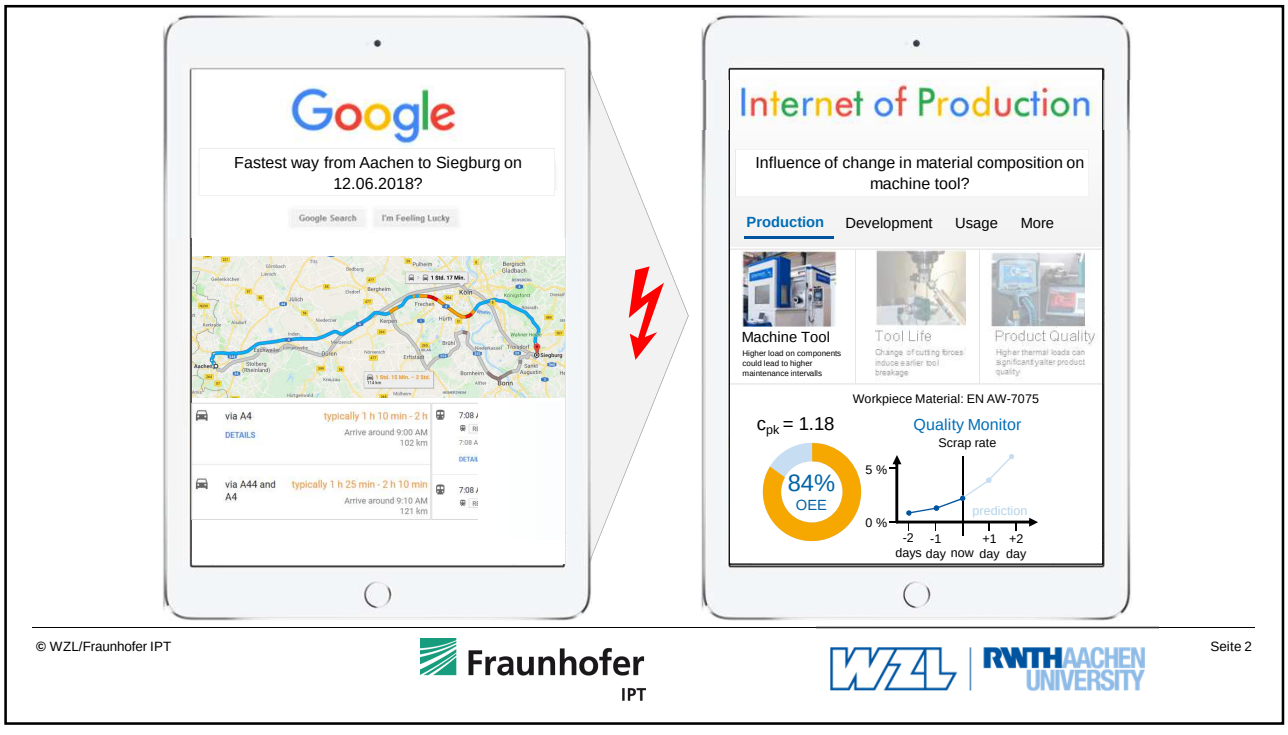
Internet of Production

Prof. Dr.-Ing. Christian Brecher



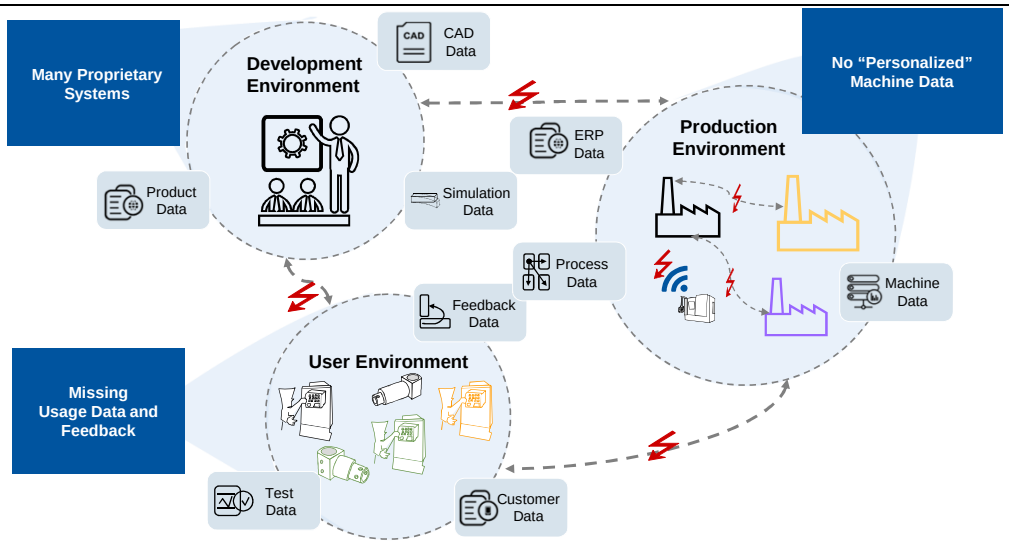
© WZL/Fraunhofer IPT

Fraunhofer IPT

© WZL

Internet of Production

Data/models not ready for cross-domain use



© WZL/Fraunhofer IPT

Fraunhofer IPT

WZL | RWTH AACHEN UNIVERSITY

The vision of the **Internet of Production:**

© WZL/Fraunhofer IPT

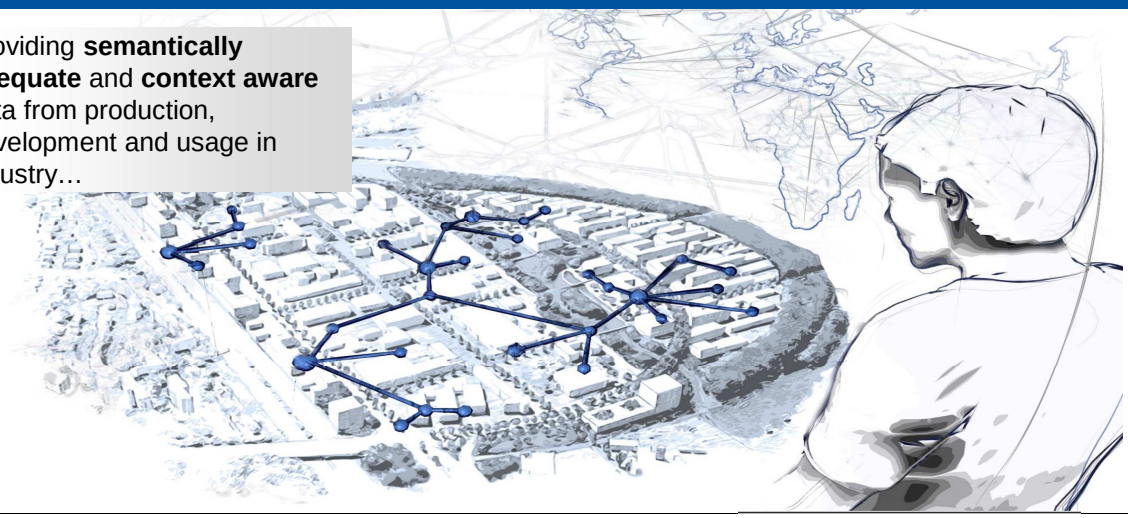
Fraunhofer IPT

WZL | RWTH AACHEN UNIVERSITY

© WZL

The vision of the **Internet of Production:**

Providing **semantically adequate** and **context aware** data from production, development and usage in industry…



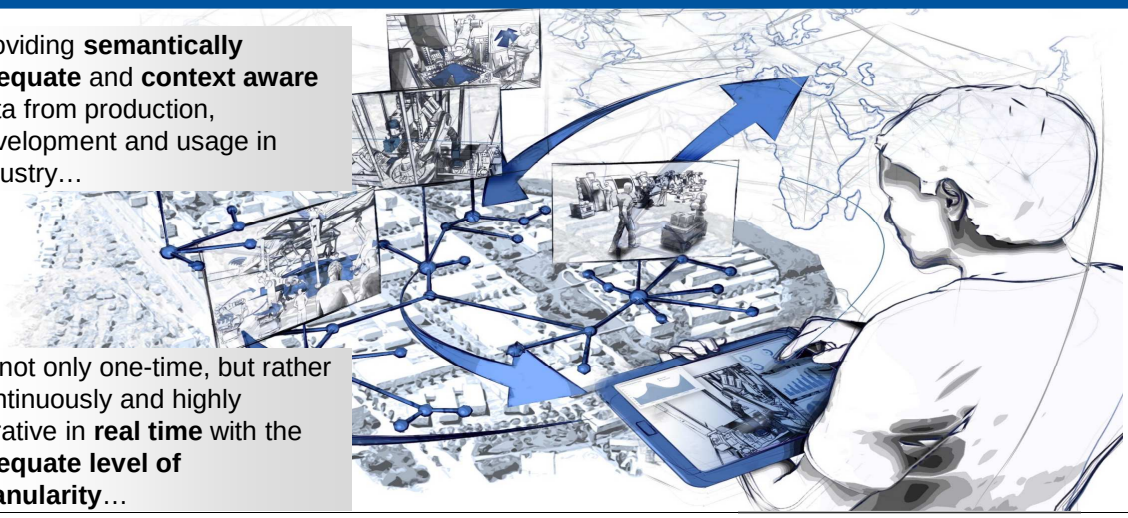
© WZL/Fraunhofer IPT

Fraunhofer IPT

WZL | RWTH AACHEN UNIVERSITY

The vision of the **Internet of Production:**

Providing **semantically adequate** and **context aware** data from production, development and usage in industry…



