IFW

Institut für Fertigungstechnik und Werkzeugmaschinen

Prof. Dr.-Ing. Berend Denkena

Challenges in software engineering for CPPS

from a mechanical engineering perspective

Dr.-Ing. Marcel Wichmann, 01.06.2023

Leibniz Universität Hannover

Produktionstechnisches Zentrum Hannover

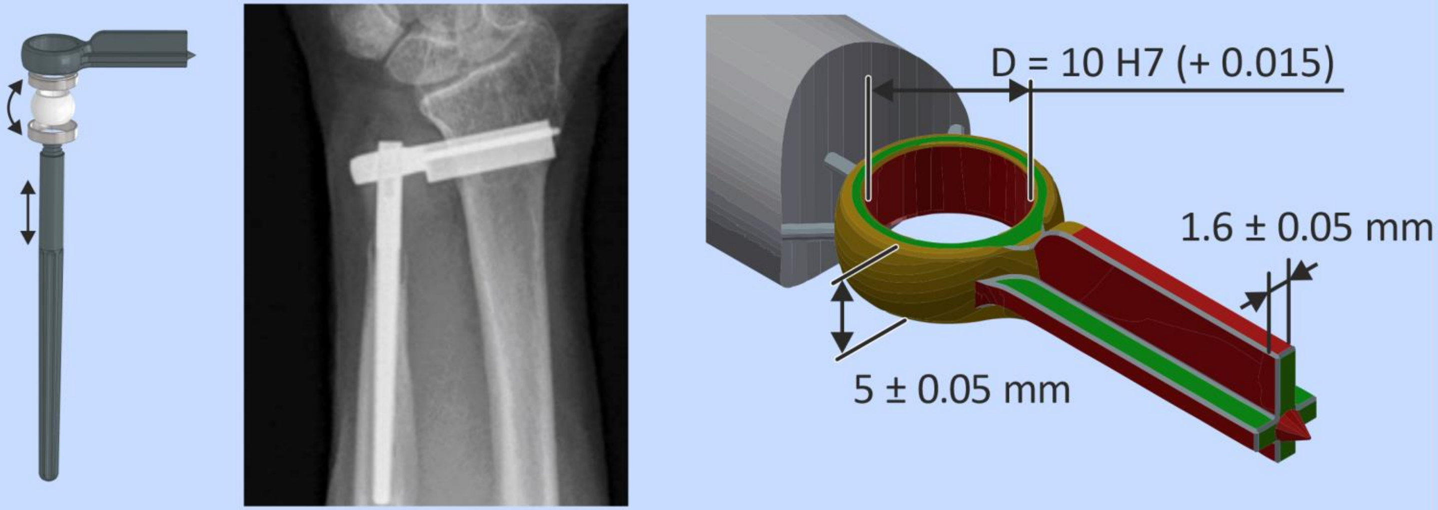
Introduction

Semi-autonomous manufacturing cell for orthopedic implants

CPPS

Semi-autonomous manufacturing cell for orthopedic implants

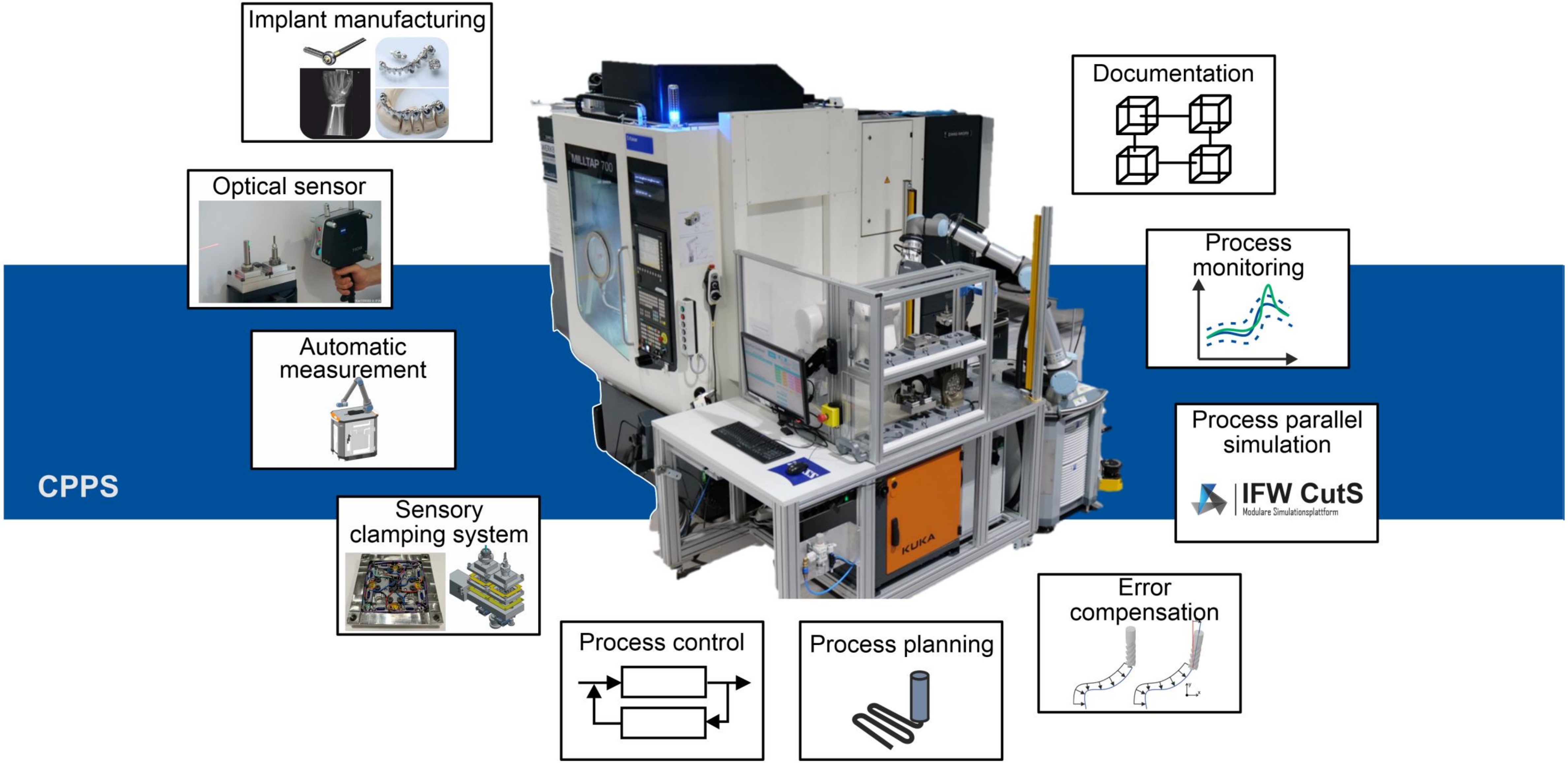
Distal radioulnar joint endoprosthesis



- Material: Ti6Al7Nb
- Manufacturing in very small batches
- CAM planning with Siemens NX
- Production time approx. 40 minutes, number of tools: 6

CPPS

Semi-autonomous manufacturing cell for orthopedic implants



Benefits and software engineering challenges

Benefits of a semi-autonomous manufacturing cell

- Automatic quality control
- Automated process planning
- Process control and error compensation
- Teach-in-free process monitoring
- Compliance with regulatory requirements

Software engineering challenges

- System and information complexity
- Product variability and Multidisciplinarity
- Knowledge management
- Data Analytics & AI (transfer learning, active learning, …)

Agenda

Competencies of the IFW

IFW

Manufacturing Processes
(Dr.-Ing. Benjamin Bergmann)

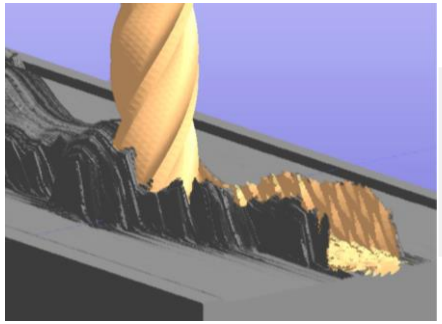
Machines and Controls
(Dipl.-Ing. Heinrich Klemme)

Production Systems
(M. Sc. Marcel Wichmann)

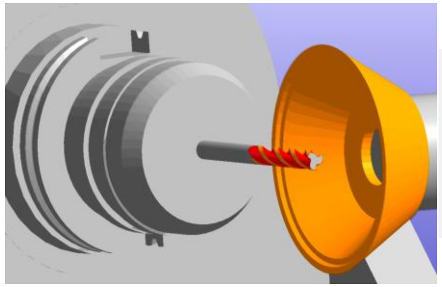
Fiber Composites
(Dr.-Ing. Carsten Schmidt)

Mittelstand 4.0
(Dr.-Ing. Michael Rehe)

