Customer integration |

From the shop floor
to top level management

Inter- and
across companies
customers

- Fully electronically integrated business processes, intercompany and across companies and customers

- Single source of truth

Photos: WZL, Siemens, BMBF

Industrie 4.0

Axel Demmer
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