… not only one-time, but rather continuously and highly iterative in **real time** with the **adequate level of granularity**…

© WZL/Fraunhofer IPT

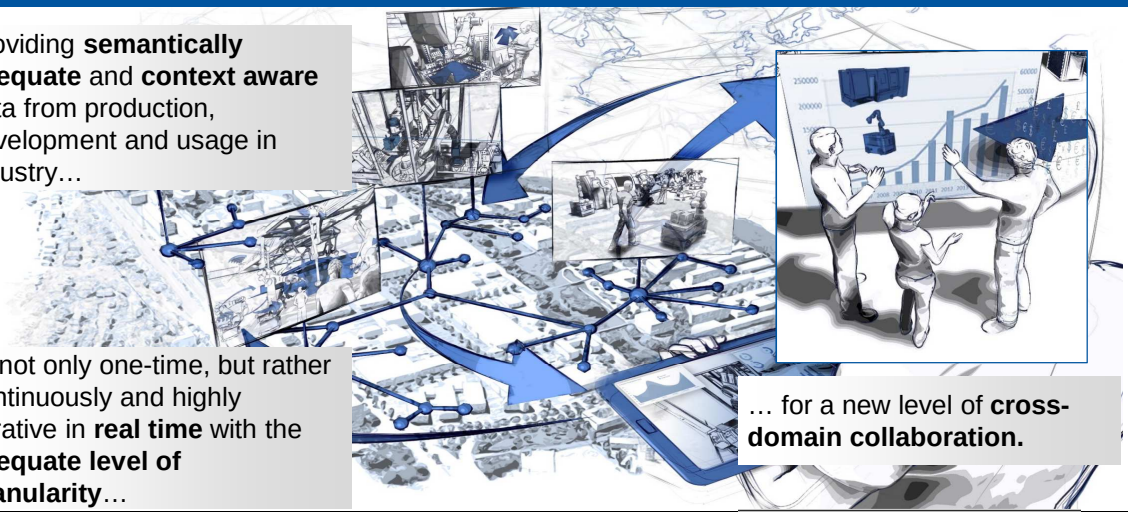
Fraunhofer IPT

WZL | RWTH AACHEN UNIVERSITY

© WZL

The vision of the **Internet of Production:**

Providing **semantically adequate** and **context aware** data from production, development and usage in industry…



… not only one-time, but rather continuously and highly iterative in **real time** with the **adequate level of granularity**…

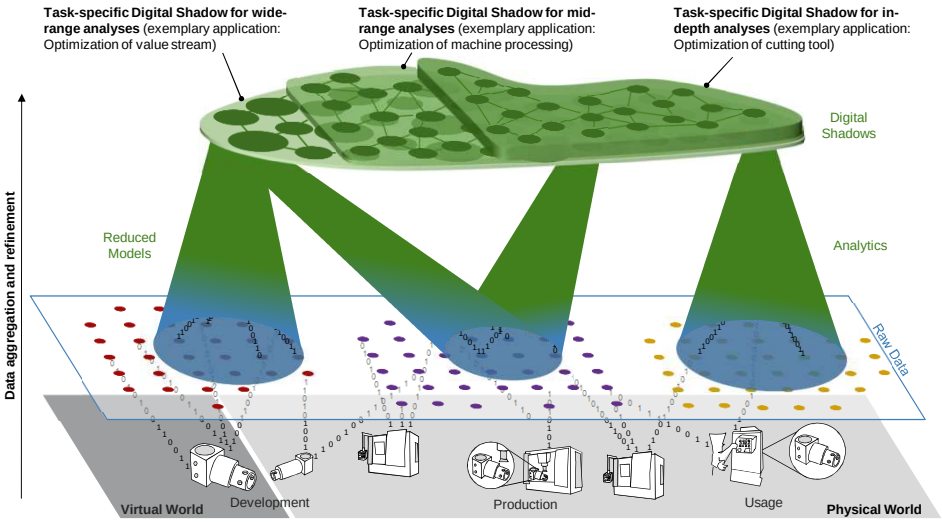
… for a new level of **cross-domain collaboration.**

© WZL/Fraunhofer IPT

Fraunhofer IPT

WZL | RWTH AACHEN UNIVERSITY

Internet of Production
Concept for Digital Shadows



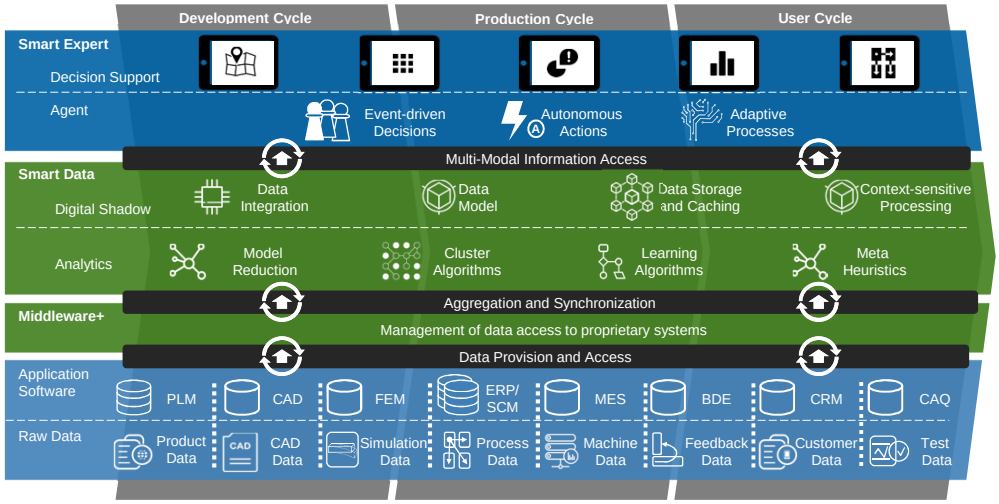
© WZL/Fraunhofer IPT

Fraunhofer IPT

WZL | RWTH AACHEN UNIVERSITY

© WZL

Internet of Production
Infrastructure of the Internet of Production

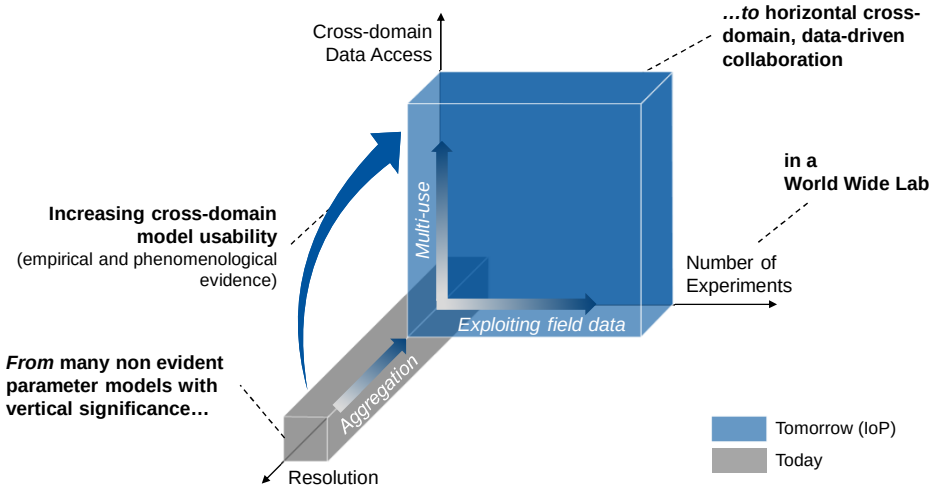


© WZL/Fraunhofer IPT

Fraunhofer IPT

WZL | RWTH AACHEN UNIVERSITY

Internet of Production
Next Level Scientification of Industry in a World Wide Lab



© WZL/Fraunhofer IPT

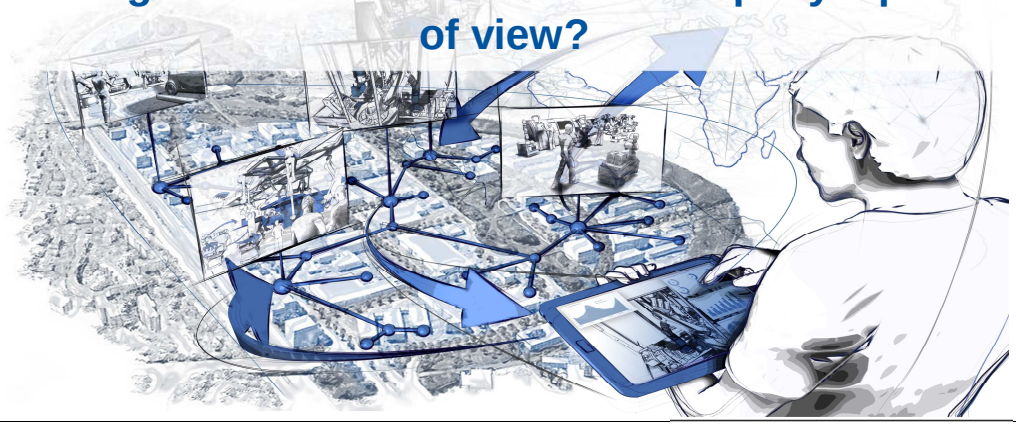
Fraunhofer IPT

WZL | RWTH AACHEN UNIVERSITY

© WZL

Internet of Production
Impact on business strategy

Which major operational and strategic changes are relevant from the company's point of view?