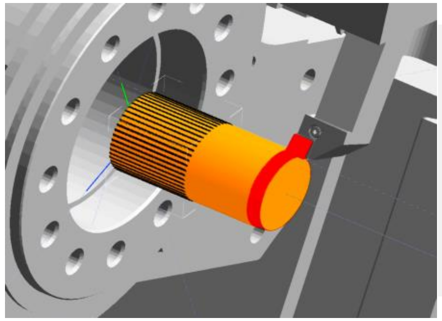
Technological NC-Simulation in IFW CutS



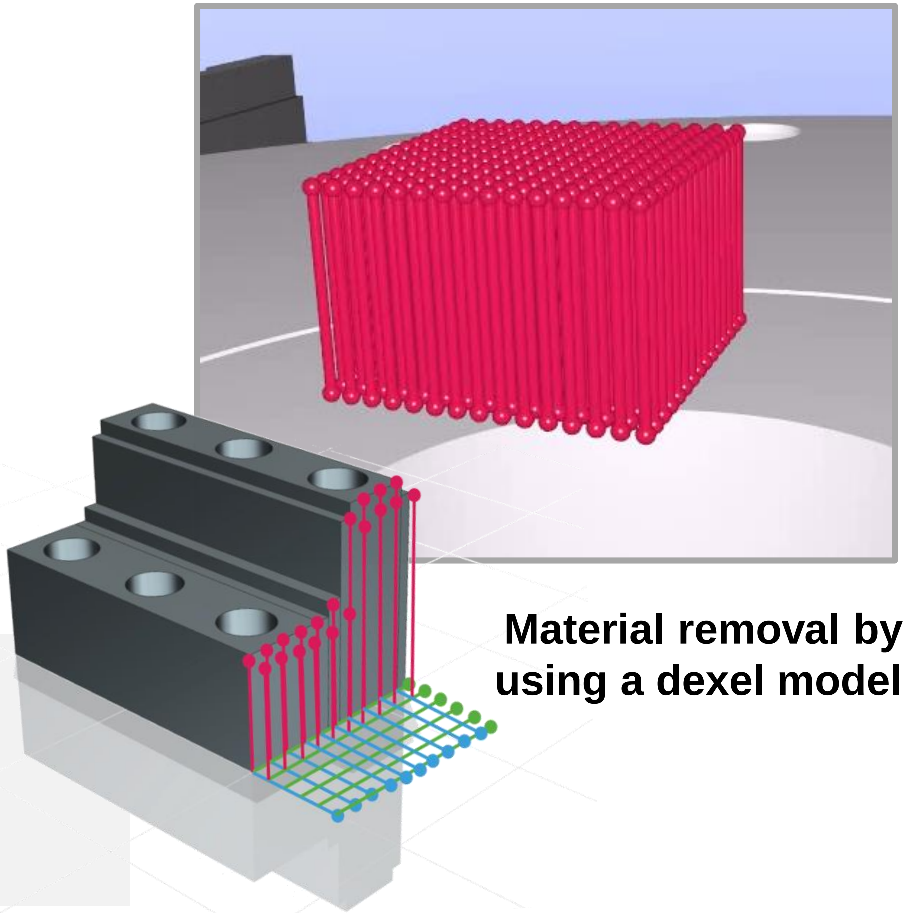
- Representation of actual workpiece geometries
- Machining with realistic tool models



- Modelling of complex kinematic movements
- Analysis of local cutting conditions



- Specific workpiece models
- Integration of further technological models
- Simulation of additive and subtractive manufacturing



