„Application of Industry 4.0 concepts at steel production from an applied research perspective“

Prof. Dr. Harald Peters

IFAC MMM 2016 vienna

17th IFAC Symposium on Control, Optimization and Automation in Mining, Mineral and Metal Processing

August 31 – September 2, 2016
Vienna, Austria

IFAC INTERNATIONAL FEDERATION OF AUTOMATIC CONTROL

TU WIEN TECHNISCHE UNIVERSITÄT WIEN Vienna University of Technology

ACIN AUTOMATION & CONTROL INSTITUTE

BFI VDEh-Betriebsforschungsinstitut GmbH

Stahl

Industrie 4.0 is everywhere …..

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Activities in steel industry in Germany / Europe

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Working Group „Industrie 4.0“ of Steelinstitute VDEh:

- *founded 10‘2014*
- *Representatives of 8 steel producers (TKSE, SZFG, HKM, AM Ruhrort, DH, voestalpine, AM Bremen, SWT), VDEh and BFI*
- *Development of guidelines*
- *First information exchange with VDMA*

ESTEP Working Group „Integrated Intelligent Manufacturing (I^2M)“:

- *founded 2008*
- *members: AM, Tata, TKSE, voestalpine, (Ilva), Primetals, Danieli, BFI, CSM, Cetic, SSSA (Uni), Uni Lulea,*
- *Development of an European roadmap, suggestions for priorities of European research programmes, initiation of common research projects („Flag Ship Projects“)*
- *Workshop in April 2012 in Maziere*

What means Industry 4.0?

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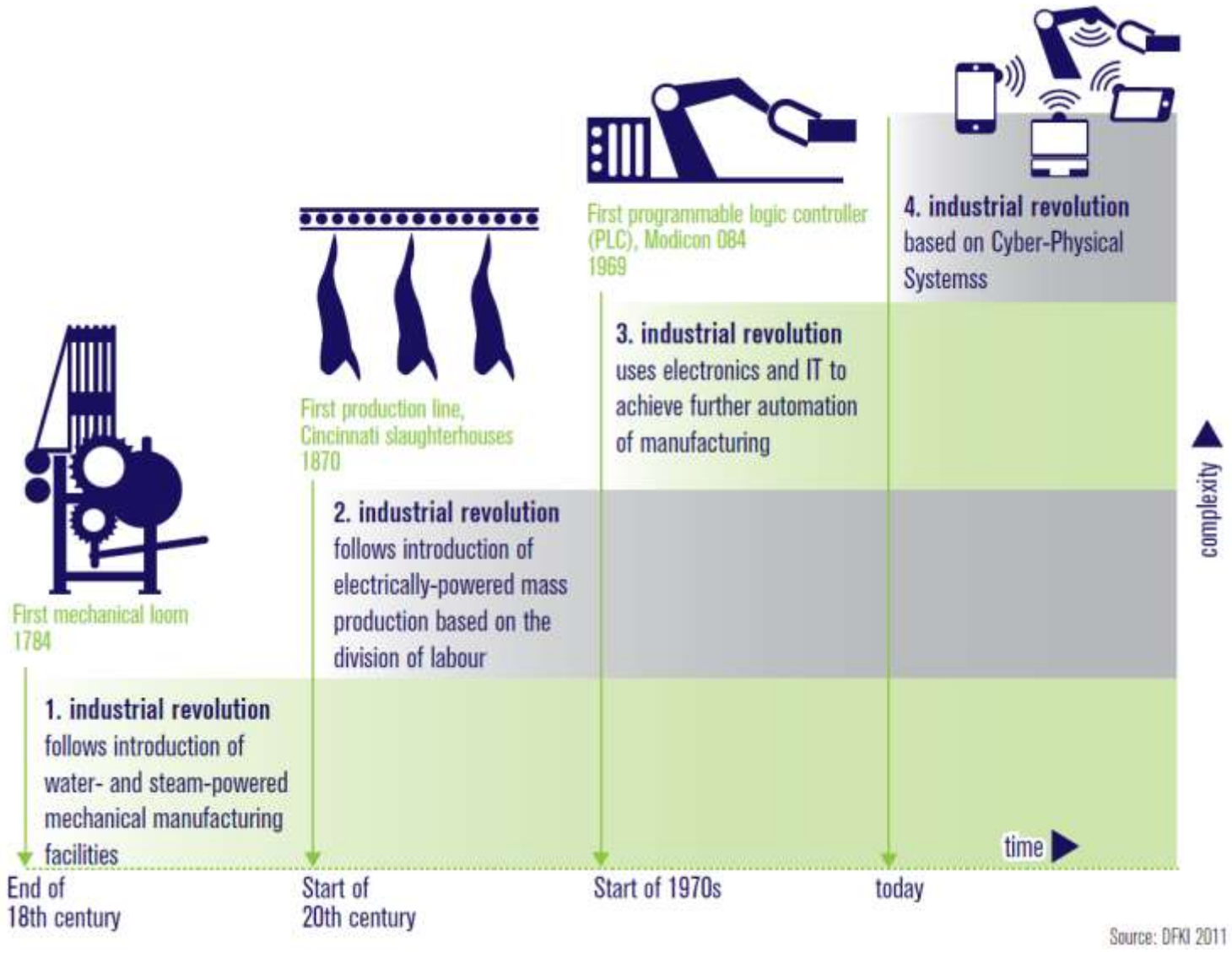

Source: Recommendations for implementing the strategic initiative INDUSTRIE 4.0, Final report of the Industrie 4.0 Working Group, April 2013

What is a cyber-physical system?

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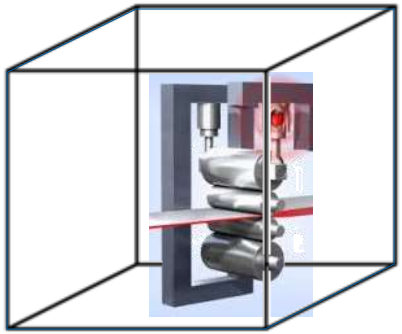
„…merging of information processing with physical processes“

- Strenghtened usage of IT-systems which are directly embedded in the technical process,
- Intensive integration of all physical processes among themselves by suitable information flows,
- Improved interaction of the technical process with its environment,
- Adaptation of technical process and IT-systems to changing environment by learning functions,
- („Big Data analytics“: intelligent usage of large data sets)

(based on J. Jasperneite)

physical process

+

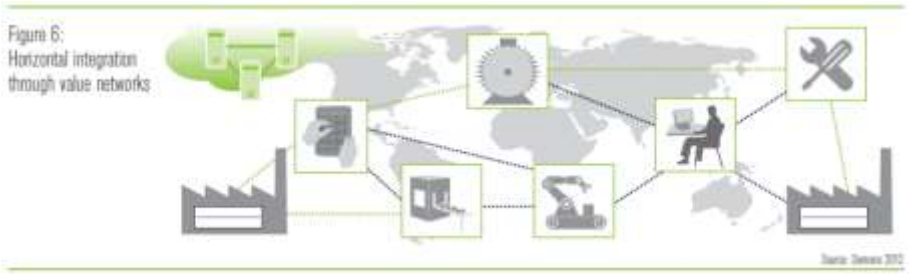


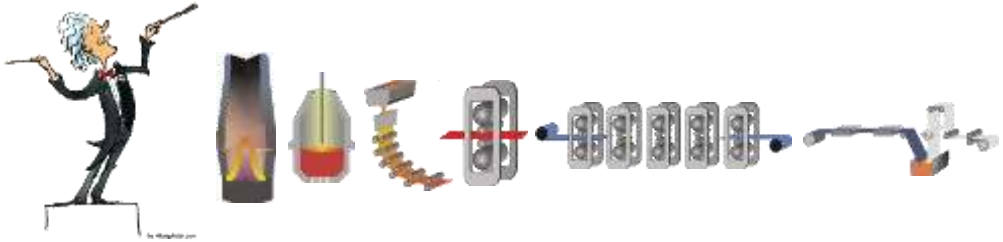
digital model

- mechanics
- elektrics
- automation
- IT + Software
- maintenance
- HMI
- identity
- ...

Aspects of Industry 4.0

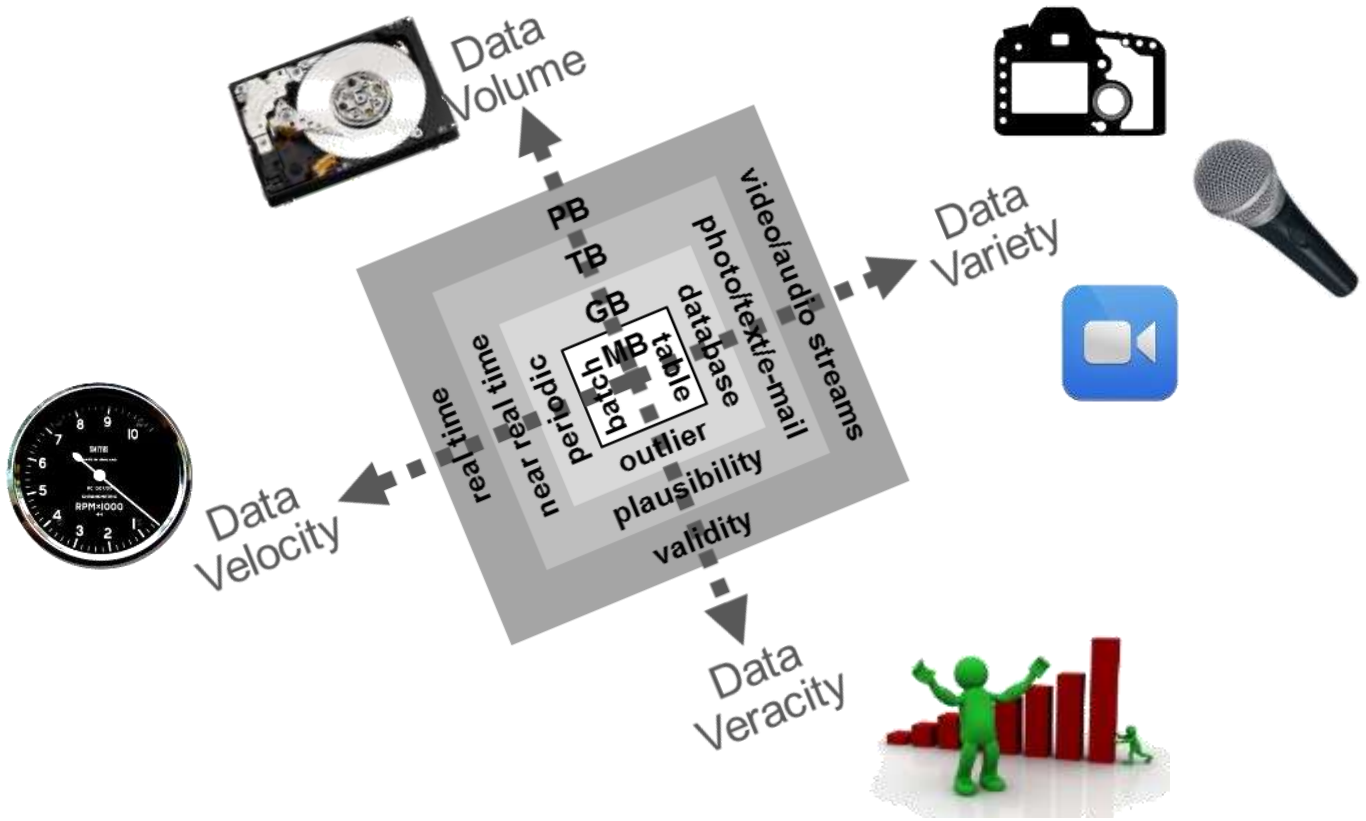
- Horizontal integration
- End-to-end engineering
- Vertical integration and networked production systems
- Human being as conductor of value chain





Source: Recommendations for implementing the strategic initiative INDUSTRIE 4.0, Final report of the Industrie 4.0 Working Group, April 2013

Big Data, the four V's



„Big Data means the analysis of large amounts of data coming from different sources with high speed and with the aim to create economic benefit" (BITKOM)