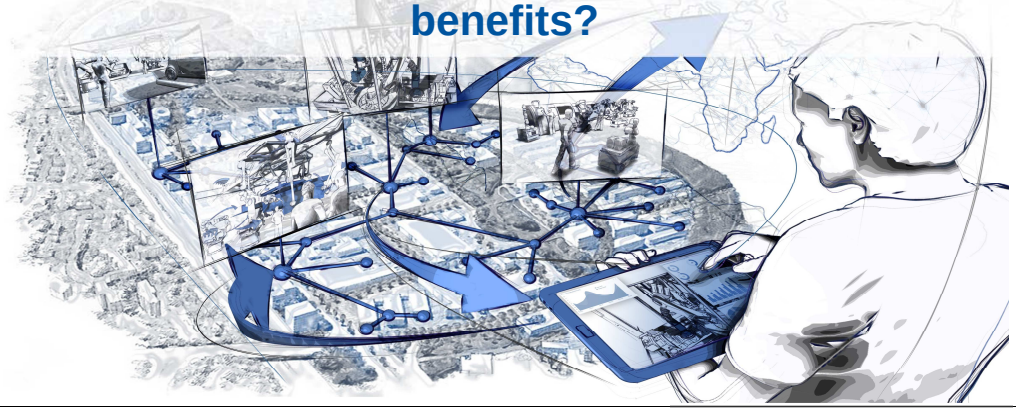
© WZL/Fraunhofer IPT

Fraunhofer IPT

WZL | RWTH AACHEN UNIVERSITY

Internet of Production
Impact on business strategy

1st Hypothesis/ question: How can data be converted into customer benefits?



© WZL/Fraunhofer IPT

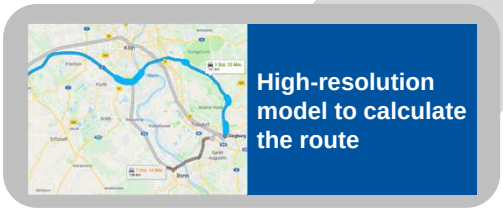
Fraunhofer IPT

WZL | RWTH AACHEN UNIVERSITY

© WZL

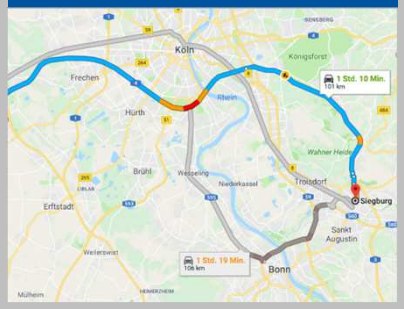
Internet of Production
Combining cross domain information

Live-data of the current traffic situation



High-resolution model to calculate the route

Optimized traffic route available anytime



Internet of Production
Transferring data driven business models to the production

- Machine internal sensors
- Additional Sensors
- Drive current
- Events
- …

- Technical information
- Tolerances
- Tools
- Quality Report
- …

Productivity

Deep insight in the ma… process

Quality

reduction of quality inspection, scrap rate and rework cost

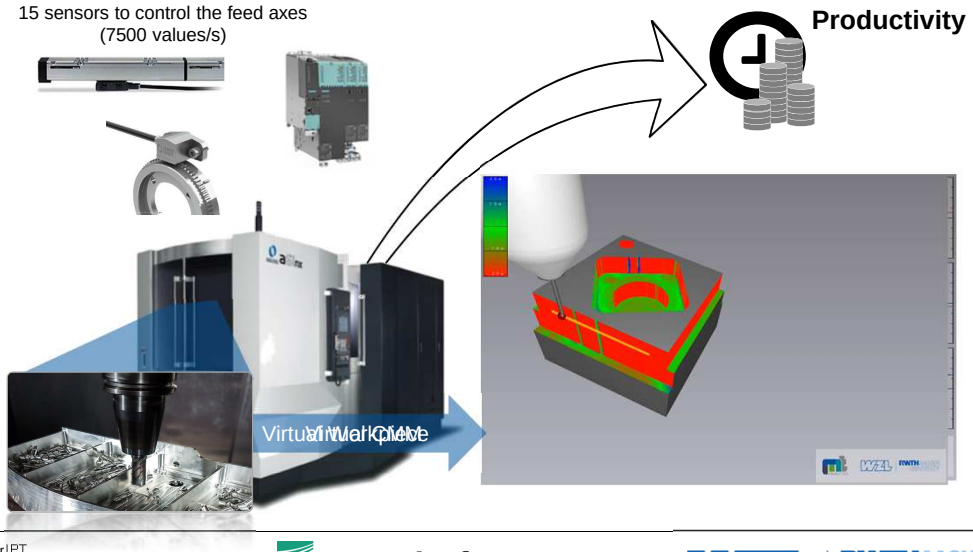
Tool Cost

reduction of tool cost by analyzing the tool history and the tool condition

Availability

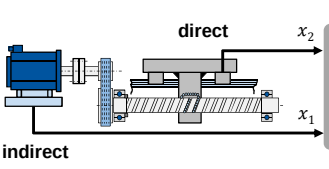
reduction of unplanned downtimes due to continuously updated end-of-life prediction

Internet of Production
General approach



Internet of Production
Estimation of process forces

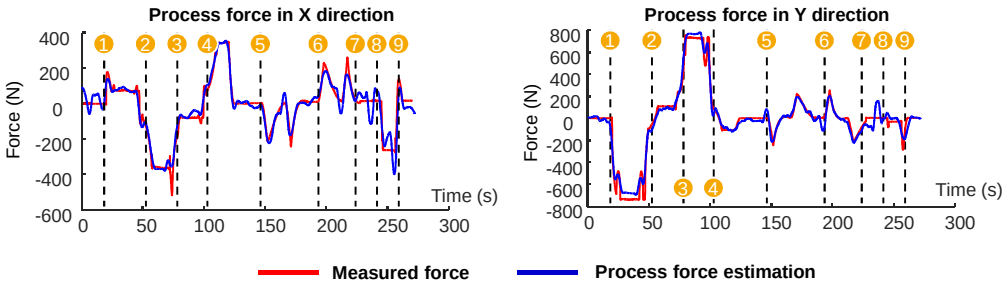
Process Force Deflection $\Delta x_{TCP} = F_{process} / k_{machine}$



Δx — Computation of differences (adjusted by lead errors, play, etc.)

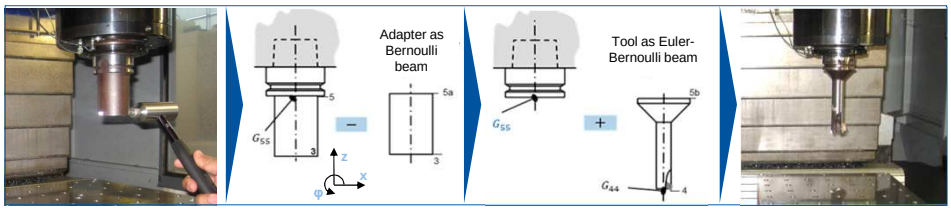
F_{axis} — Computation of **Axis loads** using position-dependent stiffness information

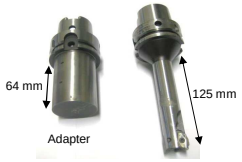
$F_{process}$ — Computation of **process forces** using a machine axis model (kinematics, friction)

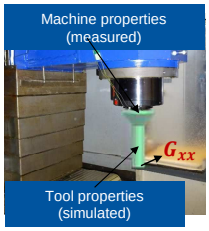


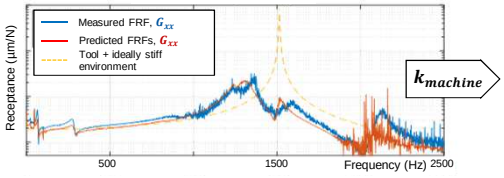
Internet of Production
Representation of Cutting Tool Properties