Material removal by using a dexel model

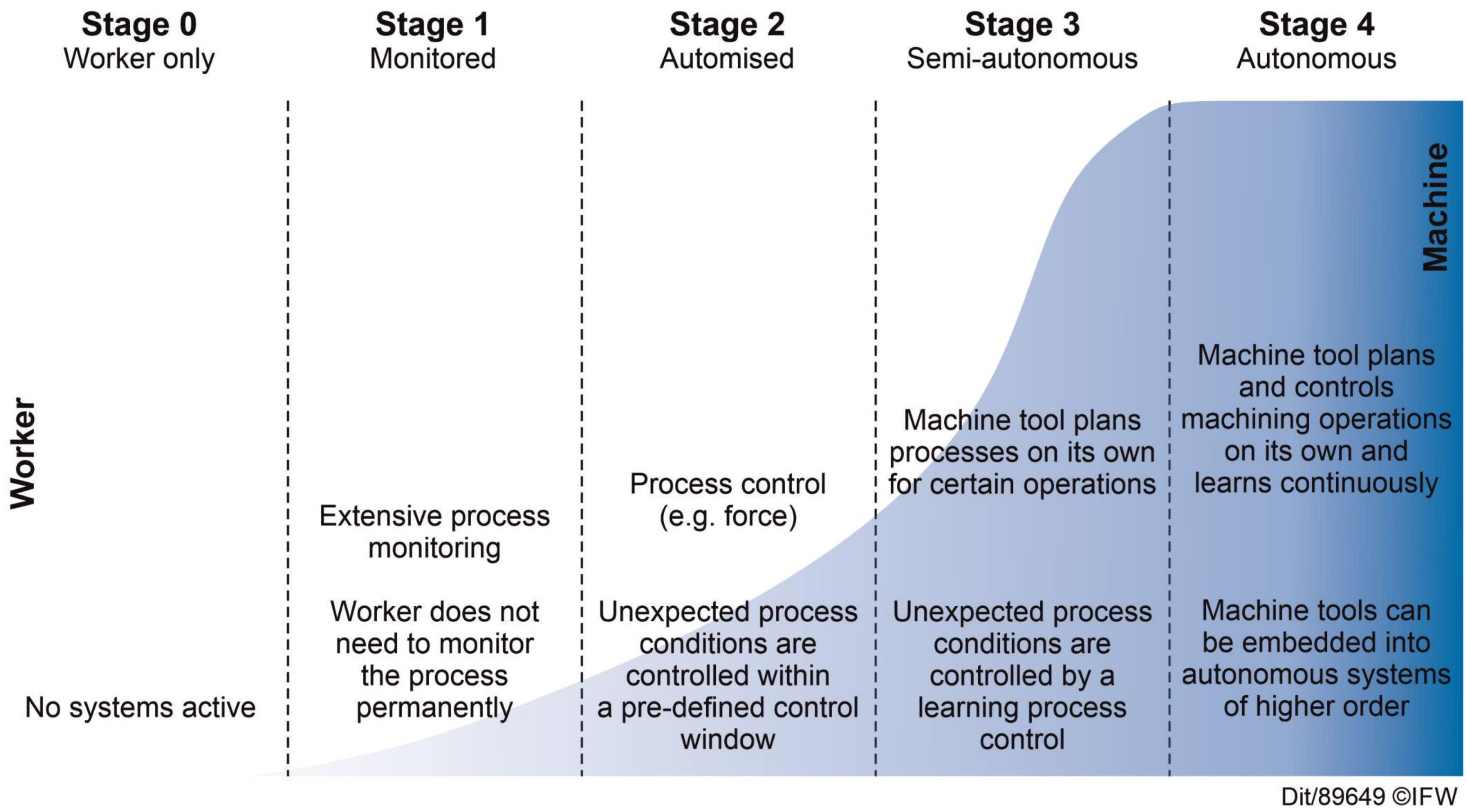
Identifying errors before they occur

IFW CutS
Modulare Simulationsplattform

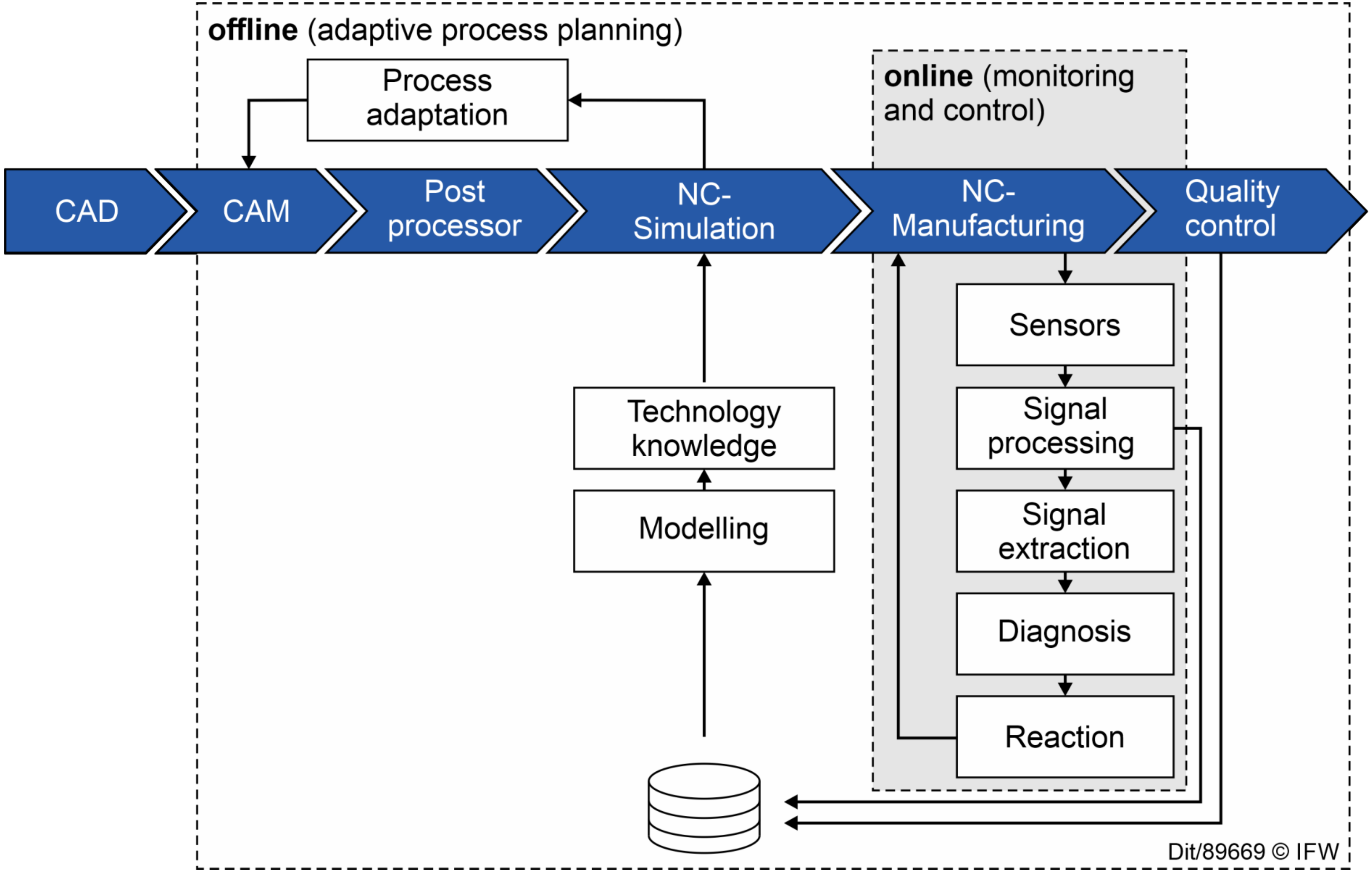
Autonomous

machine tool

Autonomous machine tool
The five levels of autonomous production



Control loops in an autonomous machine tool

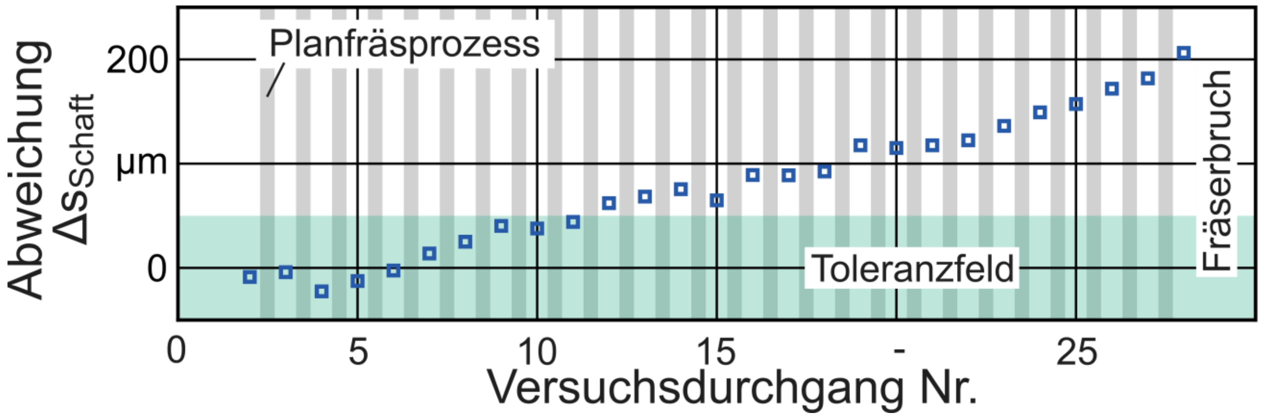


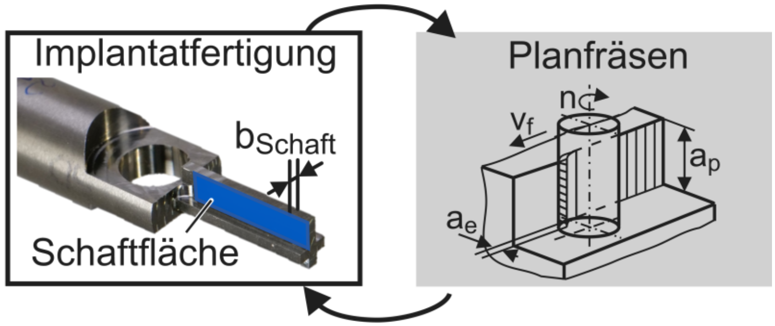
Adaptive process planning

in implant manufacturing

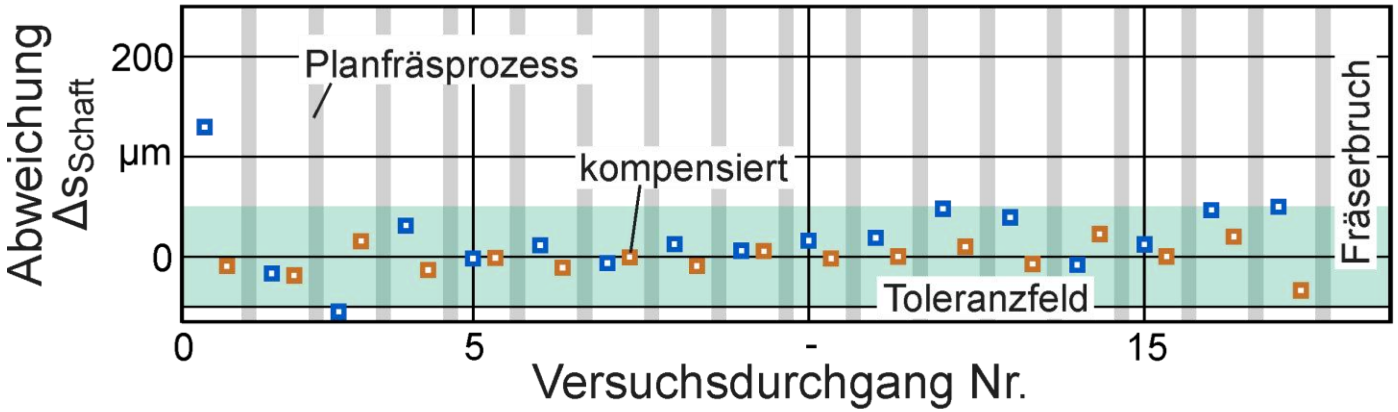
Process adaption for error compensation in series production

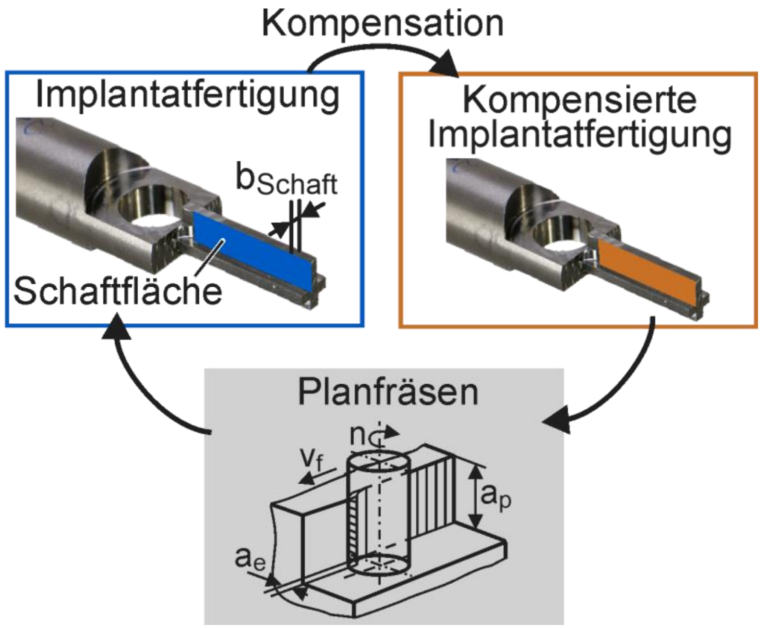
Without process adaption





With process adaption





AI-based self-learning process adaptation

Problem definition

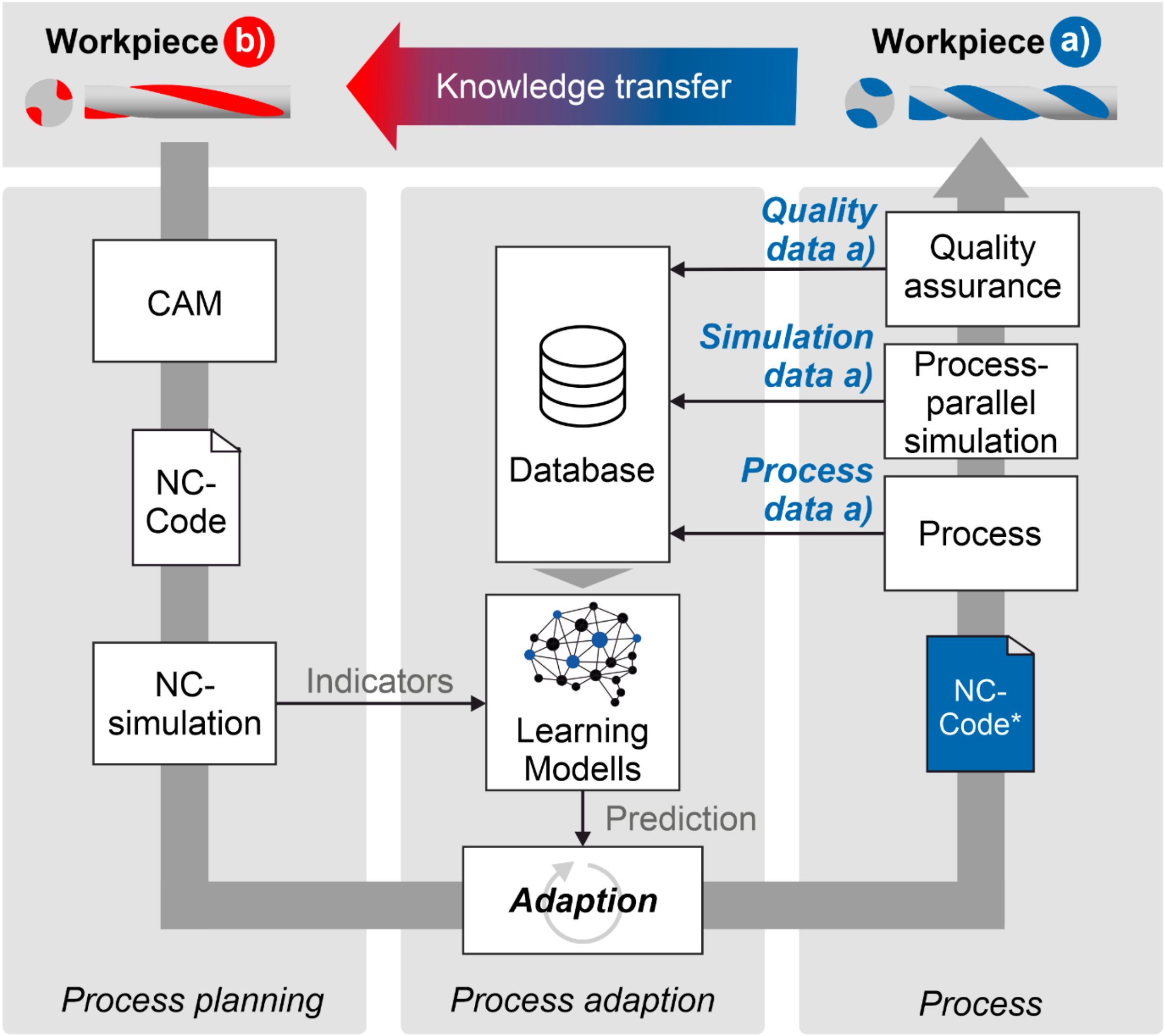
- Manufacturing data is not merged
- Knowledge remains at experienced staff
- Assistance systems in process planning are rigid