Fields of research I

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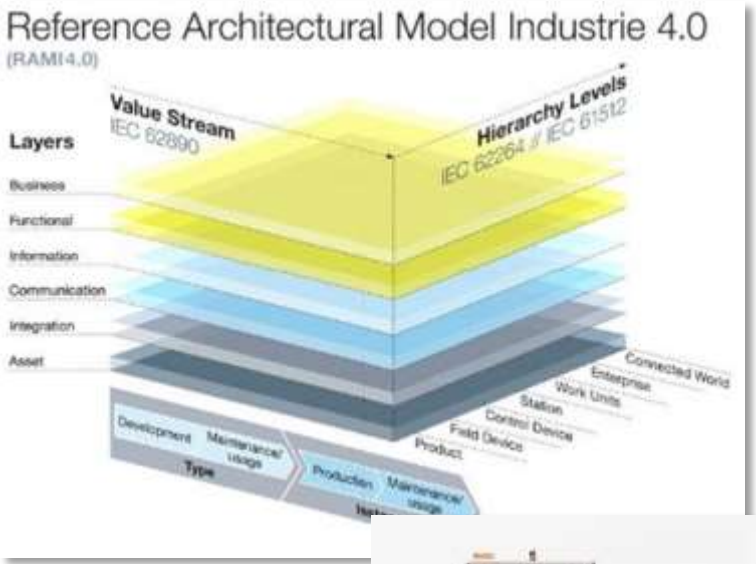
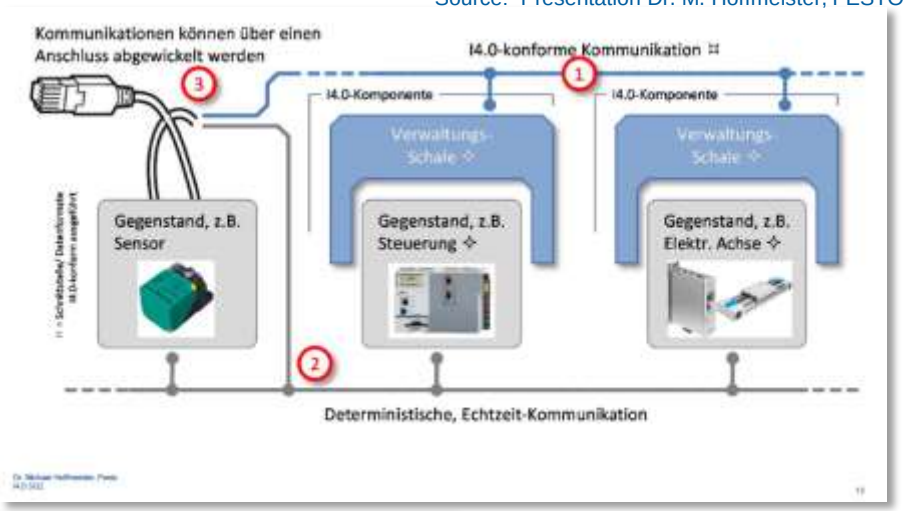
Source: Presentation Dr. M. Hoffmeister, FESTO



„RAMI“



„Internet of Things“

„Smart Factory^{KL}“

source: http://www.smartfactory-kl.de/

„Basic“ Research

Fields of research II

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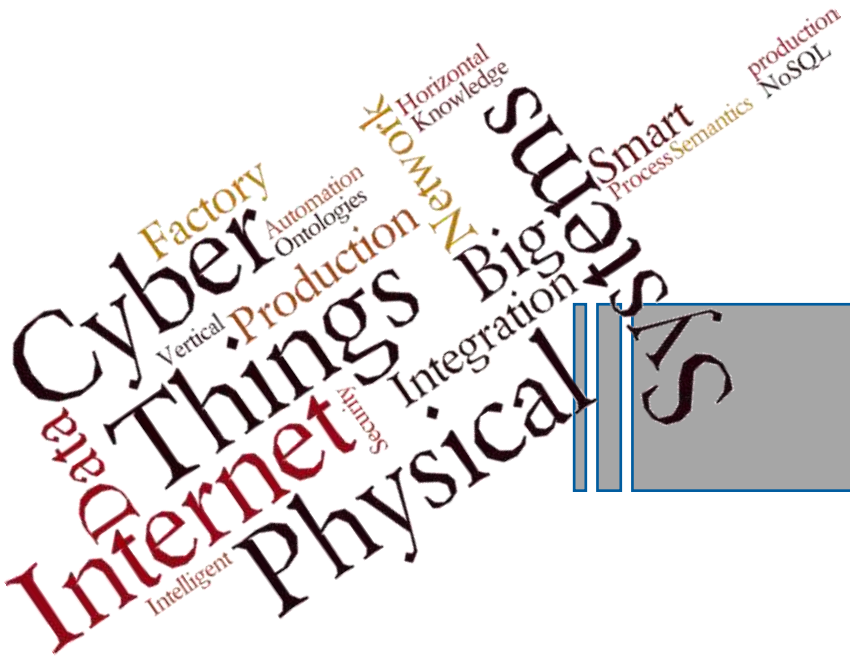
Transfer of the basic ideas and concepts into real applications in industry



Applied Research

Introduction to steel industry

Necessary process steps …

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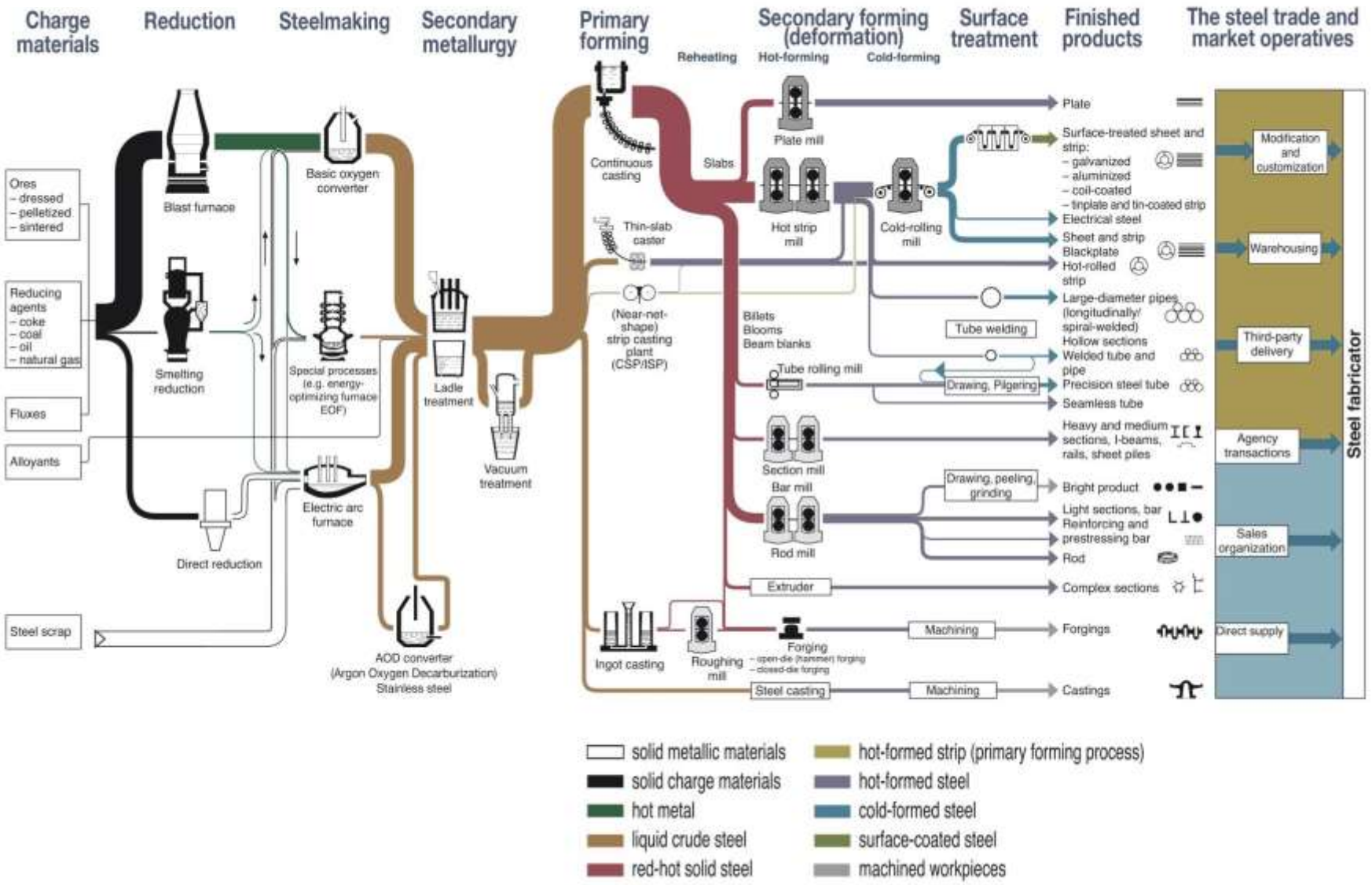

… and how they look in reality…

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…and their complexity

mixing

cooling

solid -> liquid -> solid

casting

continuous -> semi batch -> batch -> piece

forging

rolling

melt -> slab -> short coil -> long coil

welding

galvanising

annealing

linear, non linear

+ many scheduling tasks

static, highly dynamic, transient

heating

painting

cutting

melting

slow (8h) -> medium (min) -> very fast (msec)

cleaning

coiling

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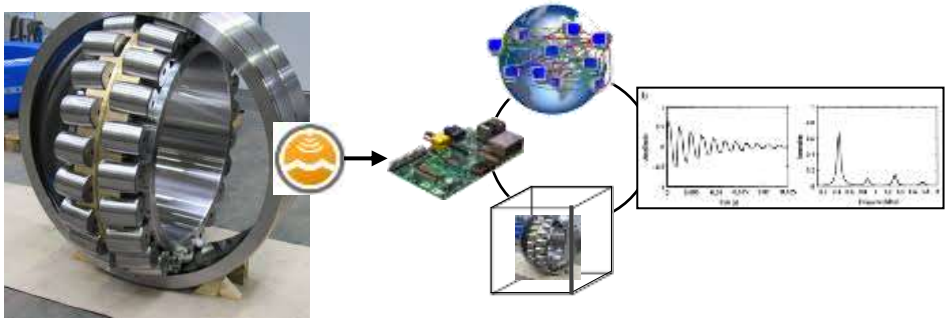
Interpretation of “Industry 4.0” for steel industry: **Steel 4.0**

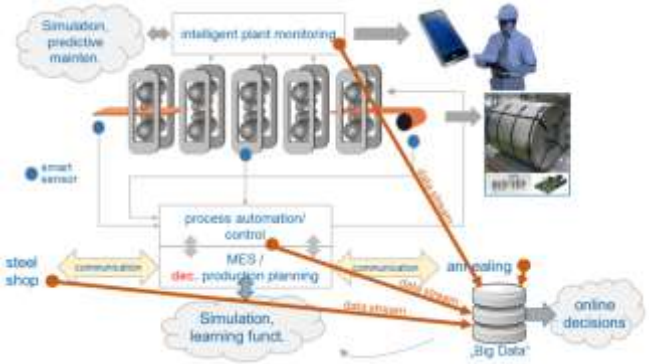
Possible cyber-physical systems in steel industry