Process Force Deflection $\Delta x_{TCP} = F_{process} / k_{machine}$







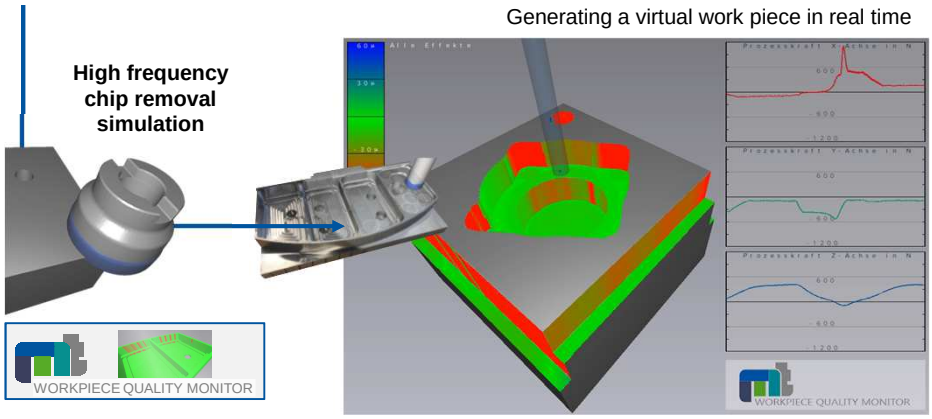


Internet of Production
Creating a virtual work piece

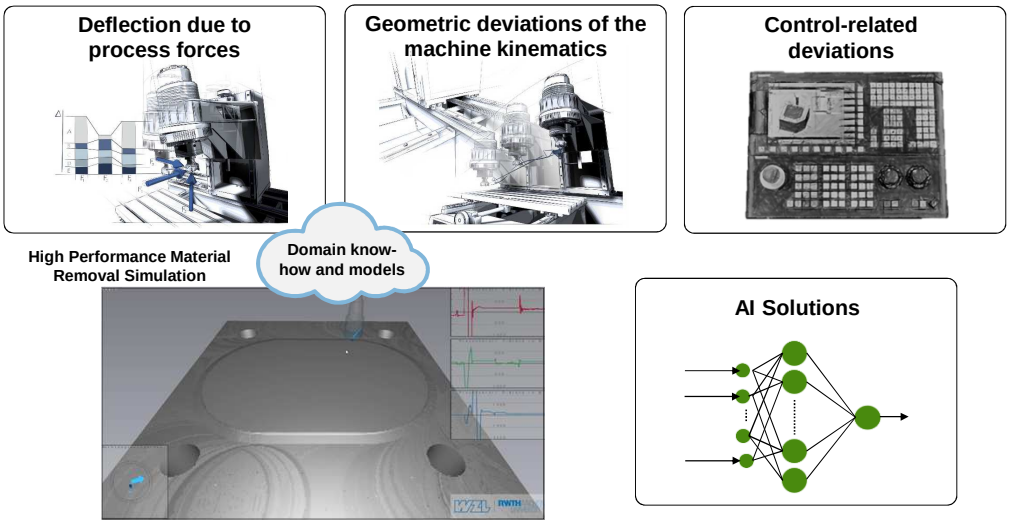
Process Force Deflection $\Delta x_{TCP} = F_{process} / k_{machine}$

Generating a virtual work piece in real time

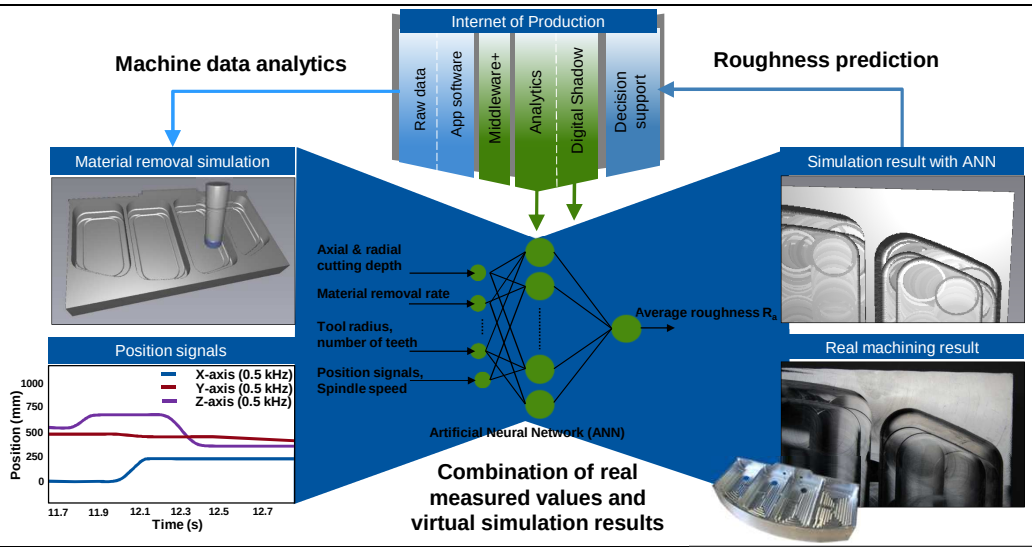
High frequency chip removal simulation



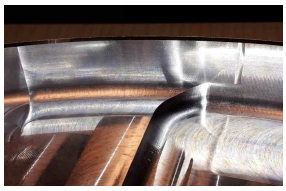
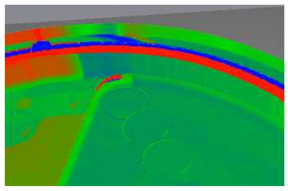
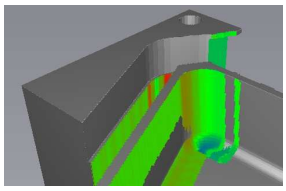
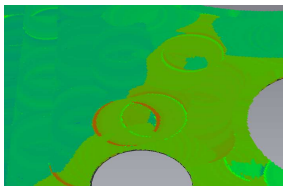
Internet of Production
Creating a virtual work piece



Internet of Production
Machine Learning for Series Production



Internet of Production
Comparison between real an virtual quality issues

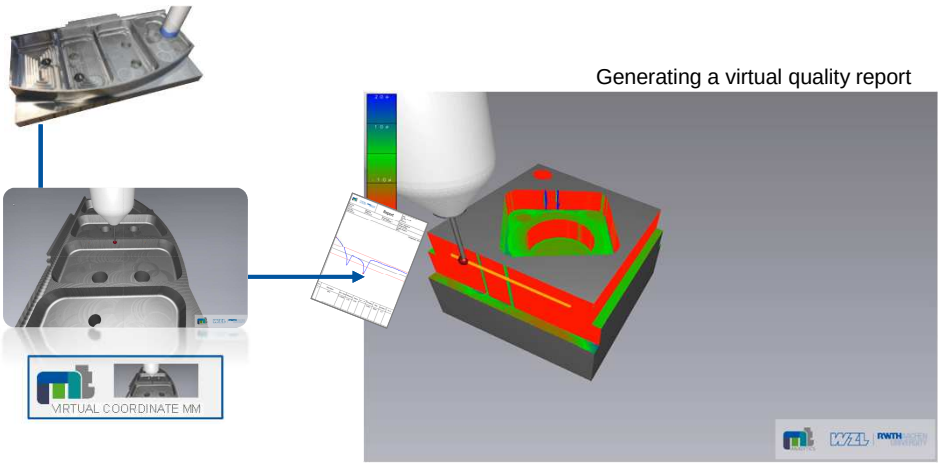
	Contour defect 1	Contour defect 2	Chattering
Real part			
Virtual part			