Objective

- Combination of different data types
- Simulation based process adaption
- Knowledge transfer to save resources

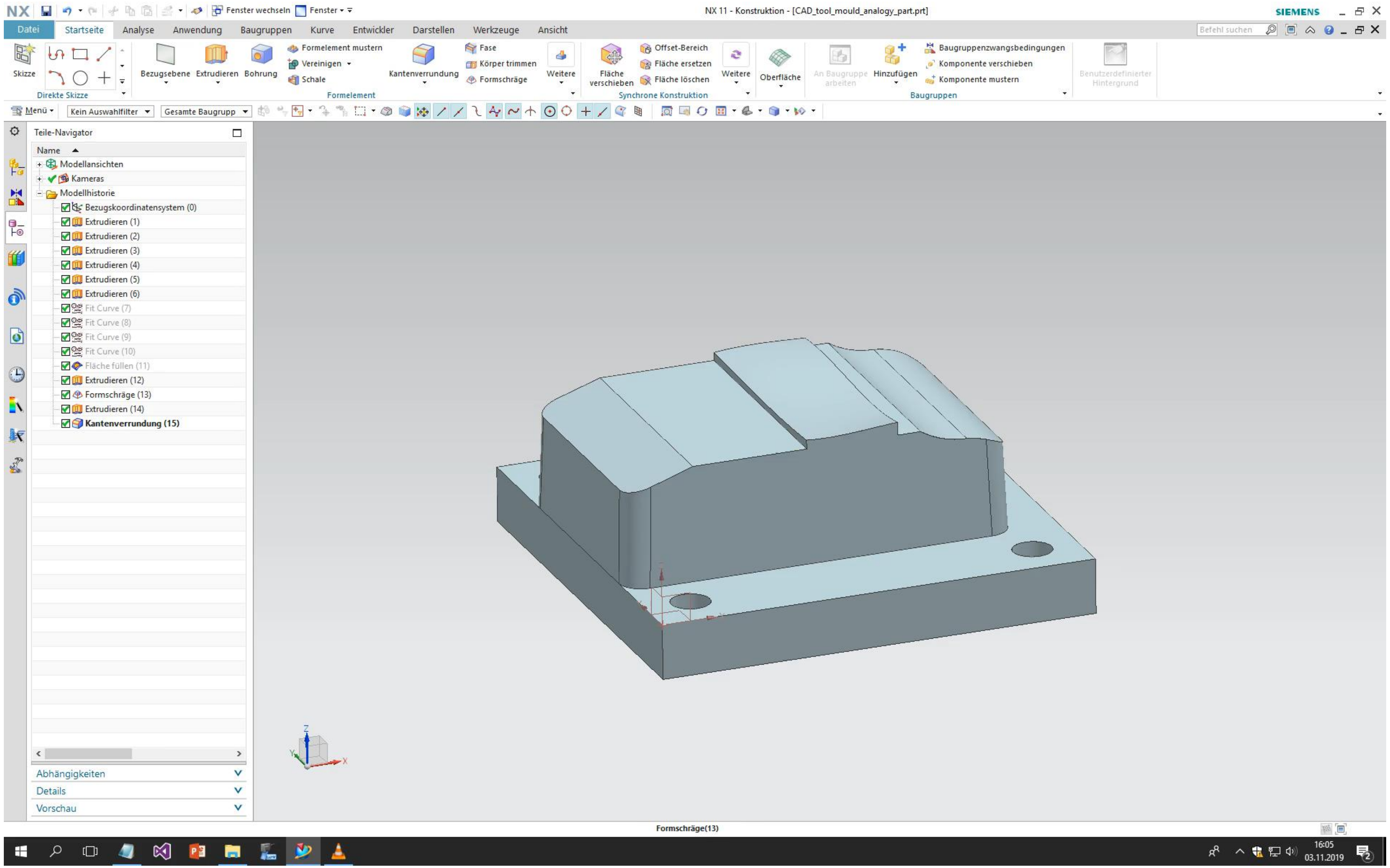
Approach

AI-based self-learning process adaptation by using digital twins in process planning



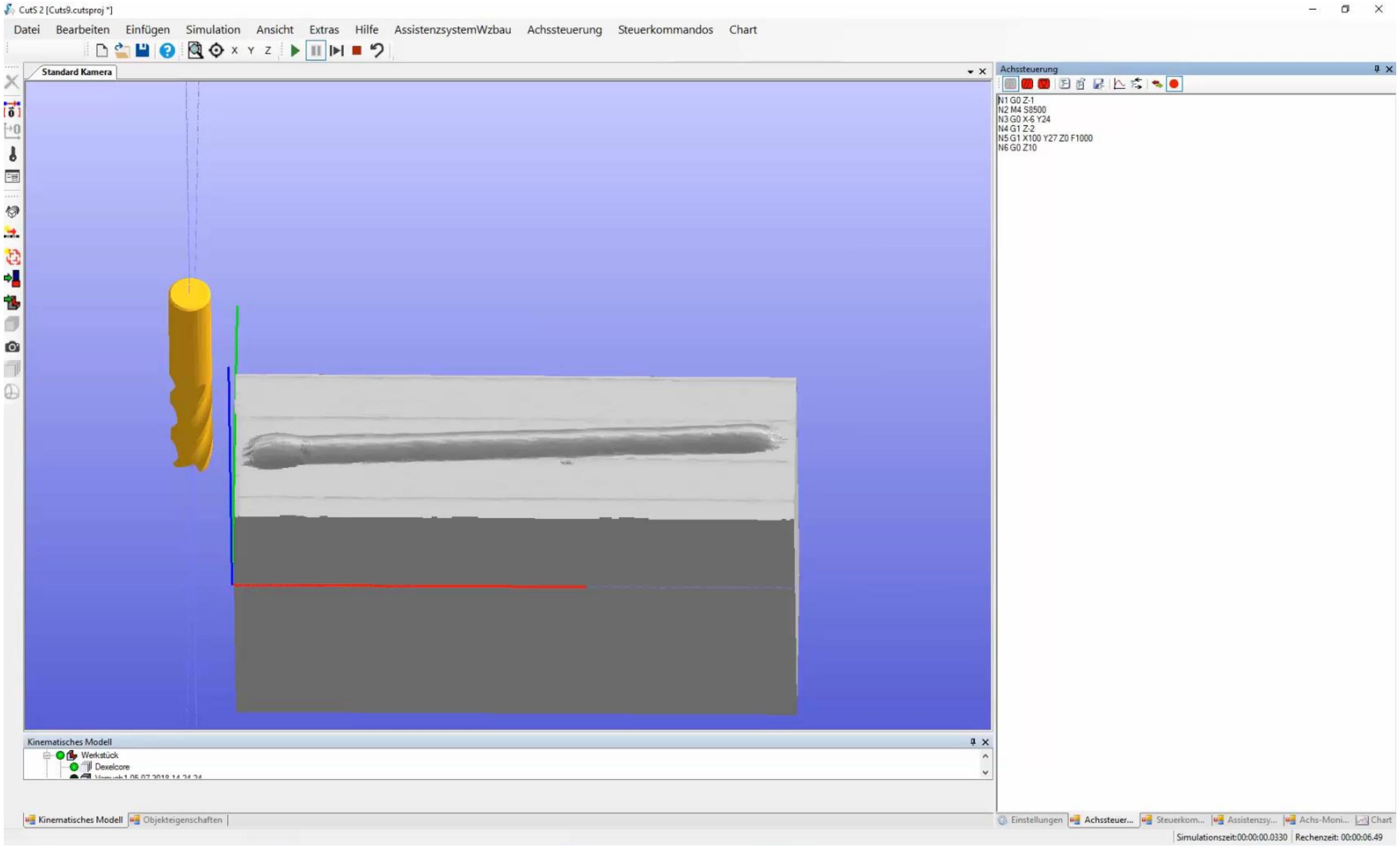
Wic/113783 © IFW

Automated process planning (CAM)