plant component



product

production plant



Cyber-Physical Production System

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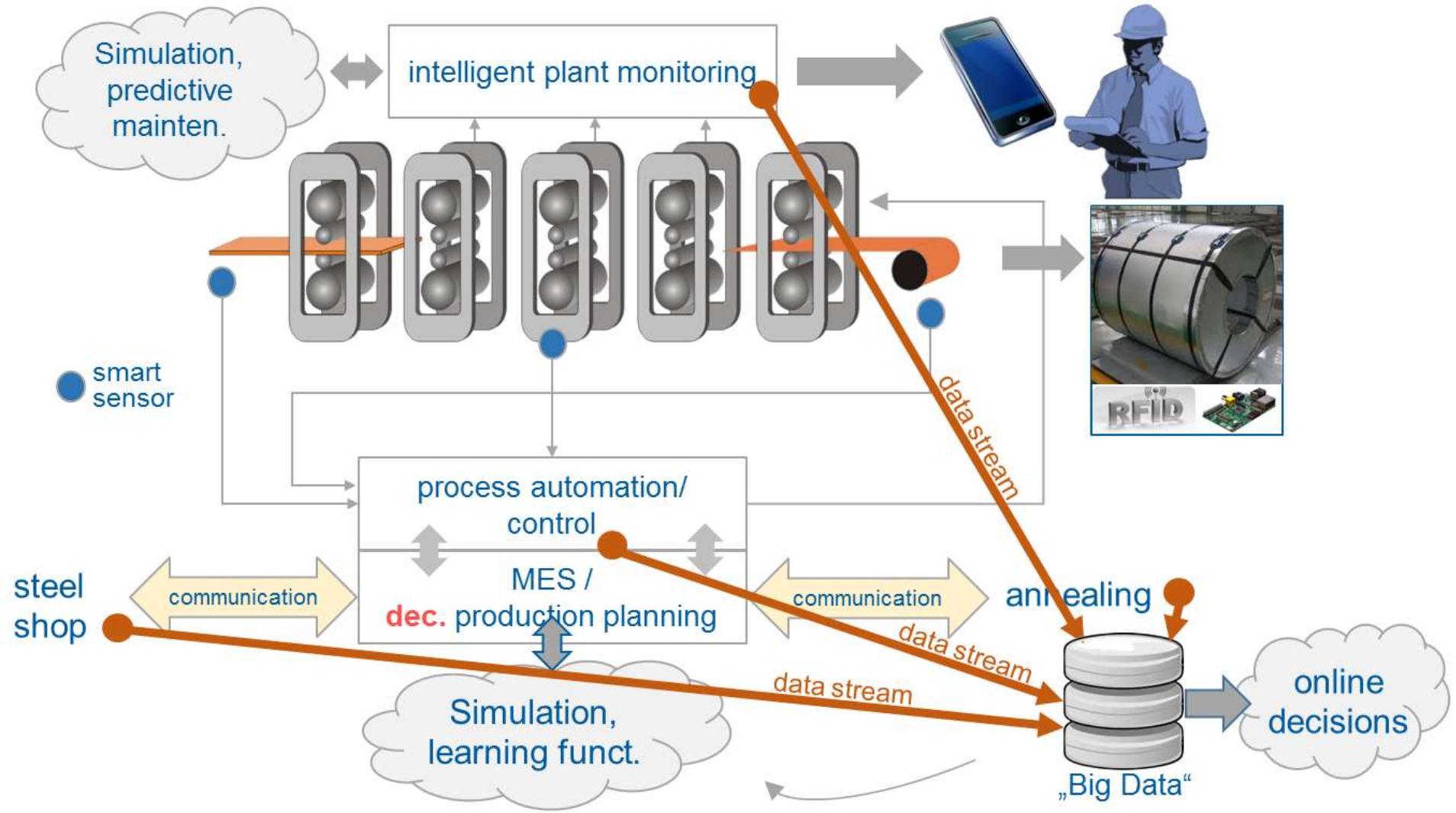
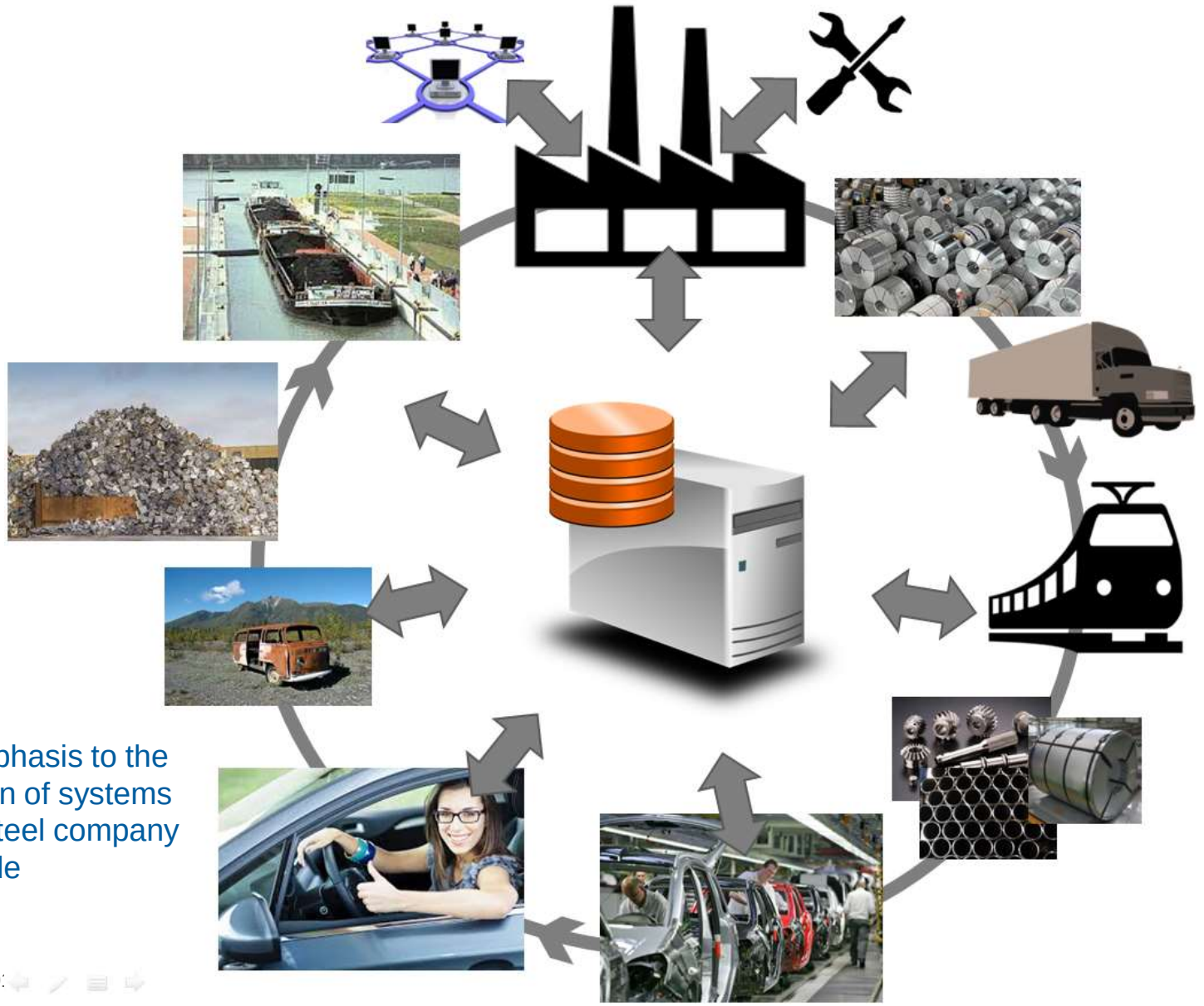


Horizontal Integration in steel industry



Value chain network

more emphasis to the integration of systems outside steel company than inside

End-to-end engineering I

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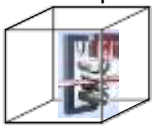
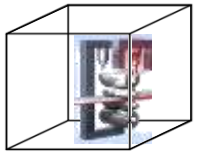
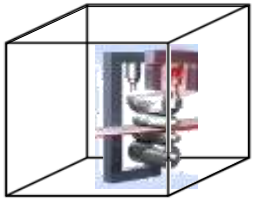
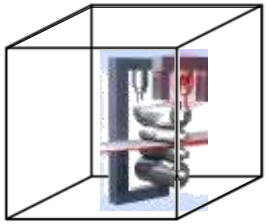
plant

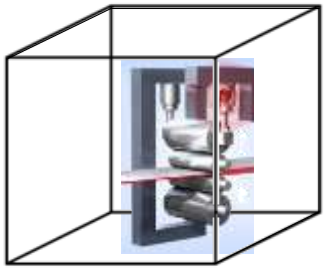
digital model of the plant



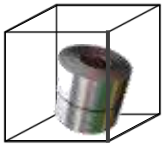




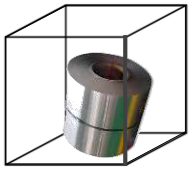


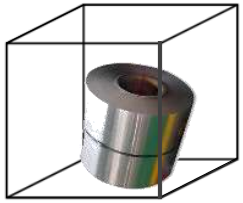


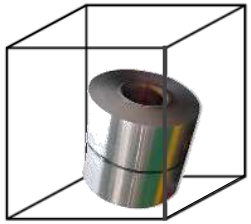
product design | production planning | production engineering | production | services