© WZL/Fraunhofer IPT

Fraunhofer IPT

WZL | RWTH AACHEN UNIVERSITY

Internet of Production
Virtual Coordinate Measurement Machine



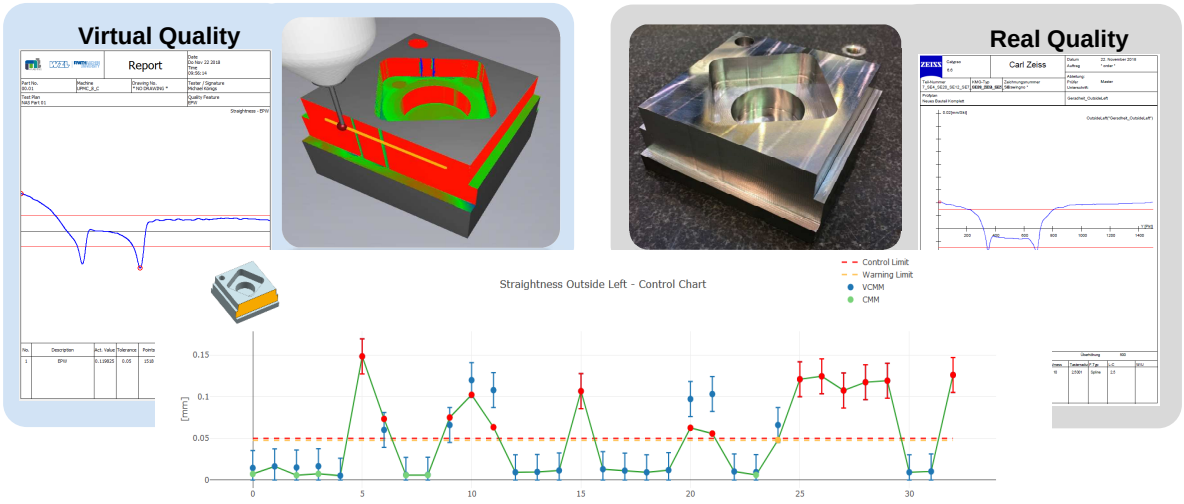
© WZL/Fraunhofer IPT

Fraunhofer IPT

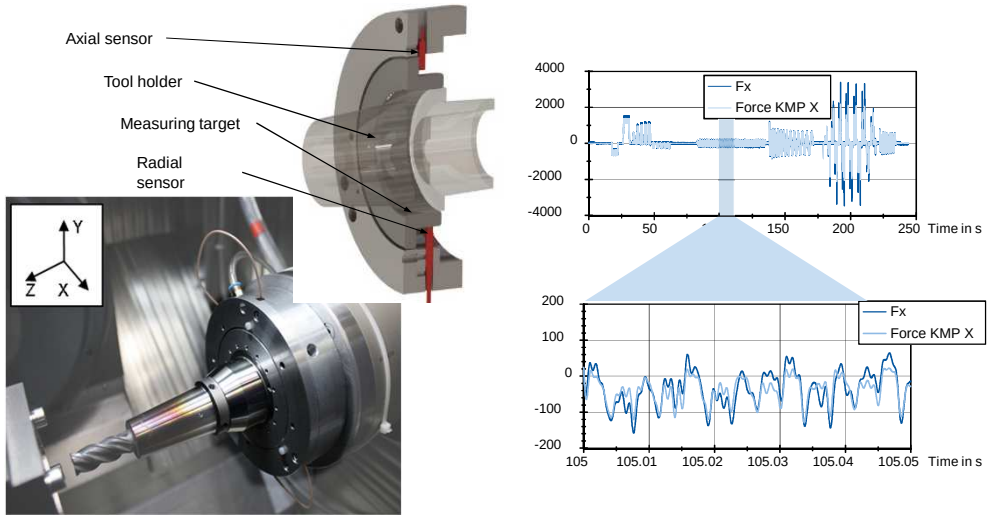
WZL | RWTH AACHEN UNIVERSITY

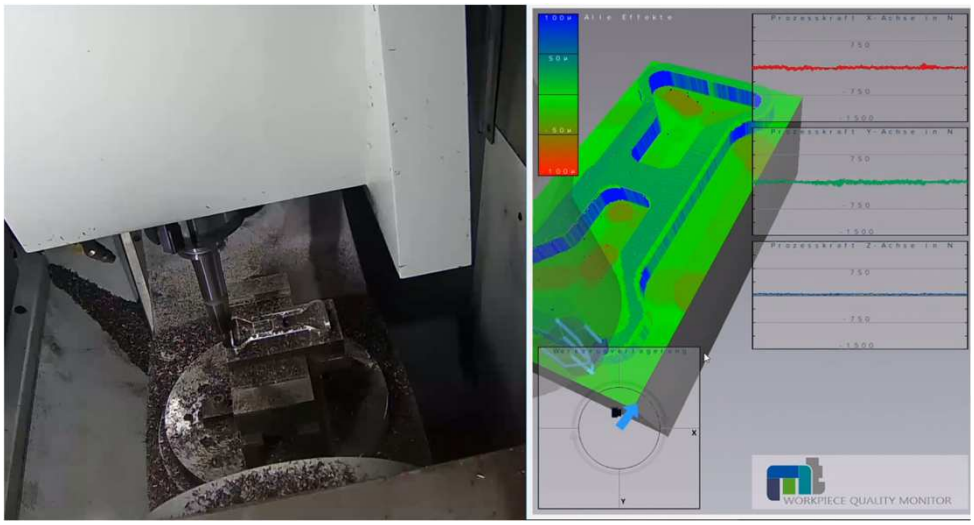
© WZL

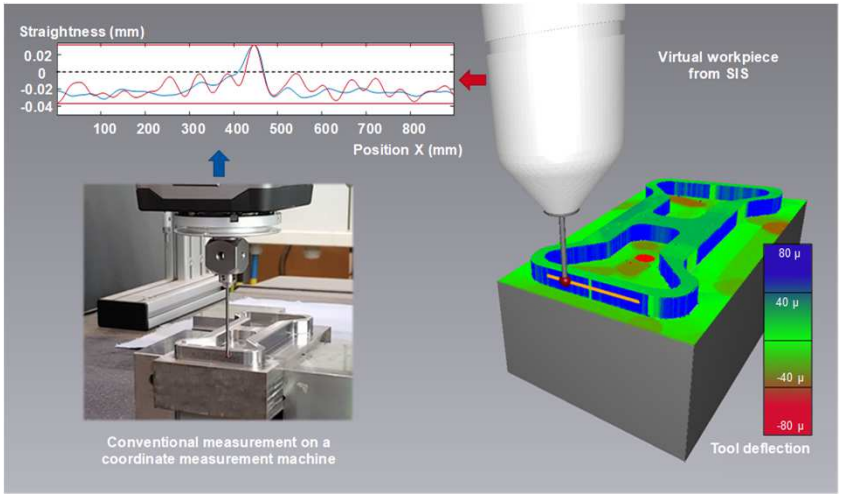
Internet of Production
Comparison of virtual and real Quality



Internet of Production
Measuring the Process Forces with a Spindle Integrated Sensor

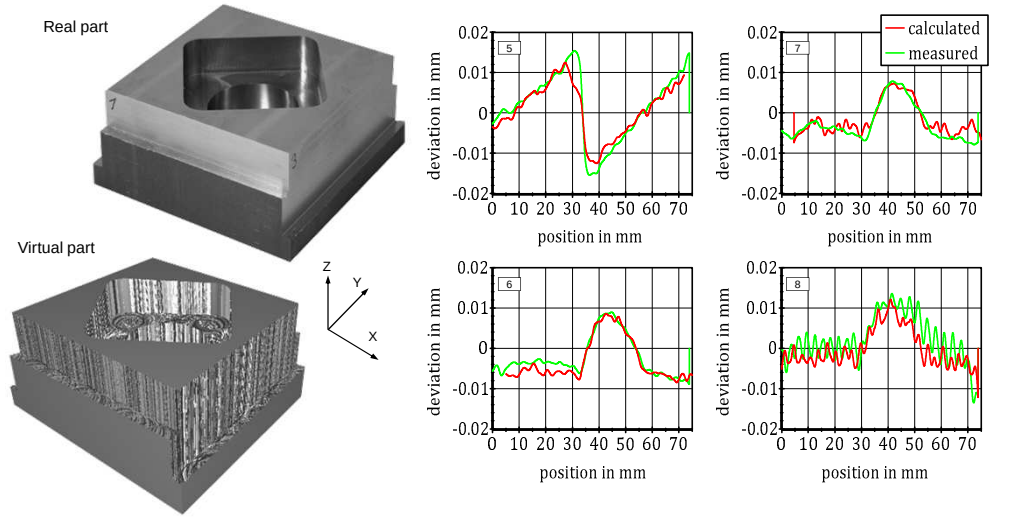



WORKPIECE QUALITY MONITOR


Straightness (mm)
0.02
0
-0.02
-0.04
100 200 300 400 500 600 700 800
Position X (mm)
Conventional measurement on a coordinate measurement machine
Virtual workpiece from SIS
80 µ
40 µ
-40 µ
-80 µ
Tool deflection