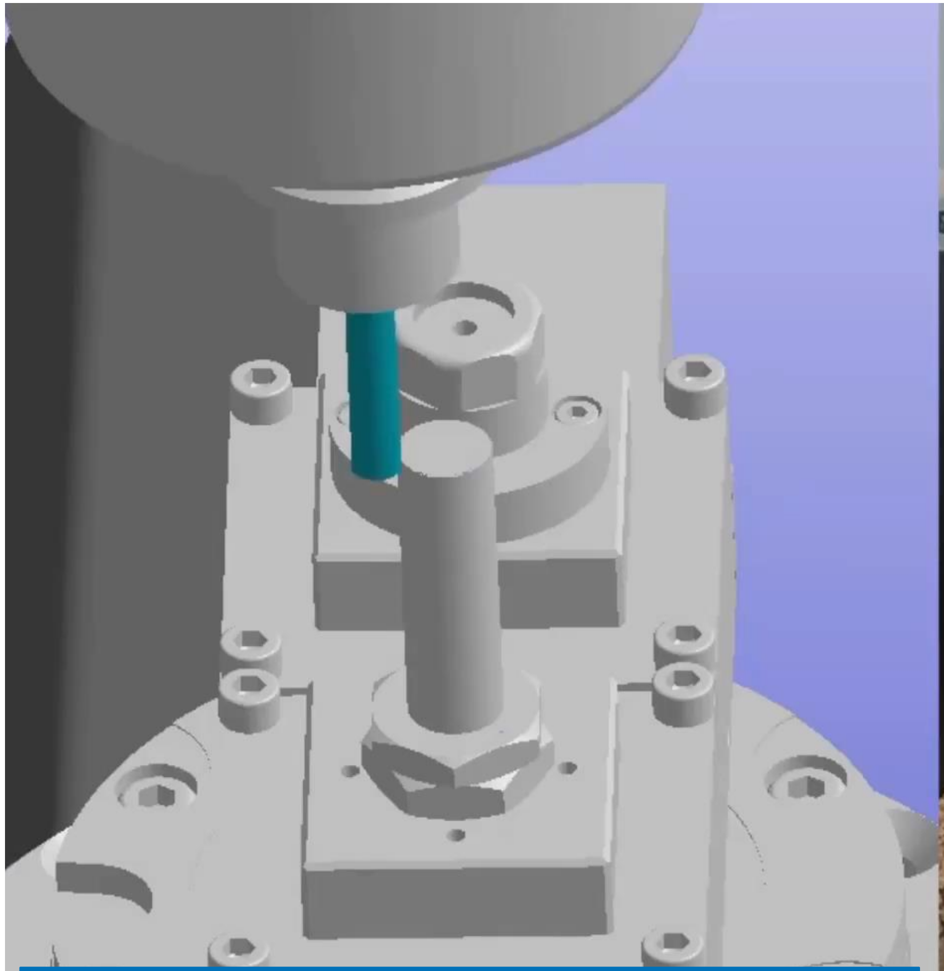


Process adaption by NC-simulation

IFW
Institut für Fertigungstechnik und Werkzeugmaschinen



Process parallel simulation as a soft sensor



Simulation – IFW CutS

Milling process – DMG Milltap 700

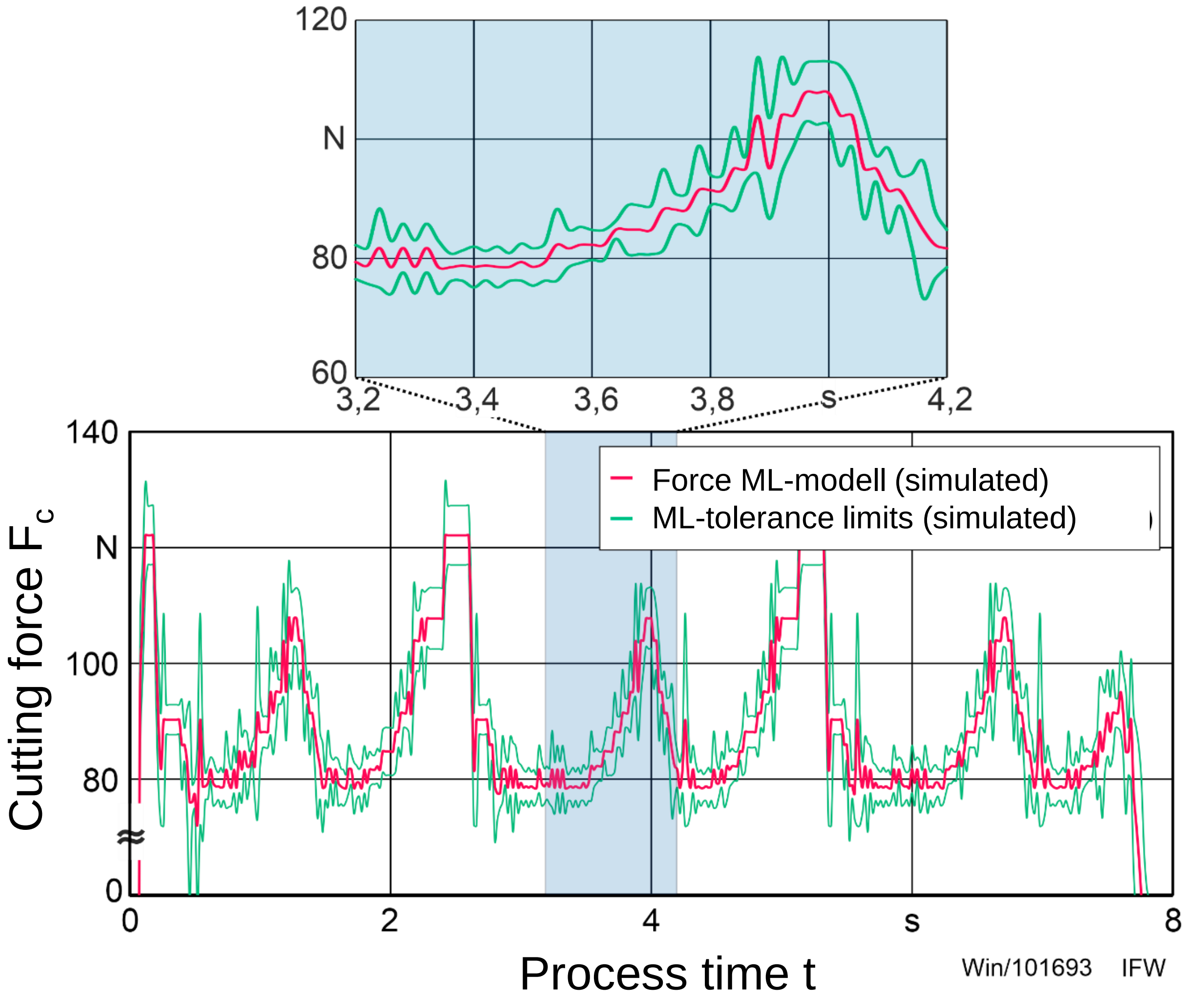
Process monitoring using simulation approaches

Set monitoring limits by a process simulation

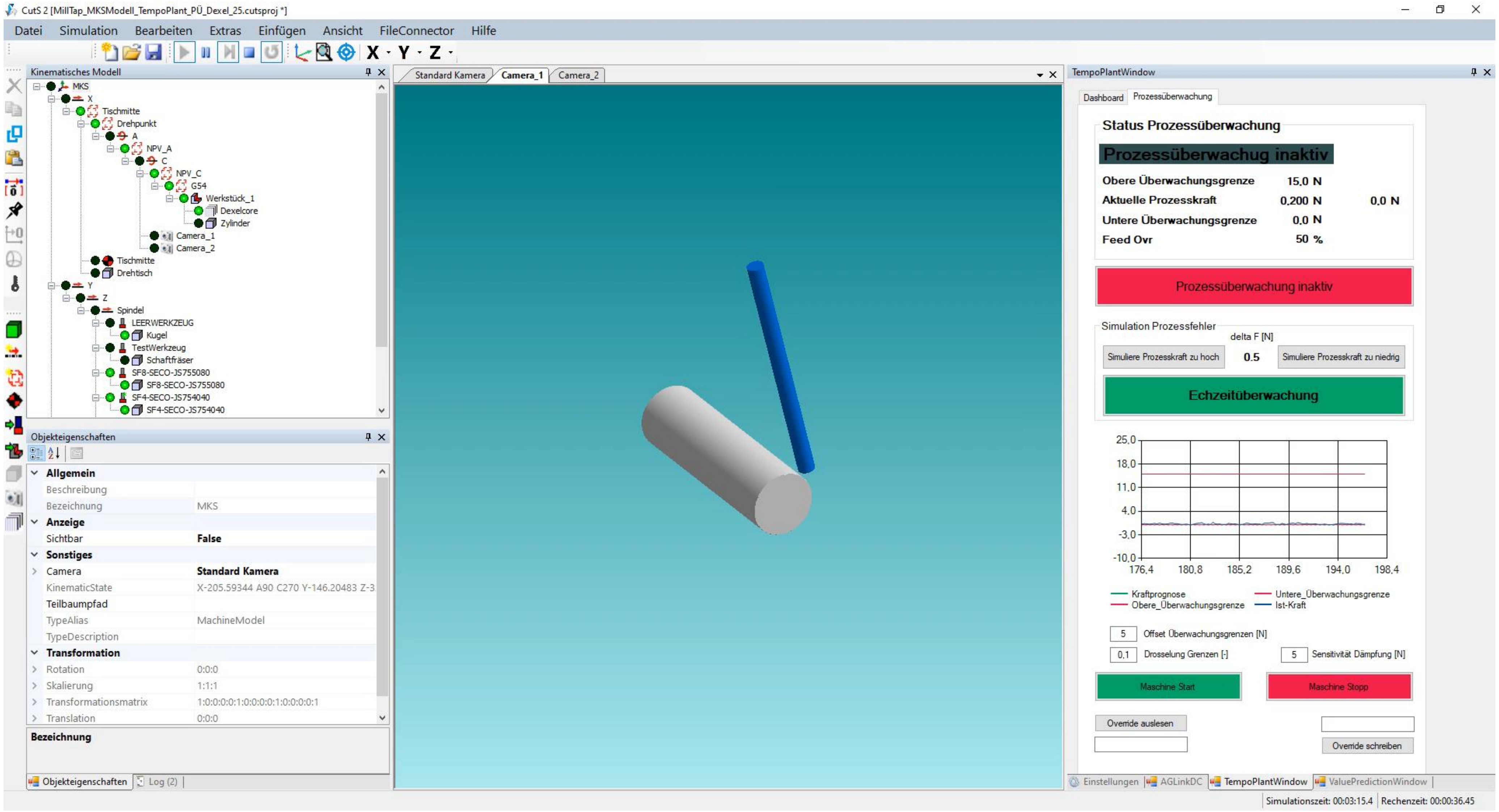
- Force prediction by ML-Modell (ML.Net)
- Limit corresponds to the standard deviation of the modeled process forces

Process monitoring using IFW CutS

- Forces are measured in the cutting process and transferred to IFW CutS in real time
- If the limits are exceeded, the CNC machine is stopped automatically by IFW CutS.