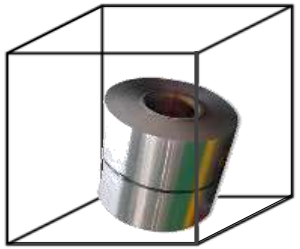


digital model of the product



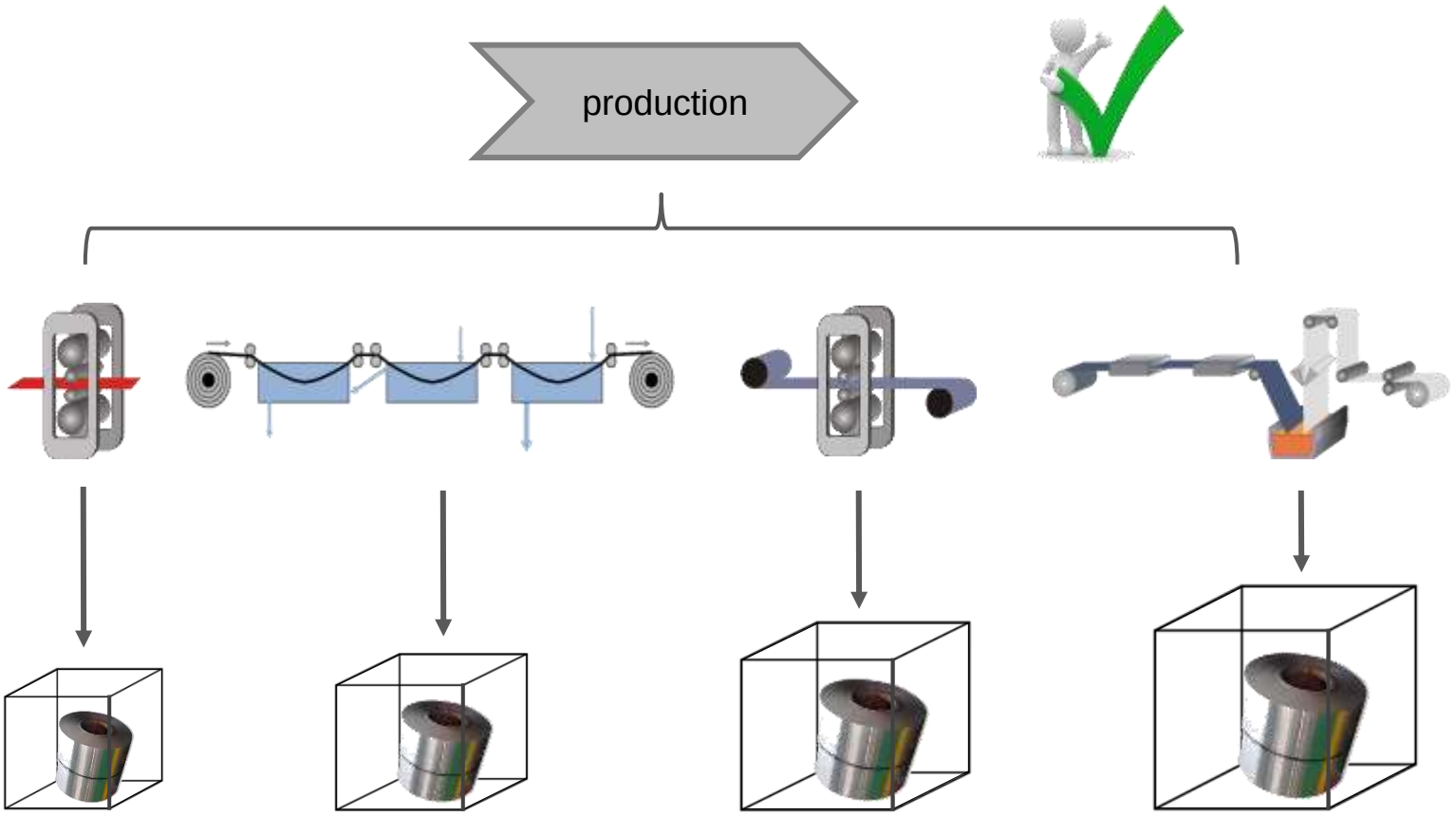




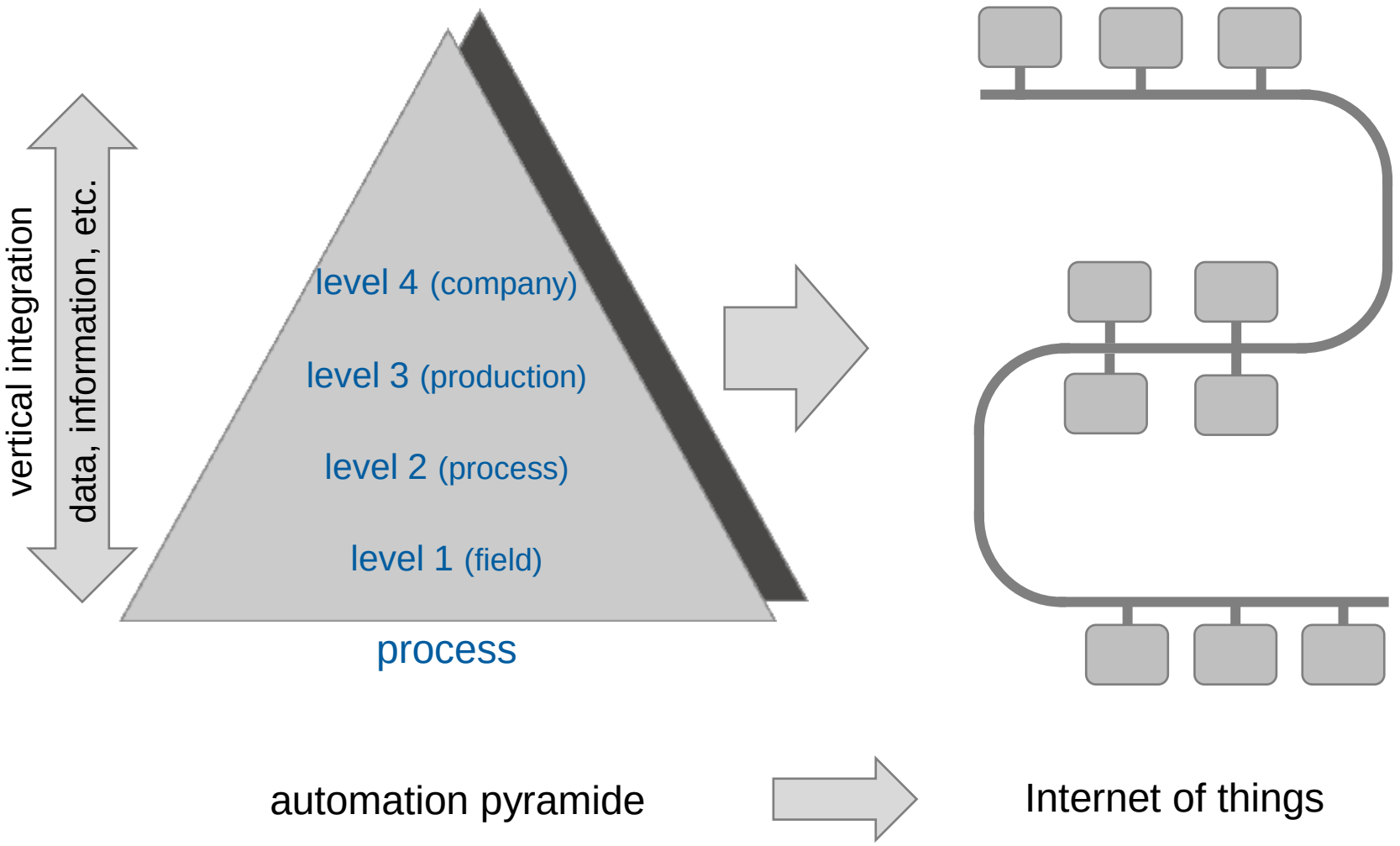


product

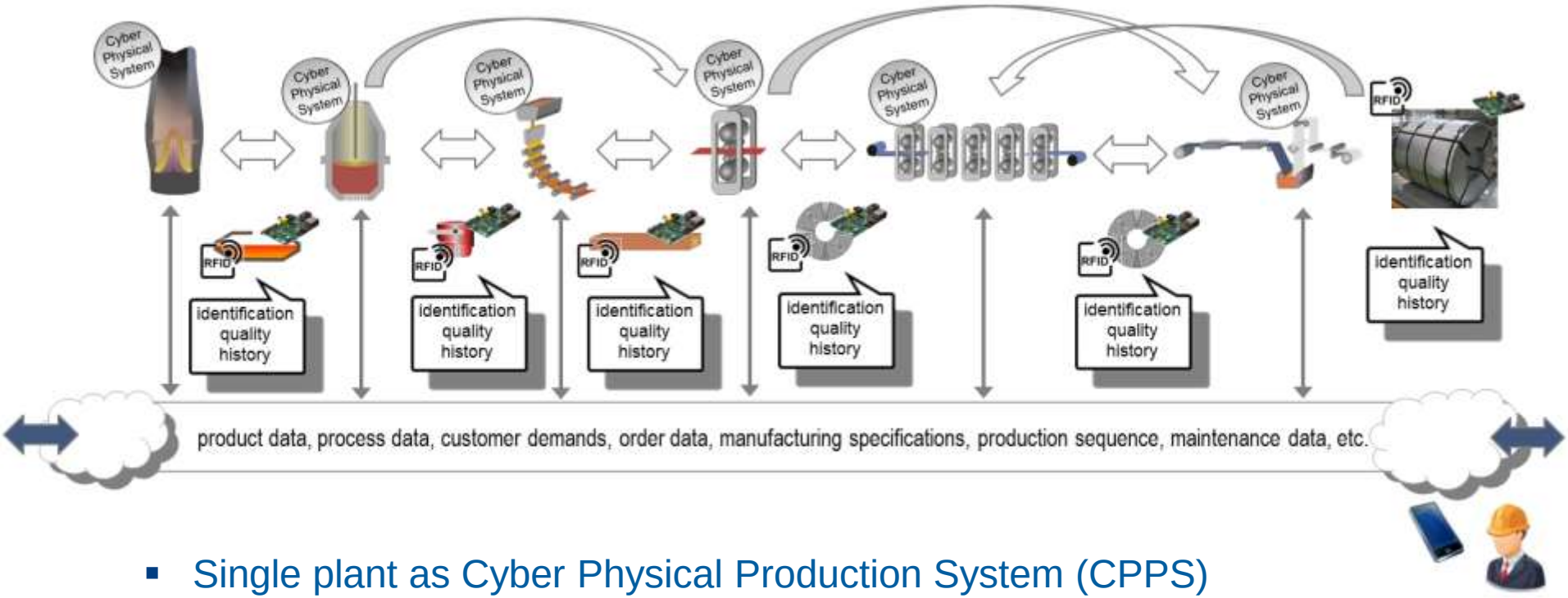
End-to-end engineering II



Vertical integration



Vertical integration and networked production



- Single plant as Cyber Physical Production System (CPPS)
- Intensive networking and communication of all plants
- „Intelligent“ product with knowledge of its own quality and production history
- De-central instead of central solutions / self-organisation

Big/Smart Data in steel industry

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- **High resolution** and synchronised data
- Transition to more-dimensional data („spatial“) instead only 1D
- Integration of text data, video-/audio-streams, data with gaps (**unstructured**)
- Fast processing and **„online“-usage** of results

Possible scenario in steel industry: "**Steel 4.0**"

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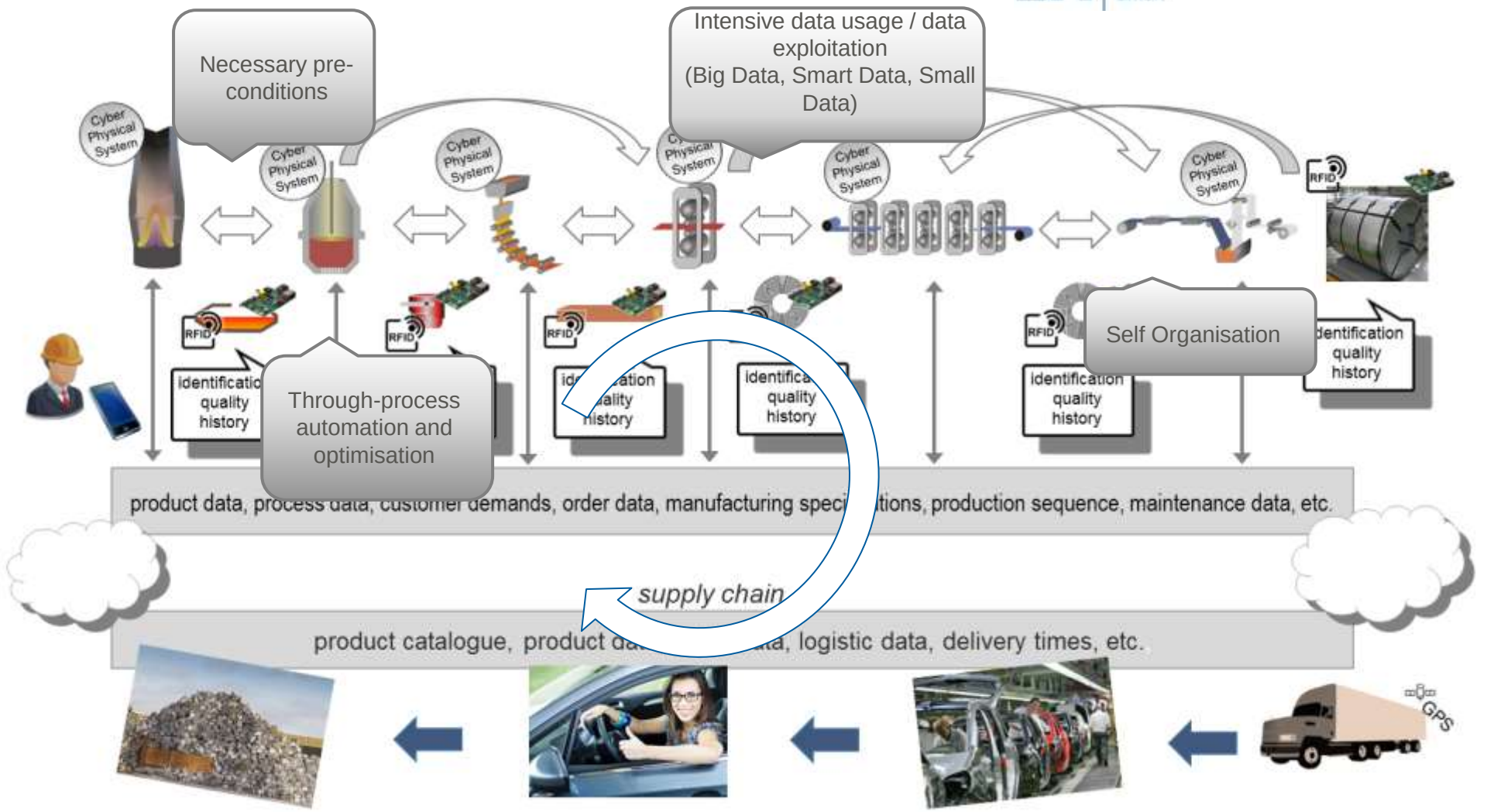
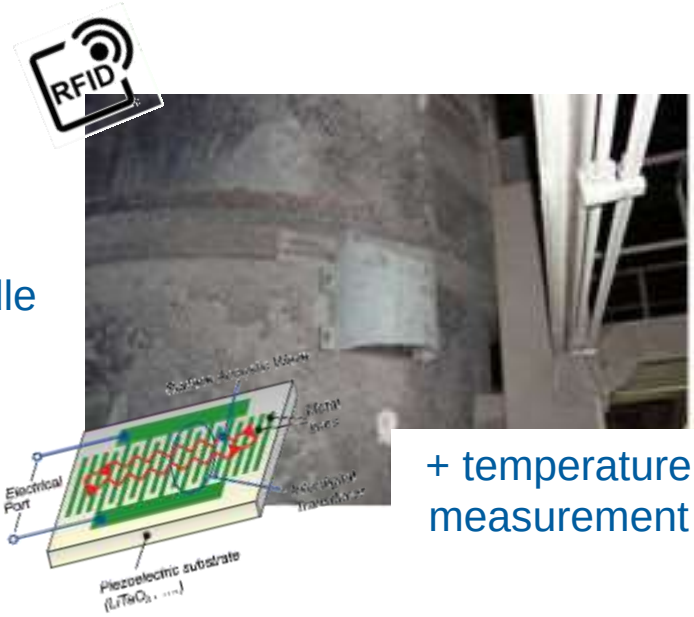