Internet of Production

Measuring the Process Forces with a Spindle Integrated Sensor



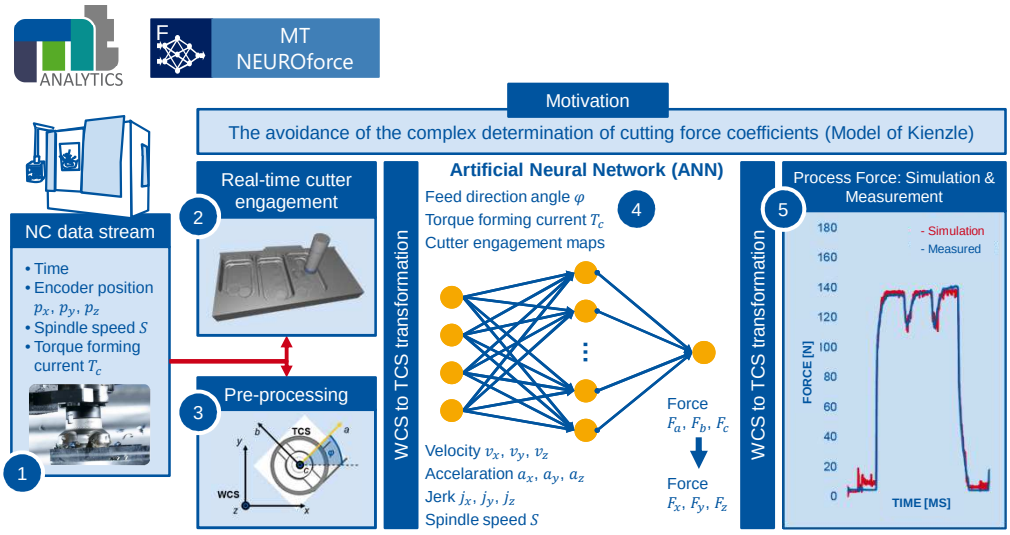
© WZL/Fraunhofer IPT

Fraunhofer IPT

WZL | RWTH AACHEN UNIVERSITY

MT NEUROforce

Combination of a real-time simulation and process signals



© WZL/Fraunhofer IPT

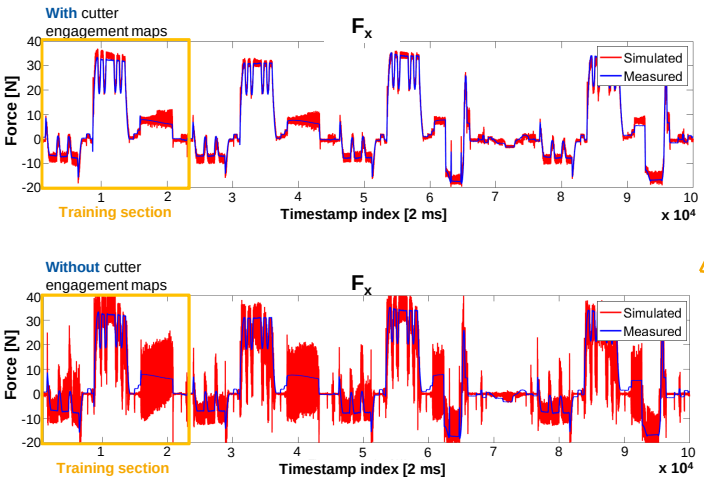
Fraunhofer IPT

WZL | RWTH AACHEN UNIVERSITY

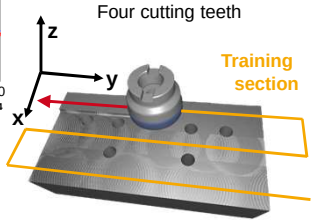
© WZL

MT NEUROforce

Assessment of modelling accuracy after initial training



Cutting tool
Inserted cutter
Diameter 80 mm
Four cutting teeth



Workpiece
Aluminum block EN AW-7075
150 mm x 300 mm x 100 mm

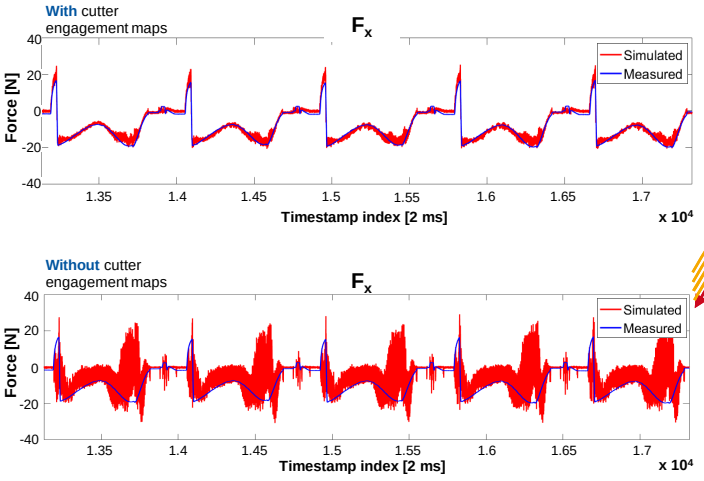
© WZL/Fraunhofer IPT

Fraunhofer IPT

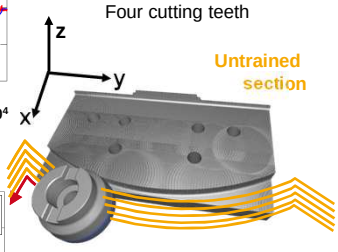
WZL | RWTH AACHEN UNIVERSITY

MT NEUROforce

Untrained sections for scalability assessment



Cutting tool
Inserted cutter
Diameter 80 mm
Four cutting teeth



Workpiece
Aluminum block EN AW-7075
150 mm x 300 mm x 100 mm

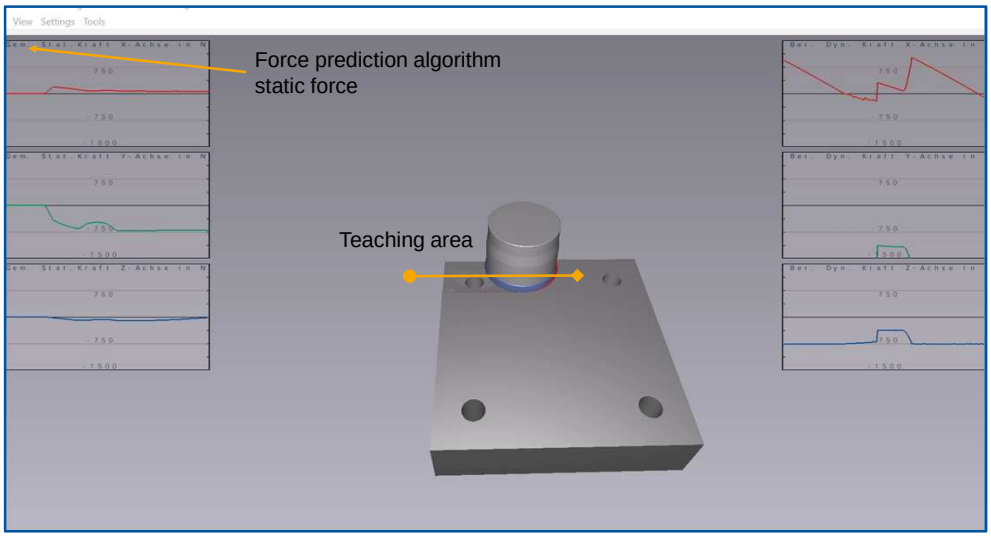
© WZL/Fraunhofer IPT

Fraunhofer IPT

WZL | RWTH AACHEN UNIVERSITY

© WZL

MT NEUROforce
Simulation NeuroForce



© WZL/Fraunhofer IPT

Fraunhofer IPT

WZL | RWTH AACHEN UNIVERSITY

Internet of Production
Productivity Tuner

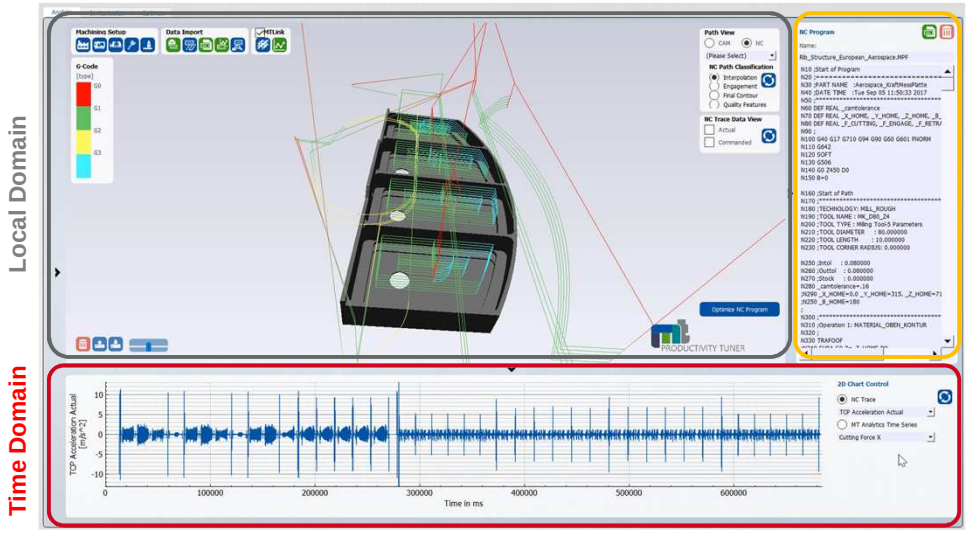
© WZL/Fraunhofer IPT

Fraunhofer IPT

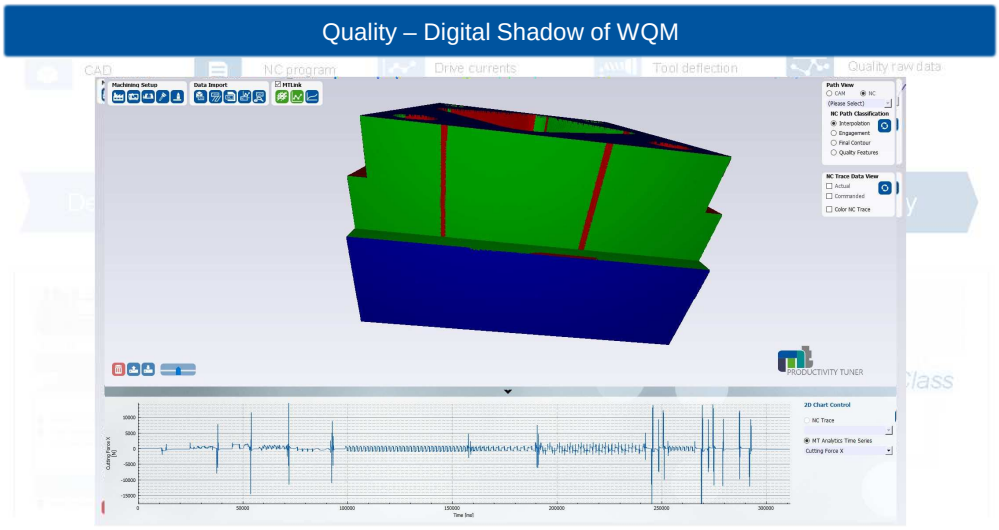
WZL | RWTH AACHEN UNIVERSITY

© WZL

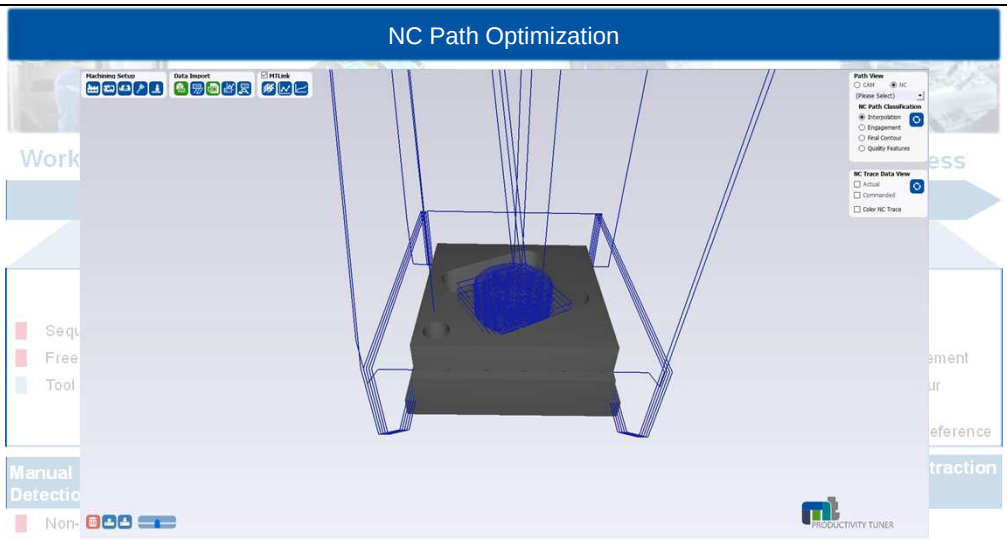
Internet of Production
Data input across different domains