Video of process monitoring (IFW CutS)



Digital Implant

Lifecycle Management

Approach for single processes – Digital Twin in tool grinding

Manufacturing

- Machine control transfers axis data, spindle current and axis currents in 200 Hz
- Sensor data can be used additionally

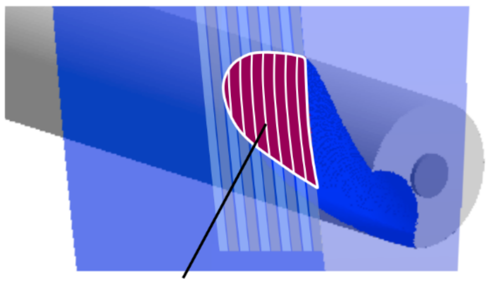
Data streams

Axis positions
- A, Y, Z, C, A

Process
- Currents

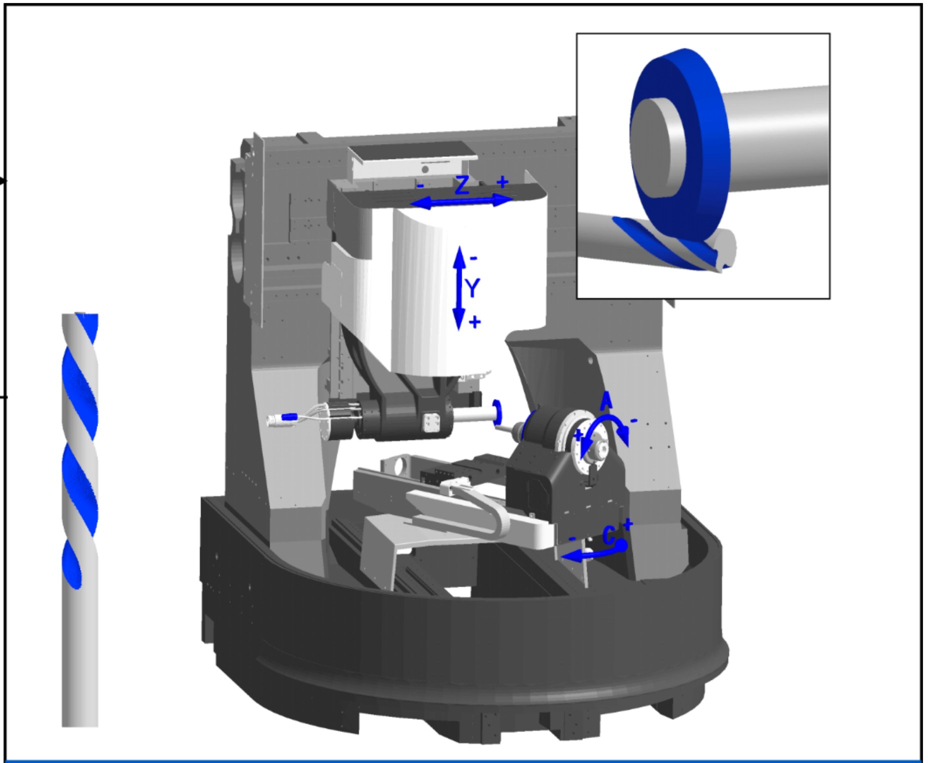
Quality
- Shape error

Simulation
- Q'_w
- h_{eq}
- l_g



Cutting conditions

Knowledge database



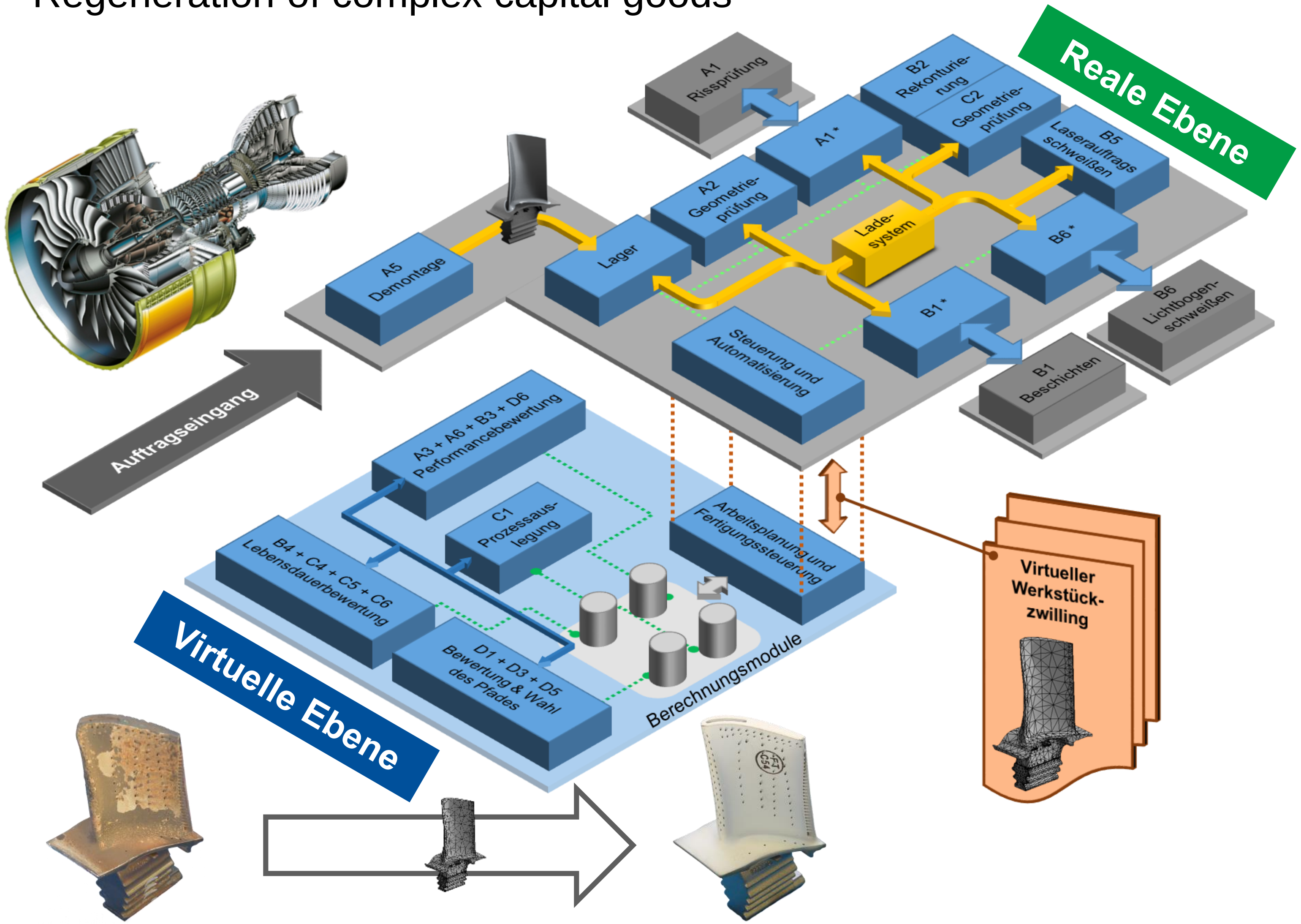
Material removal simulation

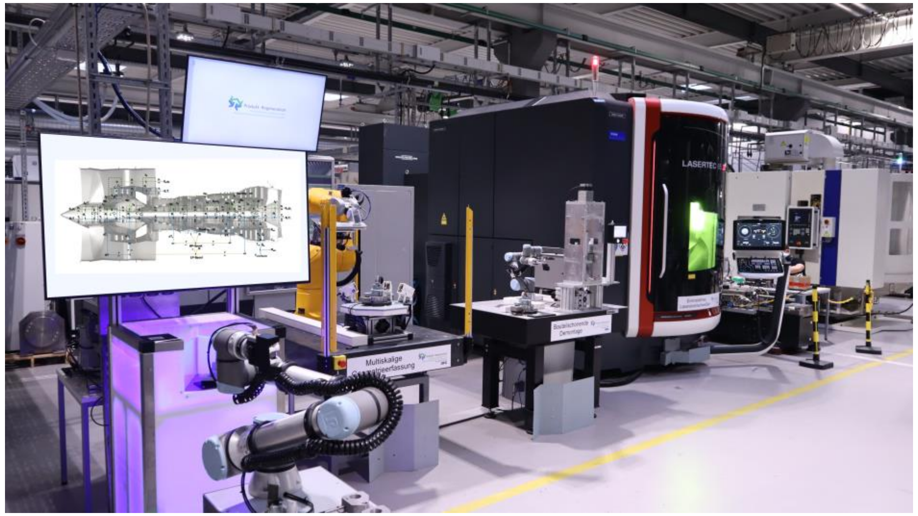
- Process-parallel material removal simulation uses the real axis data
- Calculation of the local cutting conditions