Necessary pre-conditions

Identification of products

ladle



+ temperature measurement

coil

billet / slab

Material tracking incl. genealogy

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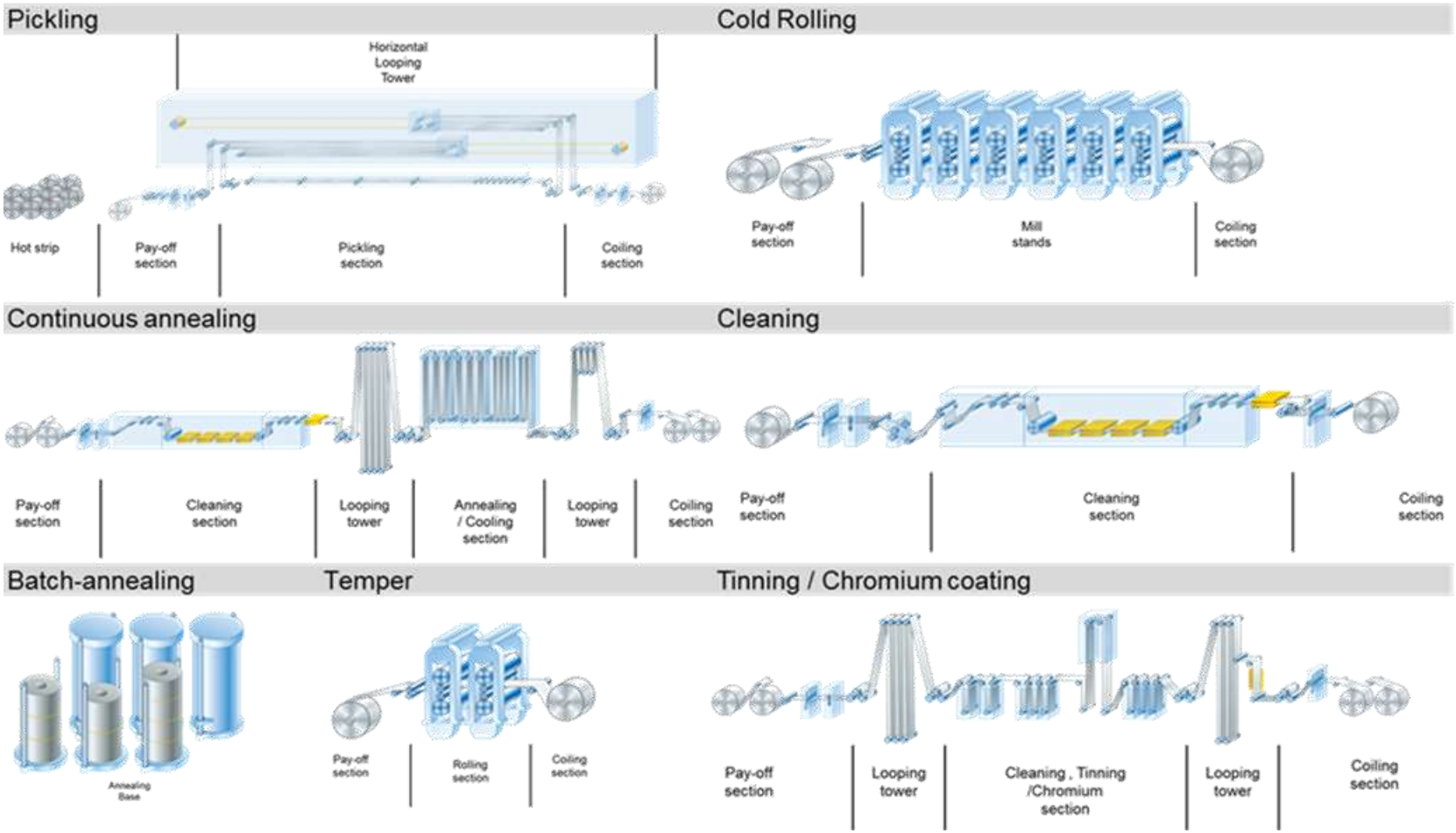
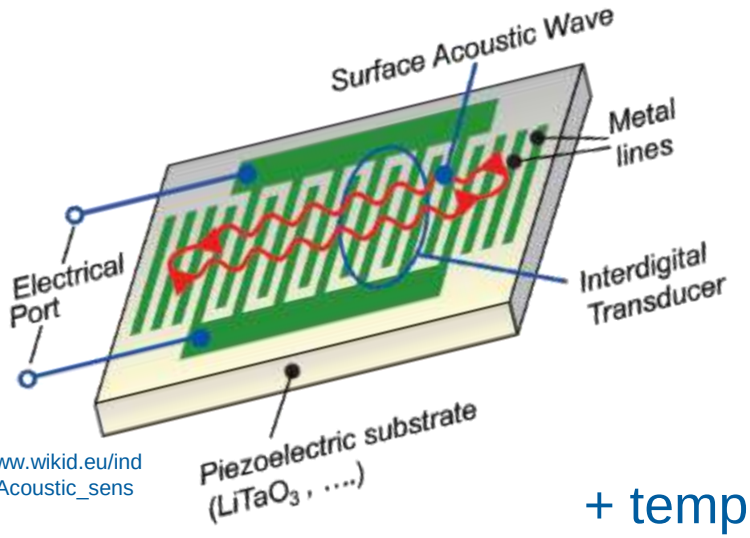
Example: TKS Rasselstein, 24 plants, 1137 variables

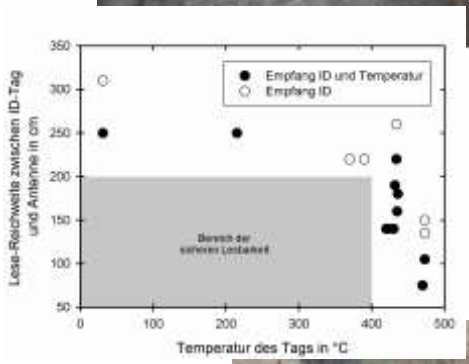


Without a suitable material tracking of all intermediate and final products Industrie 4.0 and Big Data can not be applied efficiently in steel industry.

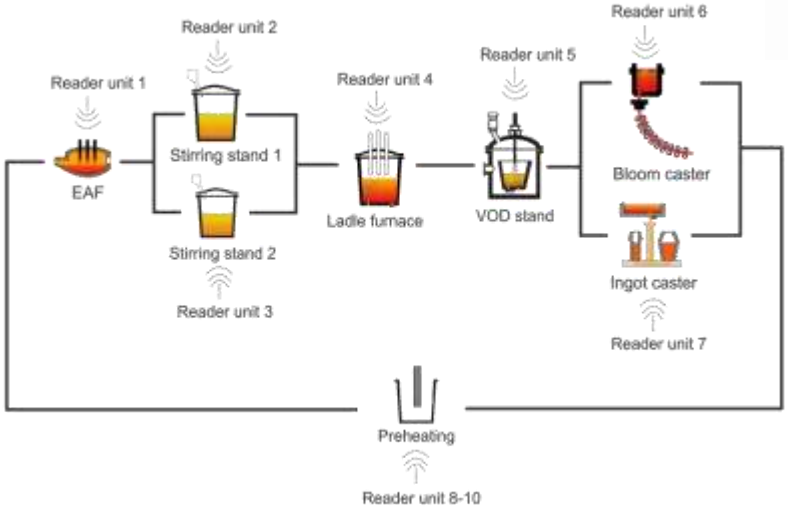
Smart Sensors



Source: http://www.wikid.eu/index.php/Acoustic_sensor



+ temperature measurement



Semantic modelling of process chain

location

has

contains

address

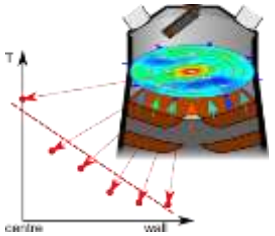
production site

contains

plant

has

measurment



stored at

storage location

computer

database

tables

columns

computer

database

database

tables

DB table

columns

DB column

Electronic manufacturing specifications

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Manufacturing specification No. 4711 Rev. 7
Strip speed for customer 1 and customer 2

For customer 1 and customer 2 the material 0815 produced via process route P5 at the annealing line a final strip temperature of about 1234°C has to be ensured. For strips up to 0,9 mm thickness the speed is around 20 m/min, for thicker strips 15 m/min.

Transformation

Rule condition	Monitored process value	Allowed values
Material=0815 **&** P=5 **&** customer like [customer 1 or customer 2]	final strip temperature	1220 °C … 1250 °C
Material=0815 **&** P=5 **&** customer like [customer 1 or customer 2] **&** thickness between 0,00 and 0,89	Strip speed	19 m/min … 21 m/min
Material=0815 **&** P=5 **&** customer like [customer 1 or customer 2] **&** thickness larger then 0,90	Strip speed	14 m/min … 16 m/min

Through-process automation and optimisation

Through-process temperature control

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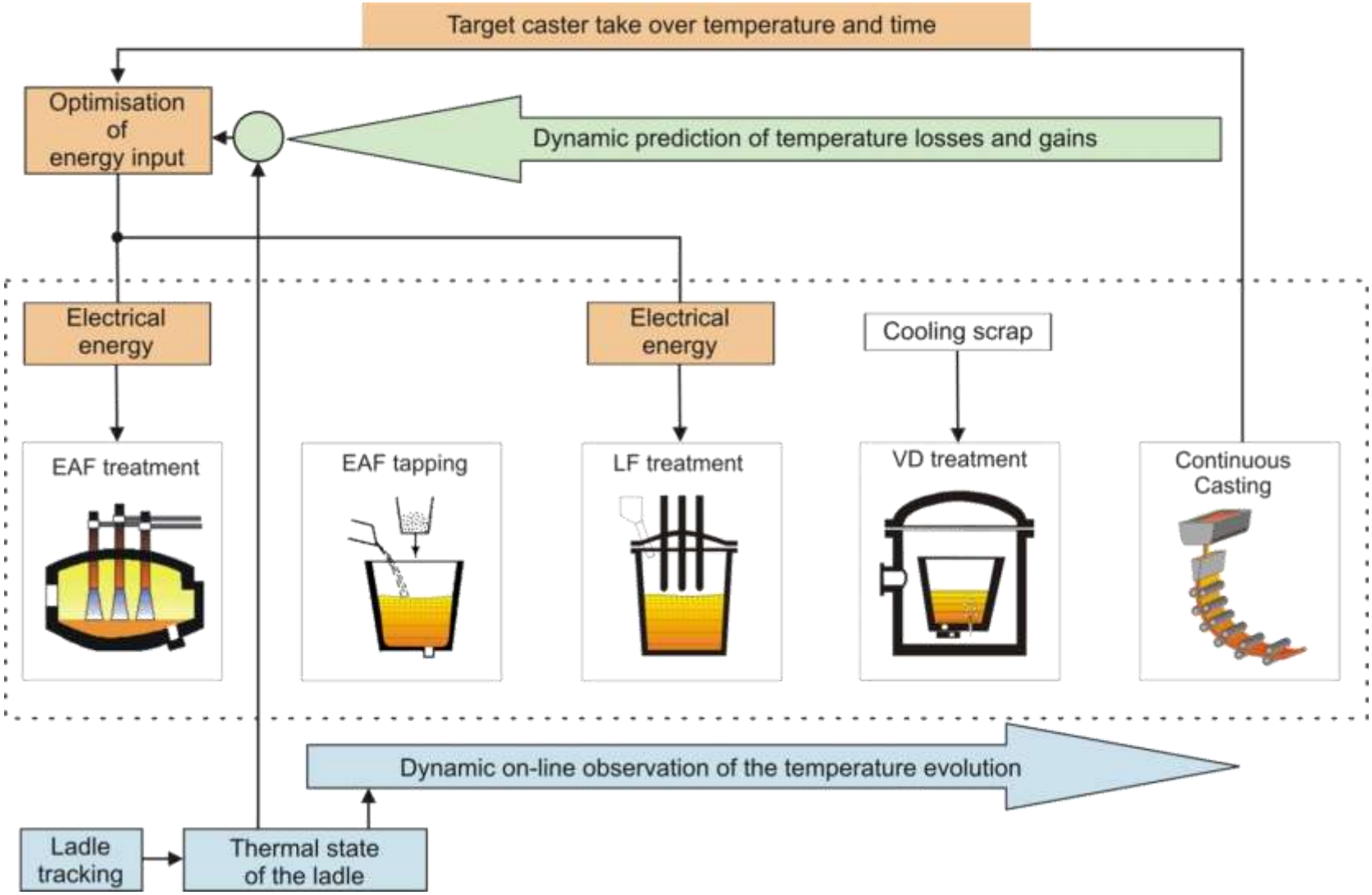

Through-process control of material properties

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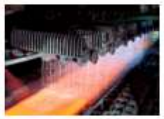
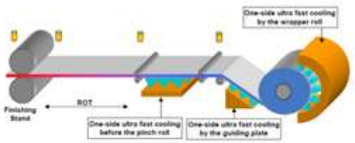