Internet of Production
Data input across different domains



Internet of Production
Optimization steps in different process domains



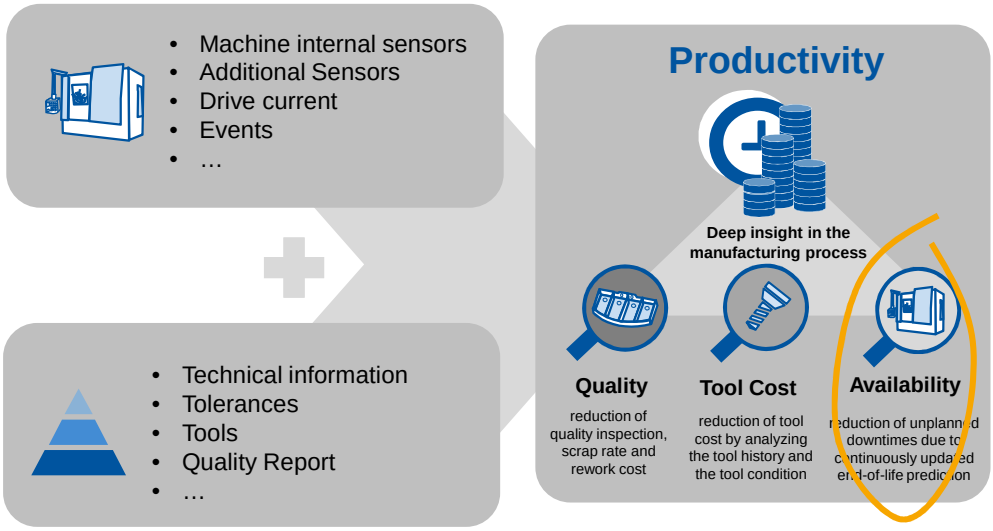
Internet of Production
Evidence-based productivity increase

Exemplary WZL Customer Project Results

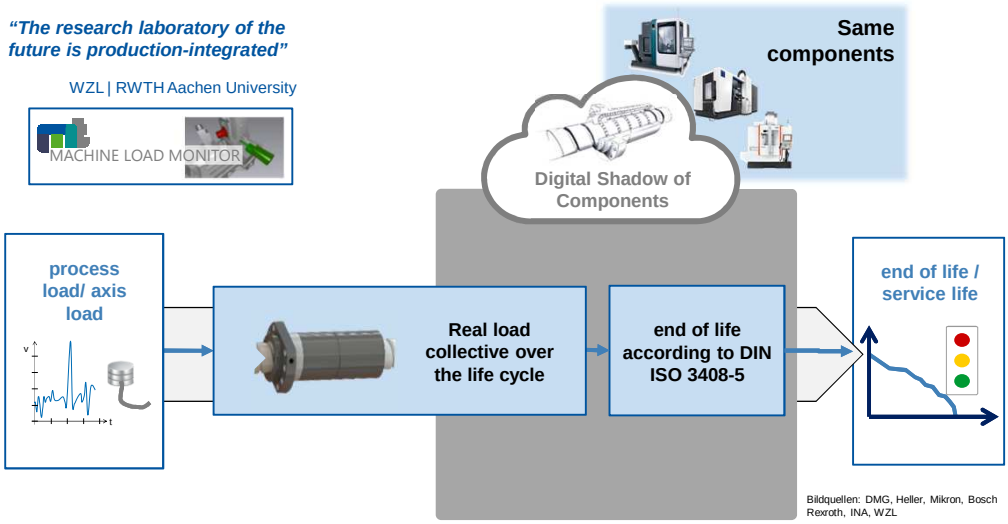
		German Automotive Powertrain	German Precision Mechanical Engineering
Use Case	Customer & Component	Motor Block	Drive Components
	Issue	Restricted process ramp-up time	Long cycle times for class A parts
	Type	Mass Production	Small batch Production
Result	Quality*	before: after:	before: after:
	Productivity	+ 24 %	+ 96 %

* in respect to customer-defined tolerances

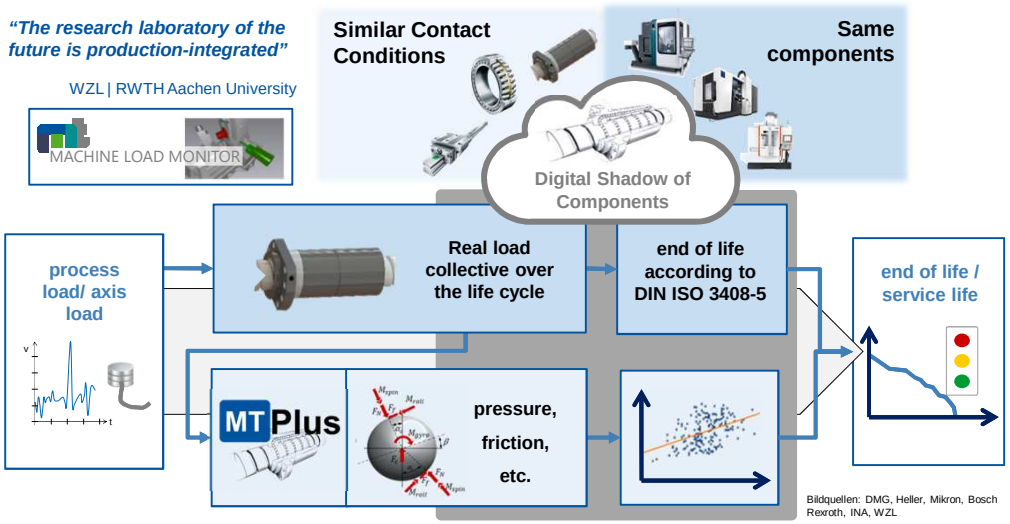
Internet of Production
Transferring data driven business models to the production



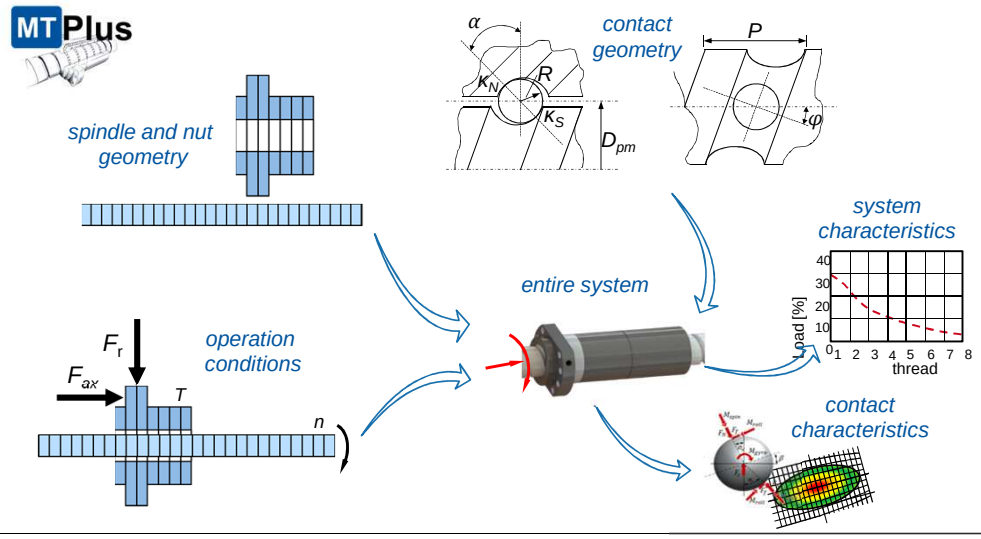
Internet of Production
Ball screw life time according DIN ISO



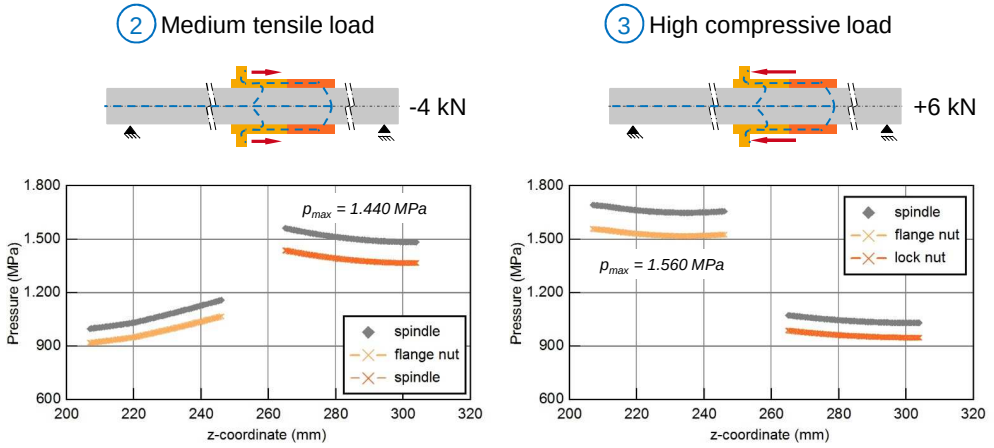
Internet of Production
Ball screw life time with model based approach