Wic/ 113808 © IFW

Aproach for process chains – Repair procedures for aircraft engines

Regeneration of complex capital goods

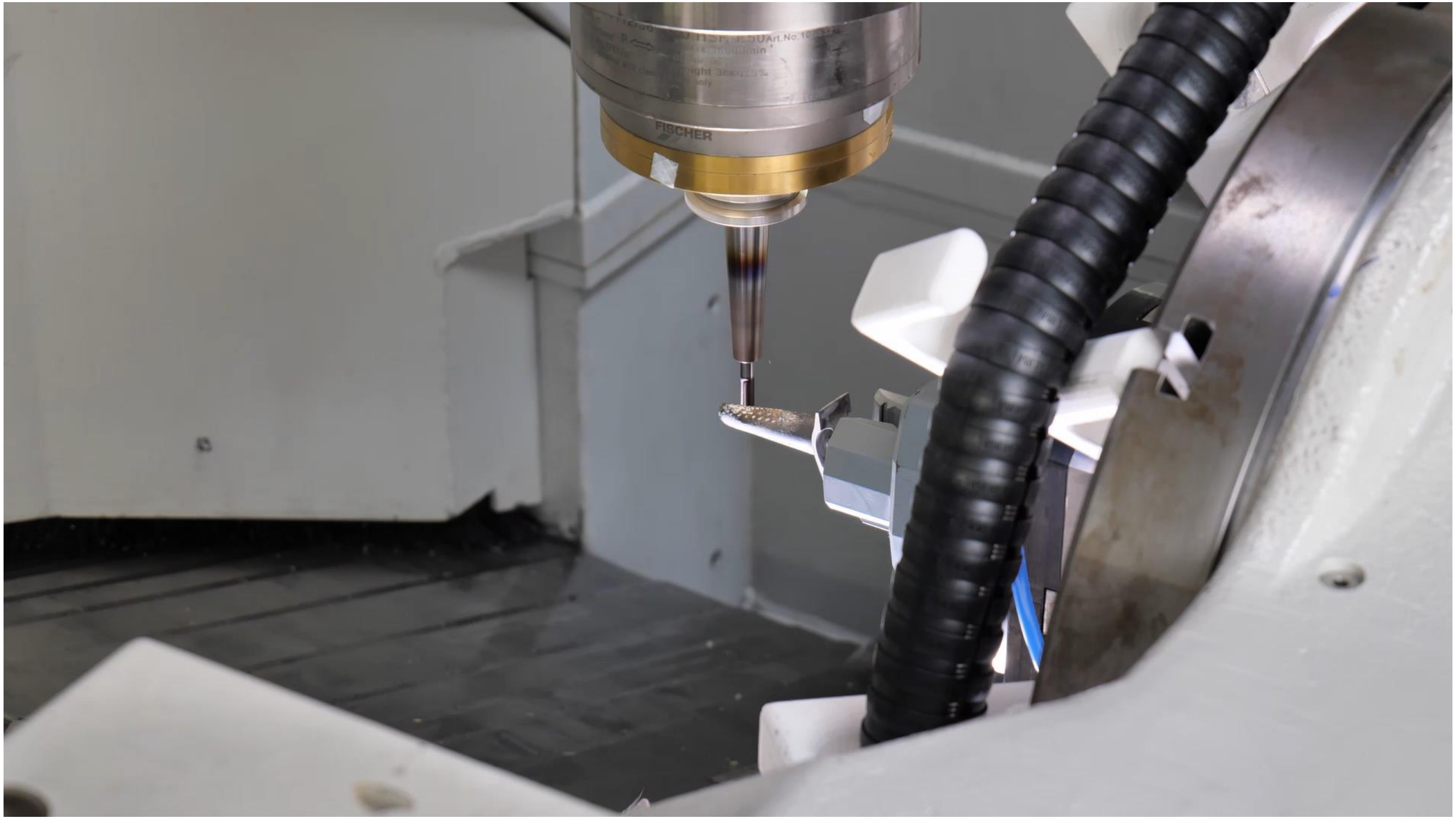




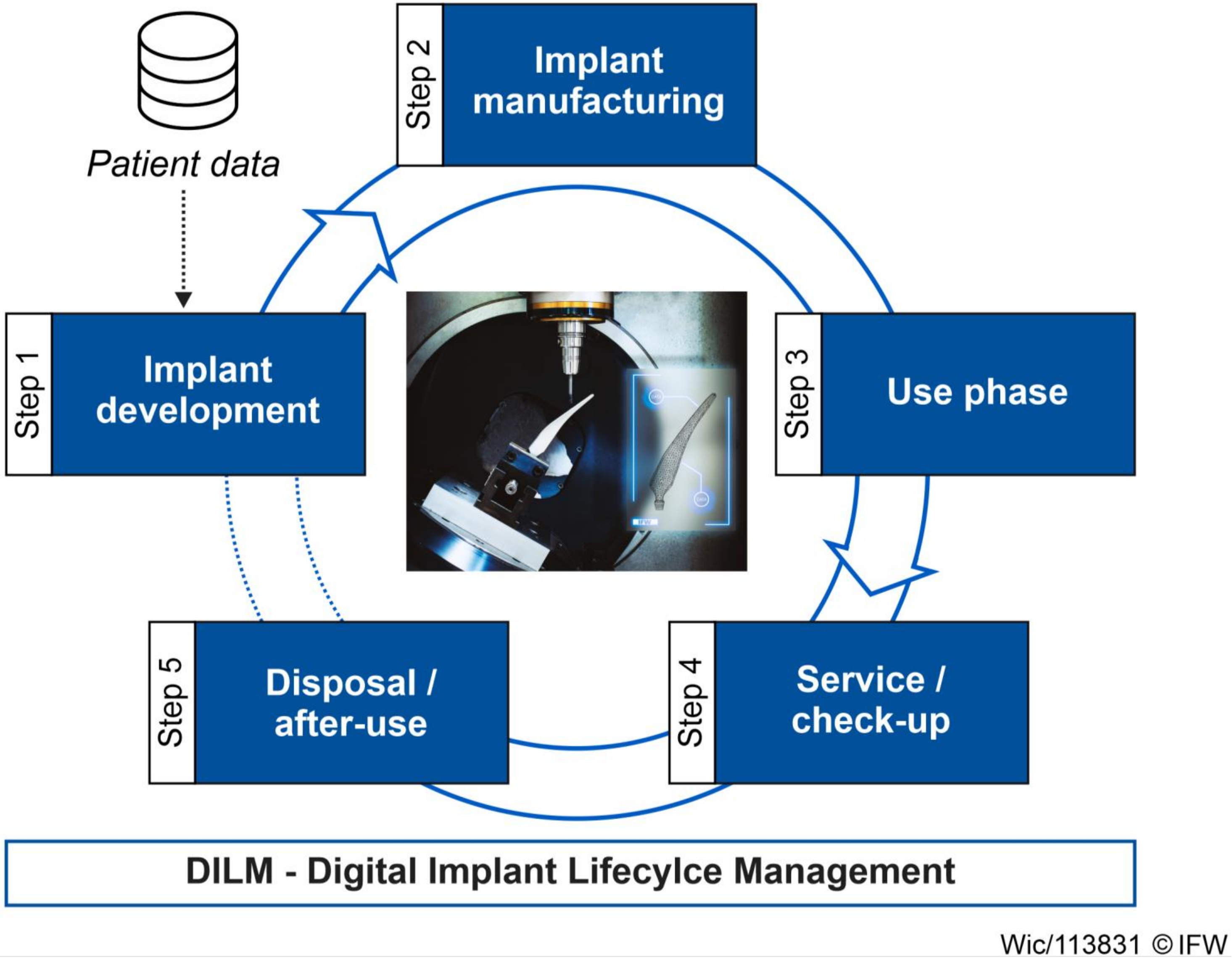
- **Digitalization:** Real level of the repair process ⟺ virtual level of the digital twin
- **Consideration:** Functional benefit of repairs
- **Benefits:** Automated decision making in complex systems