HSM

ROT

Selective cooling device

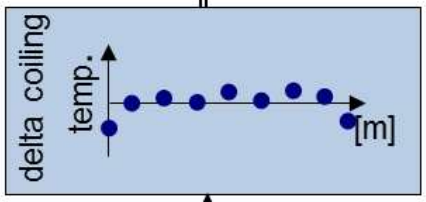
Coiler

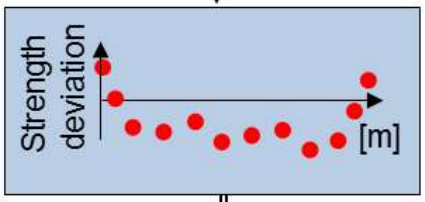
Fast coil cooling system

Decoiler, pickling line

FFB, IMPOC

Strip accumul., coiler

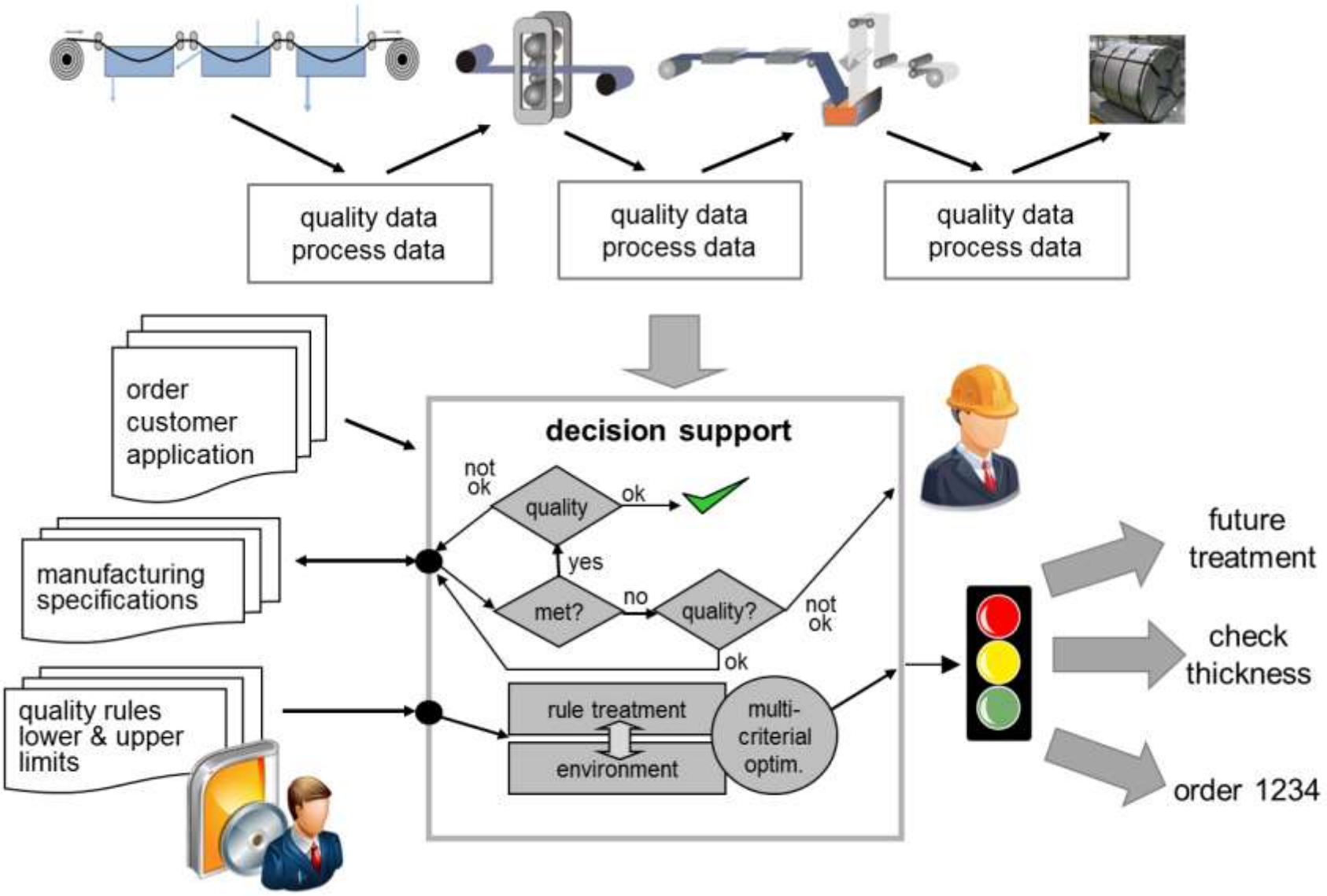




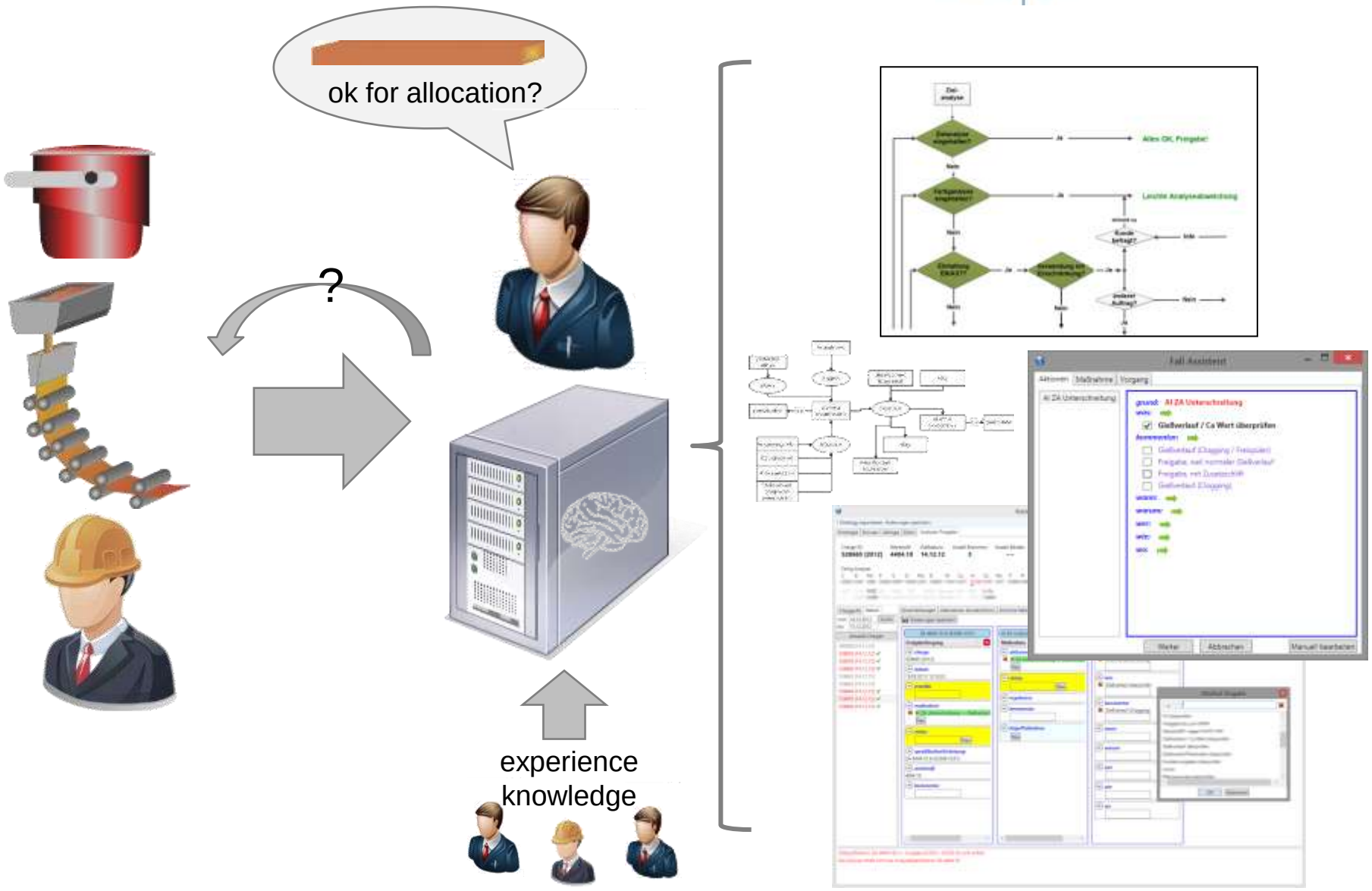
Iterative learning control

Database

Through-process Decision Support System

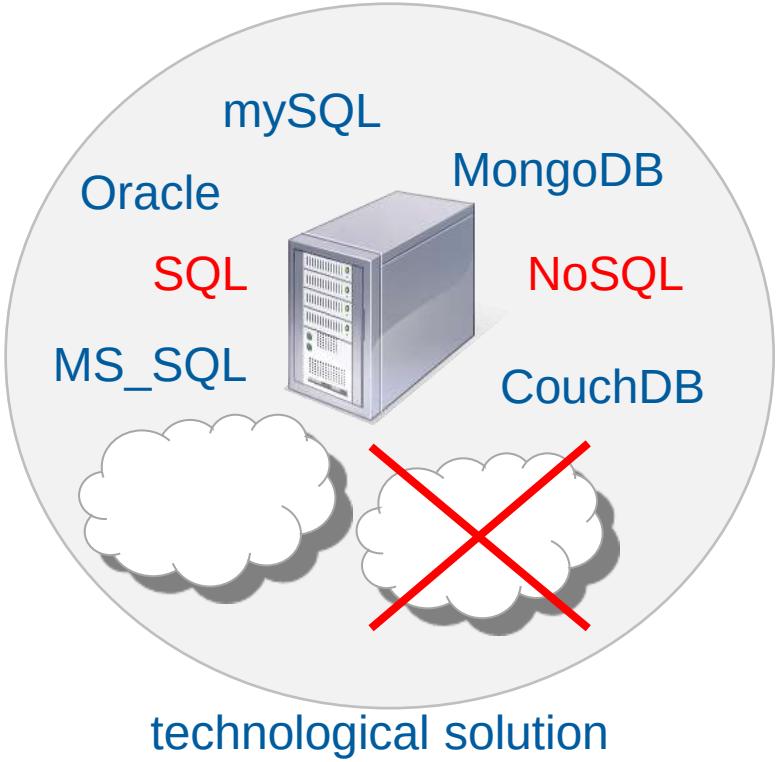


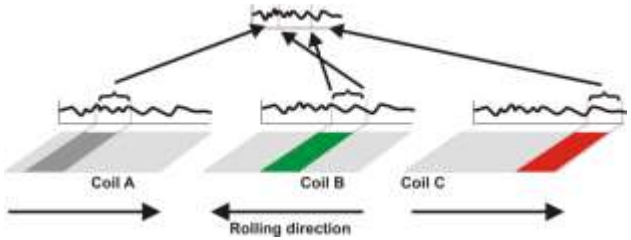
Ontology based material allocation

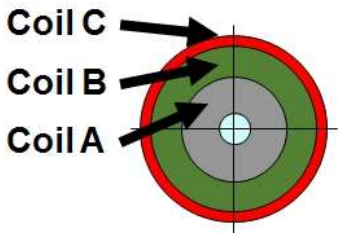


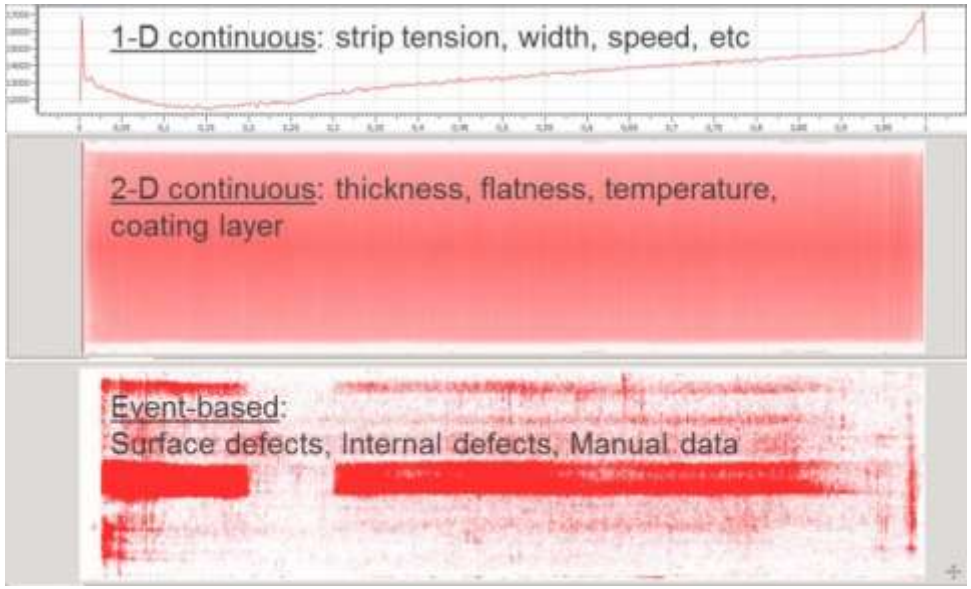
Intensive data usage / data exploitation
(“Big Data”, “Smart Data”, “Small Data”)