Internet of Production
Detailed simulation of contact characteristics

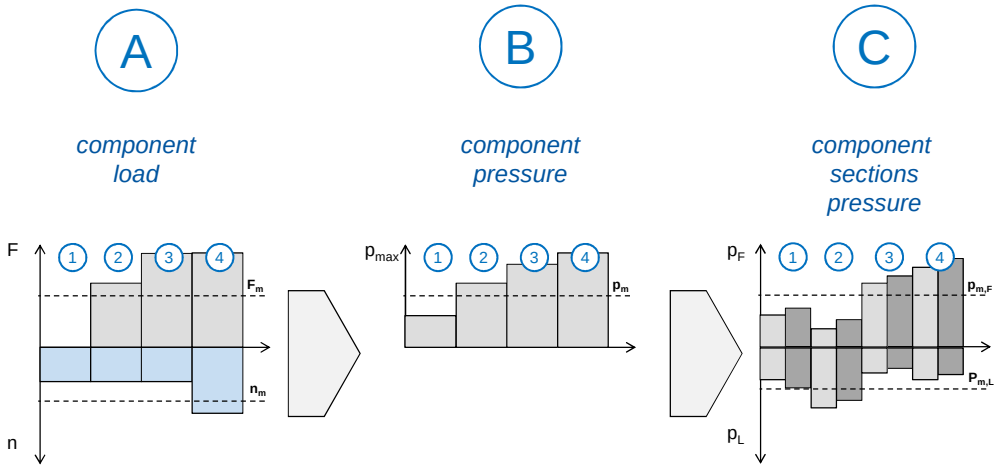


Internet of Production
Contact pressure: medium tensile and high compresive load



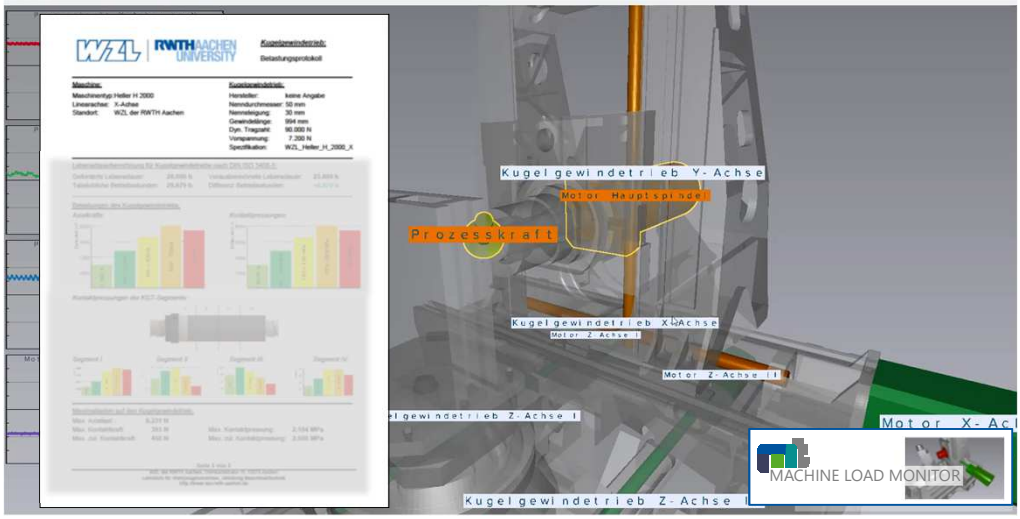
*maximum values for **spindle** and **nut***

Internet of Production
From component load to contact pressures in sections



© WZL

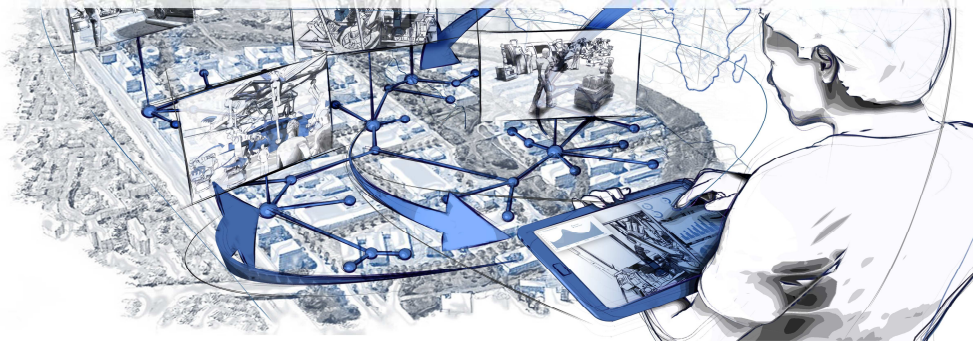
Internet of Production
Process-parallel machine component load monitoring



© WZL/Fraunhofer IPT
Fraunhofer IPT
WZL | RWTH AACHEN UNIVERSITY

Internet of Production
Challenges in automation and control technology

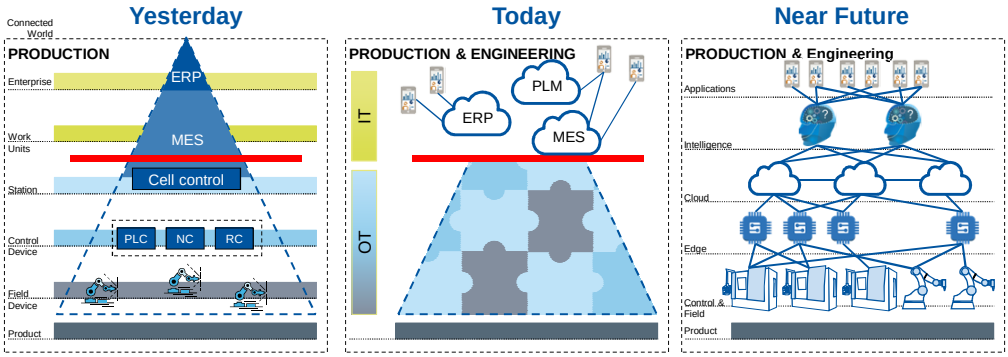
2nd Hypothesis:
Value-adding IoT services require seamless integration of "IT" and "OT"



© WZL/Fraunhofer IPT
Fraunhofer IPT
WZL | RWTH AACHEN UNIVERSITY

© WZL

Internet of Production
IT versus OT? Or IT in synergy with OT?



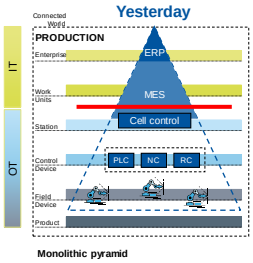
Monolithic pyramid	The two worlds of IT & OT	End-to-end through services
■ Hierarchical architecture	■ The cloud revolutionizes IT	■ Seamless switch between IT and OT
■ Individual applications	■ Modularized architectures are created	■ Web-Services on Field-Level
■ Industrial standards	■ Semantics is an essential component	■ Intelligence instead of operational description

© WZL/Fraunhofer IPT

Fraunhofer IPT

WZL | RWTH AACHEN UNIVERSITY

Internet of Production
IT versus OT? Or IT in synergy with OT?



Monolithic pyramid

What is the reason for this?

?

The cloud revolutionizes current software architectures (seconds)

Law of physics

Latency can be unacceptable for scenarios that involve **timely automated decision** making

Law of economics

Cost of bandwidth is not falling as fast as the **cost of storage and compute**

Law of the land

For **legal or compliance** reasons, some industries prefer to store or duplicate some **data locally**.

© WZL/Fraunhofer IPT

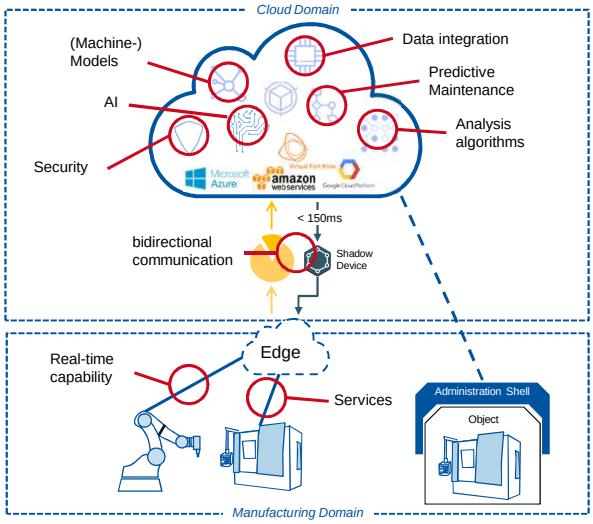
Fraunhofer IPT

WZL | RWTH AACHEN UNIVERSITY

© WZL

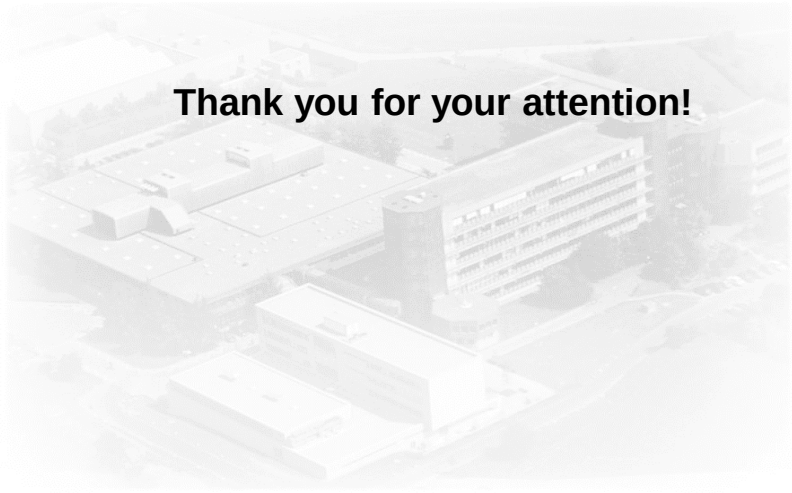
Internet of Production

Current development direction of industrial production Challenges



- Cloud and Internet platforms are playing an increasingly important role in future production
- While already established systems already exist in the consumer sector, e. g. at Apple (App Store), production technology faces great challenges

How do we combine the established "Internet world" together with established industrial production technology and what potentials arise?



Thank you for your attention!

© WZL