Additive Manufacturing – Deposition welding process

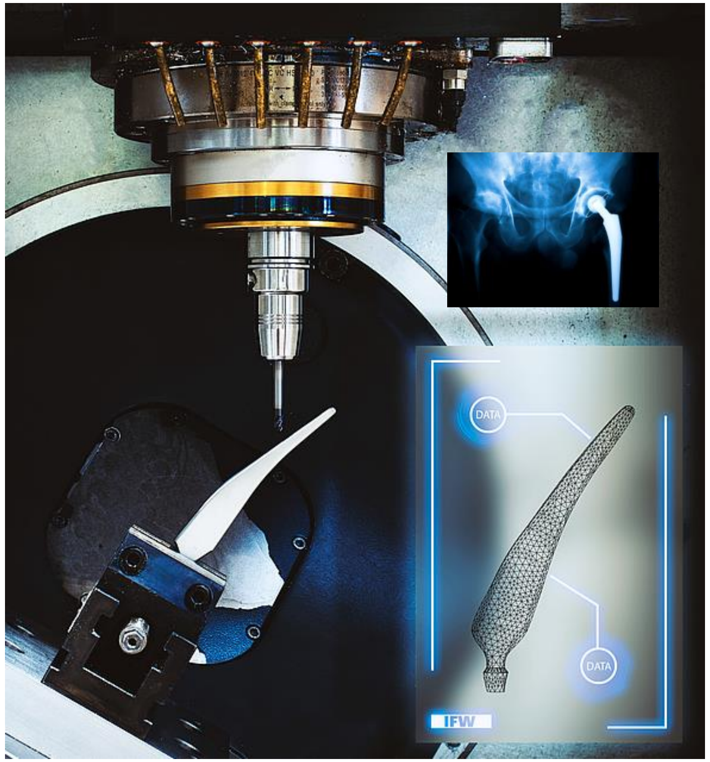
Subtractive Manufacturing: Recontouring

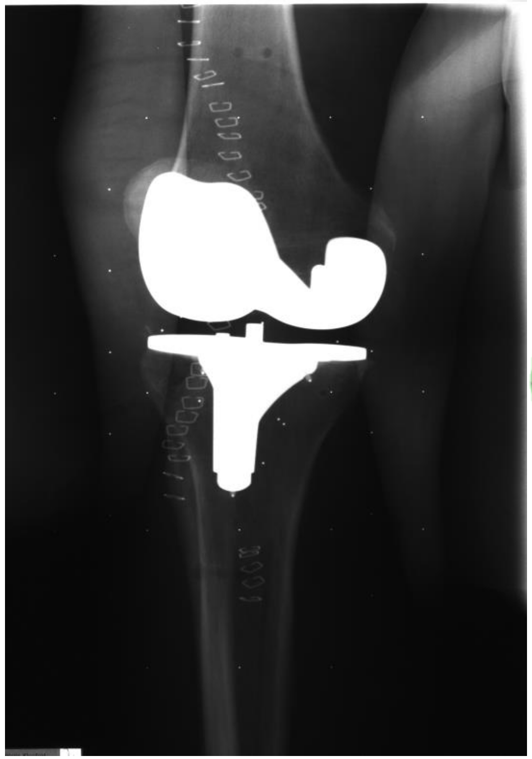


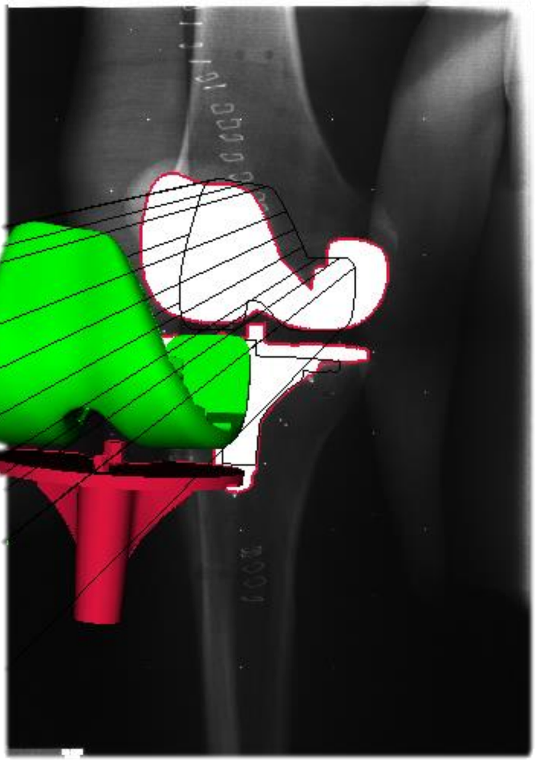
Digital Implant Lifecycle Management

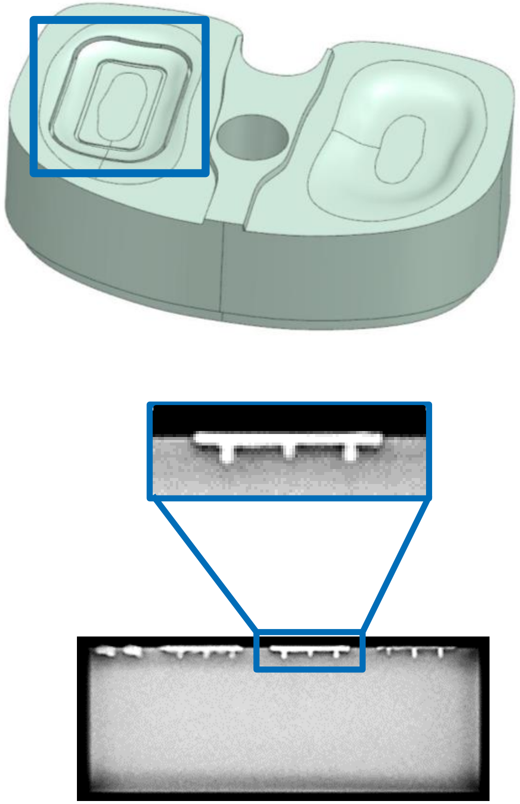


Open question for the discussion: How can data formats be combined?









Feeding, processing and simulation of data into the Digital Twin before, during and after the use of the implant helps to improve manufacturing, monitoring and patient well-being.

Software Engineering
for CPPS

Challenges in production technology

General trends

- Economical production in high-wage countries
- Flexible but also highly automated production systems
- Variations in machine tools (age, component manufacturers)

Challenges regarding digitalization

- Interfaces between different software systems
- Data management (type and location of storage)
- Different data sources and differences in the frequency of data
- Computer scientists must assist with data science

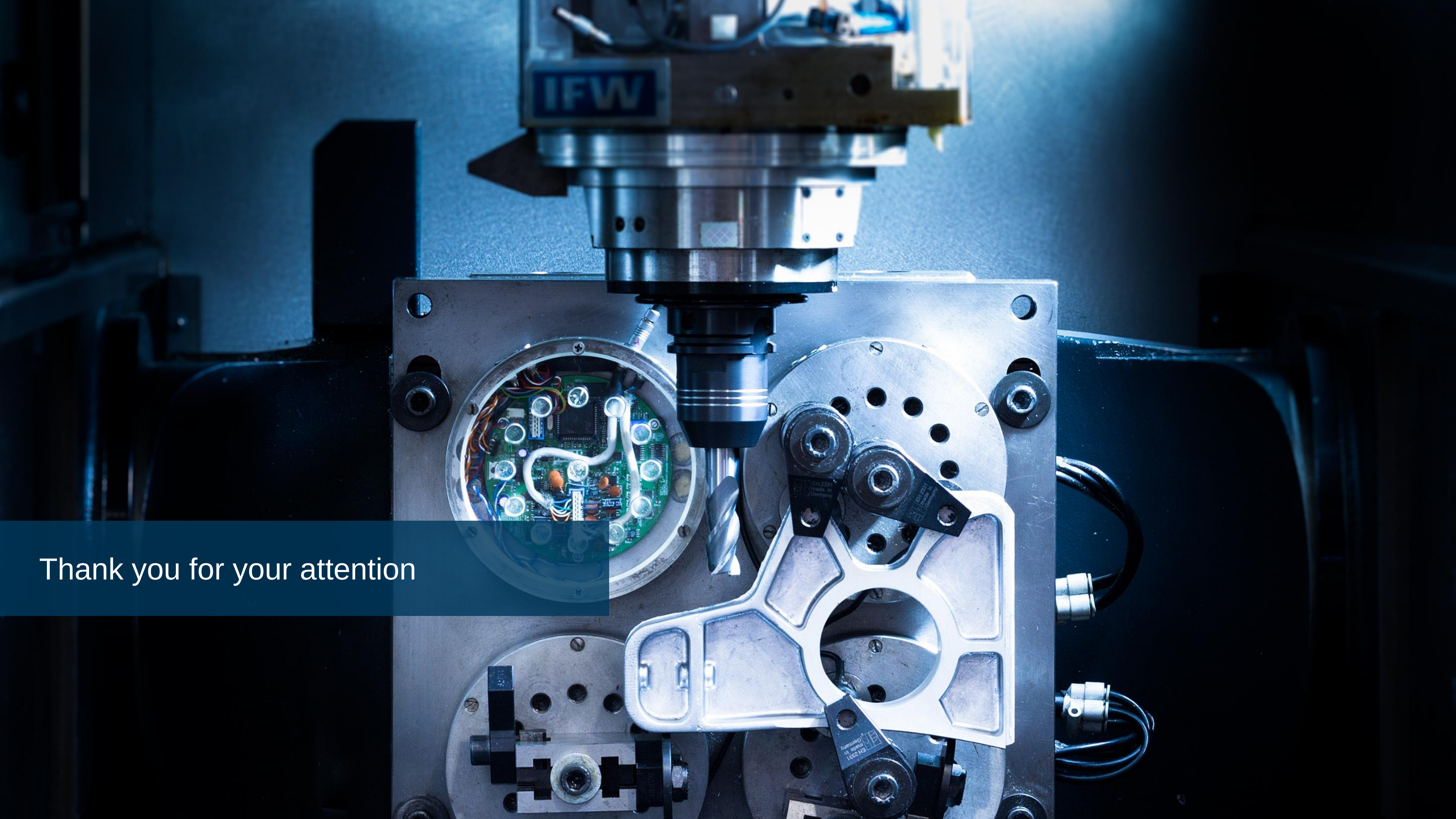
- Software architects (for specific domains)
- System design → Development of an algorithm
- Communication of the problem and interface to other departments → Shape shifters

- Collect requirements (method,...), requirement moderators - neutral interface
- Detailed program flow chart → Specifications for programming
- Implementation (technical rough realizers), Keyword: Iterative implementation

- Prototype development and pre-development
- VDI guideline 2221
- Unbiased approach

→ What is the requirement for a CPPS?

Conclusion



Thank you for your attention

Contact

Institut für Fertigungstechnik und Werkzeugmaschinen (IFW)

Produktionstechnisches Zentrum

Leibniz Universität Hannover

An der Universität 2, 30823 Garbsen

http://www.ifw.uni-hannover.de

Dr.-Ing. Marcel Wichmann

Tel. +49 511 762 2554

Wichmann@ifw.uni-hannover.de