Data storage / handling









Data usage (“Big Data”, “Smart Data”, “Small Data”)

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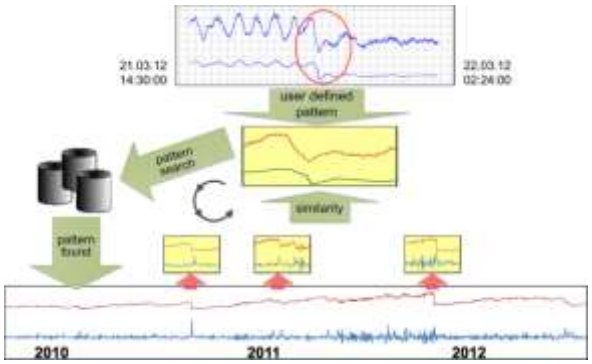
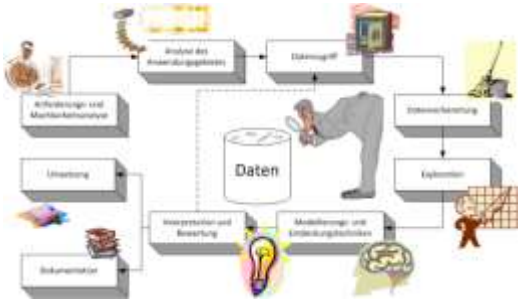
Fast Pattern Matching



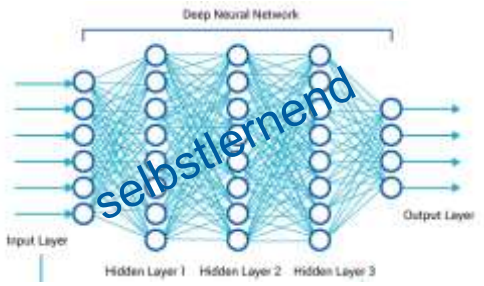
Did we had such a situation in the past?

Data Mining



What are the root causes of the surface defect „slivers“?

Predictive Analytics



How will the product quality at the end of production look like?

Data reliability!!!

Large Data Sets: recognition of process situations

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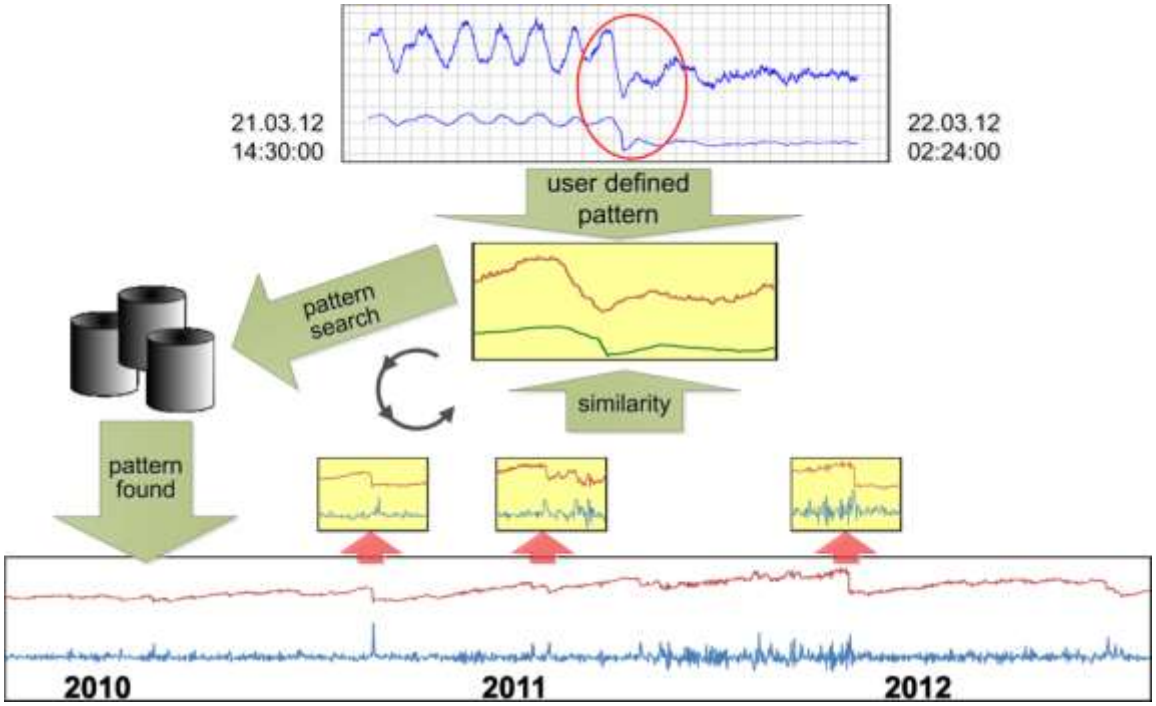
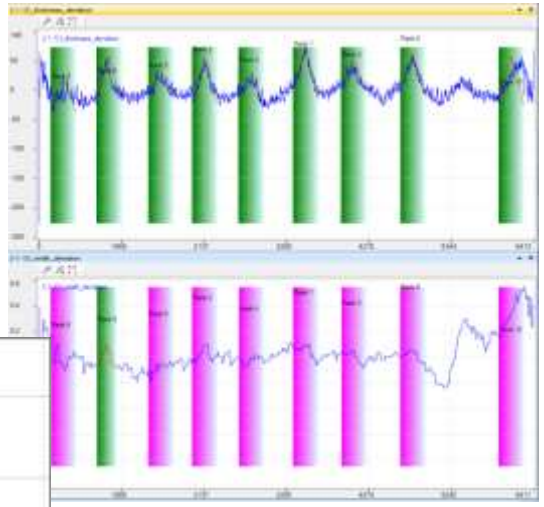
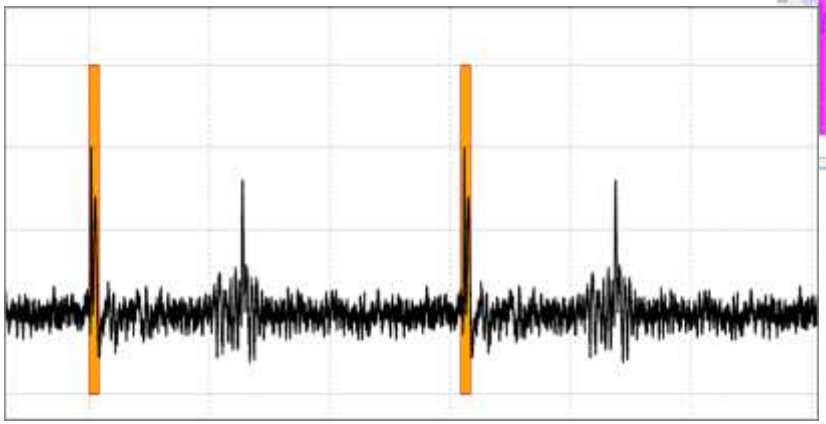




more dimensional
fast search in large
data sets



Smart Data for correlation of surface defects

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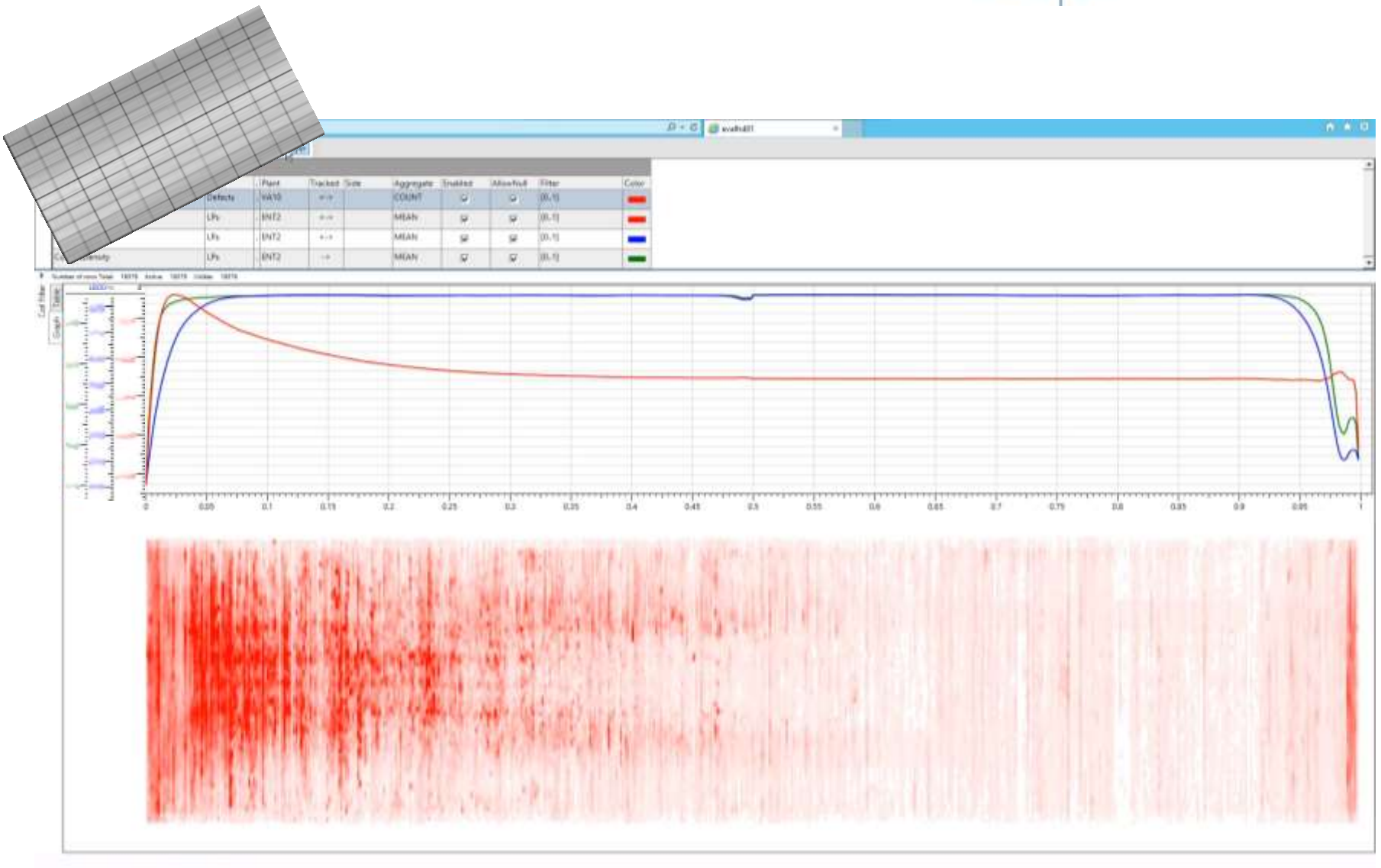
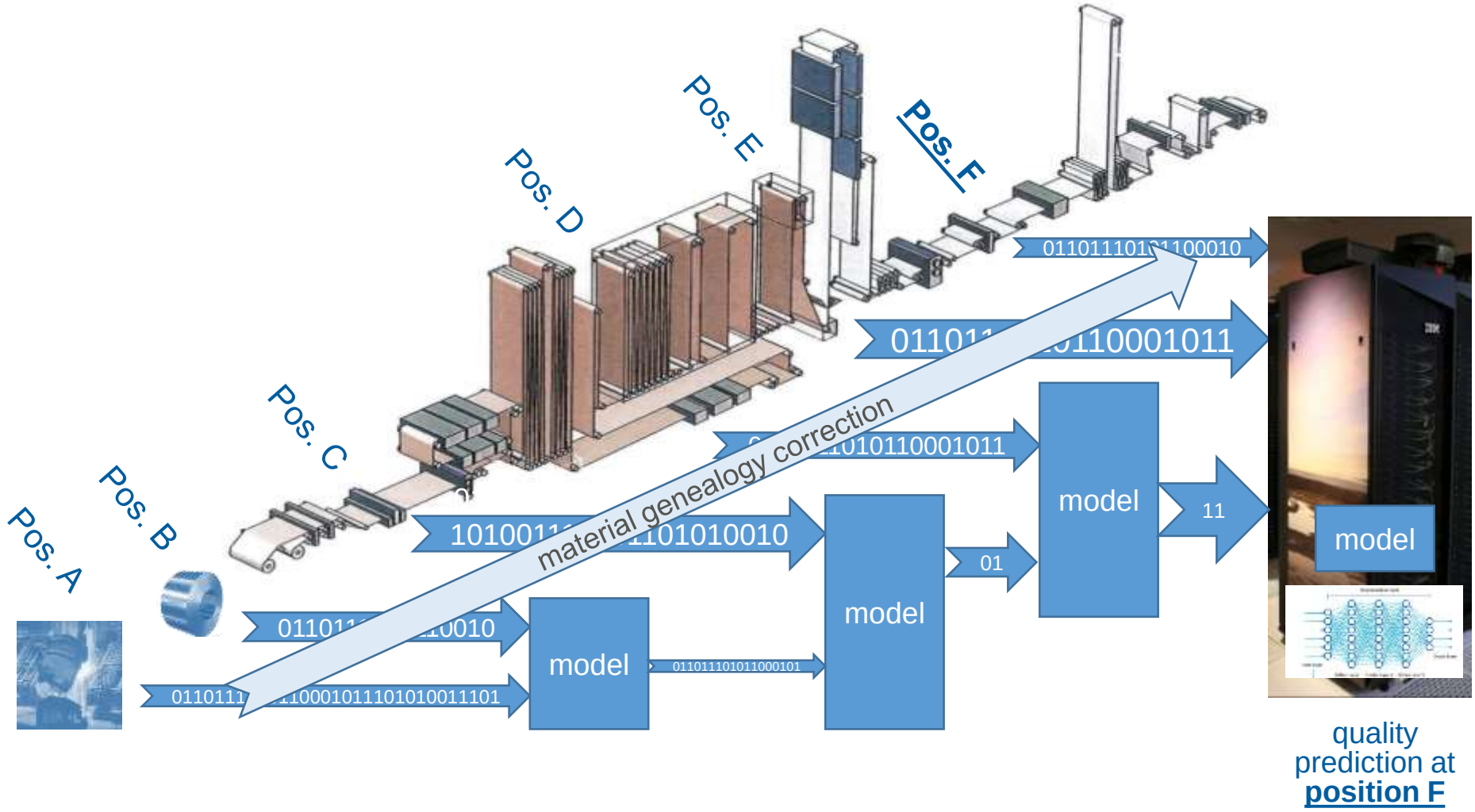


Big Data by Streaming Technologies



Self-Organisation

Decentral production planning

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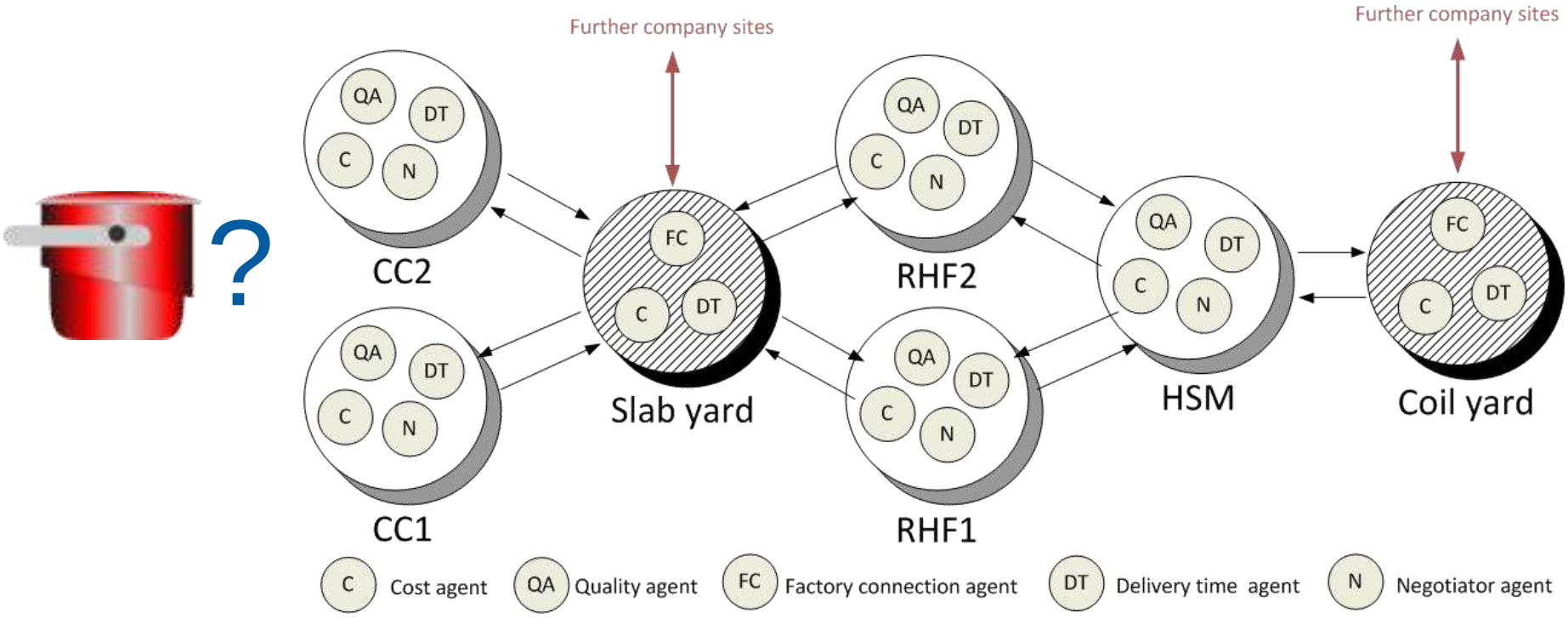

- The product moves self organised along the process chain
- Search for best solution by using **„software agents“**
- Event triggered instead of planed in advance in a centralised way
- Larger flexibility in case of short term changes

Software agents to realise a virtual market place

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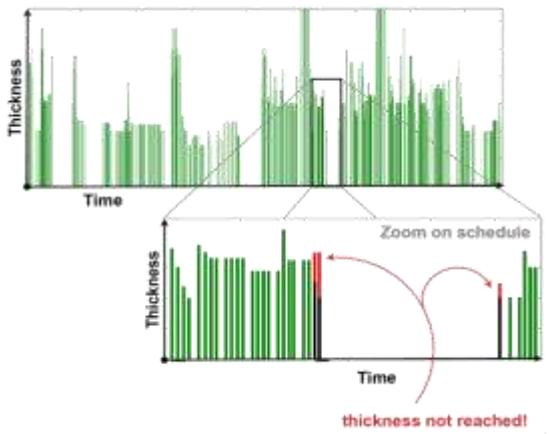
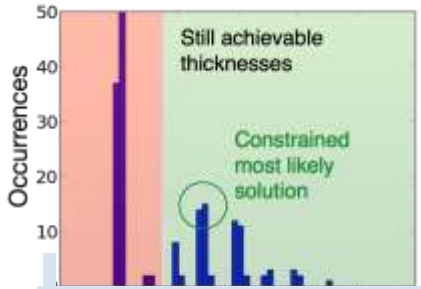
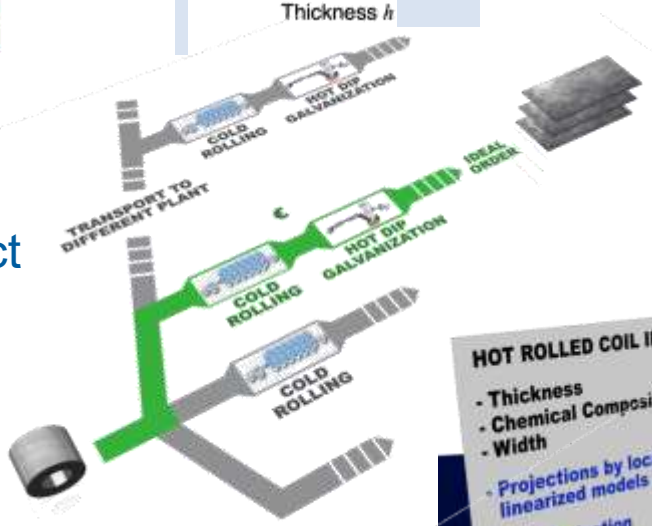




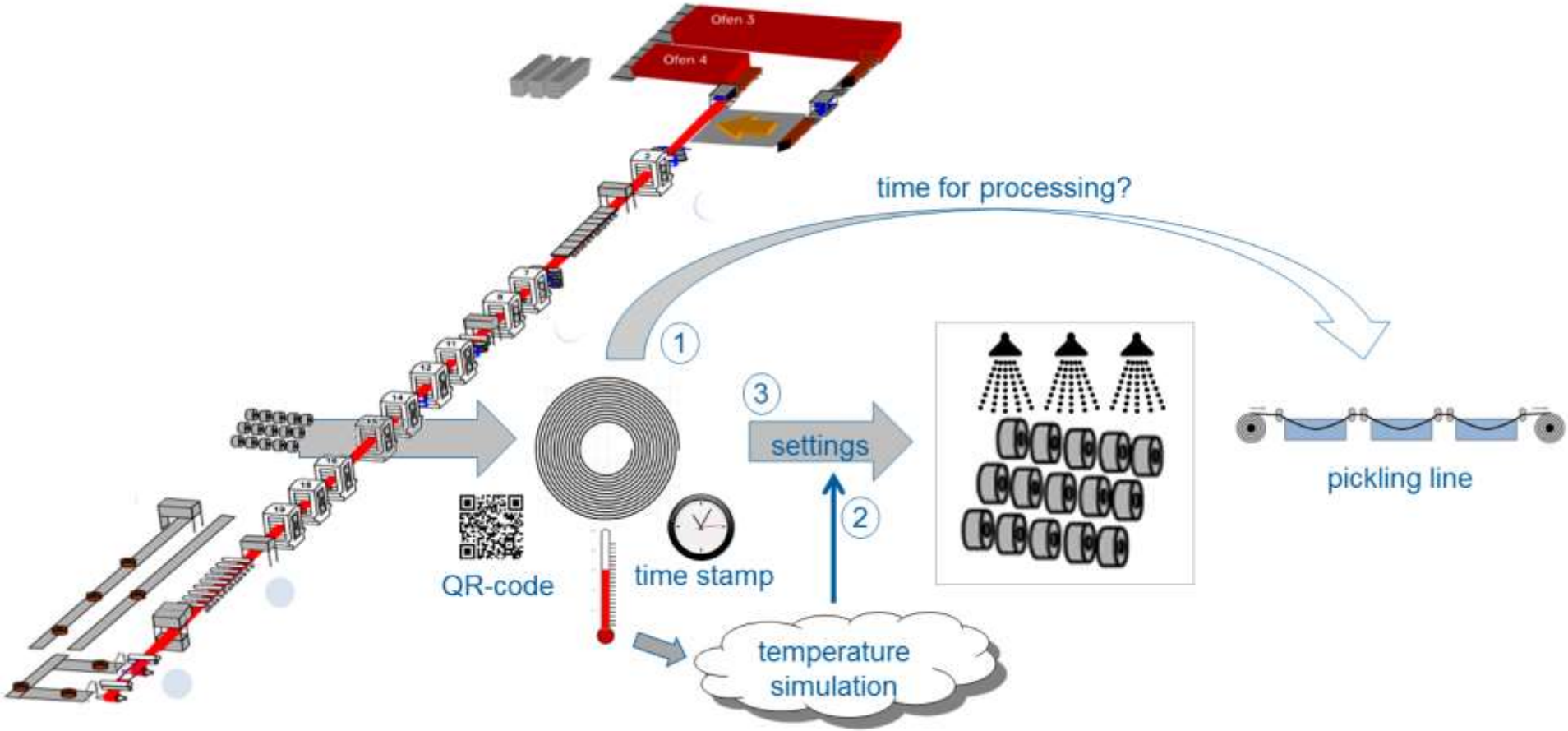
one piece of product misses it‘s target specifications…

… uses models to predict it‘s future state…



… and negotiates at a virtual market place for an alternative order.

Self-organised production



Final remarks

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- We are at the beginning of a long term process
- Industrial companies have understood what the benefit of Industry 4.0 could be
- It takes time to realise all necessary pre-conditions
- Just now it is necessary to develop methods and concepts to transfer the idea of Industry 4.0 to each industrial sector
- First applications were still implemented without the final solution of the Internet-of-Things technology
- Industry 4.0 is from our point of view an evolution and not a revolution

Many thanks for your attention!

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