PREDICTIVE MAINTENANCE IN FORMING MACHINES

Actual RTD topics

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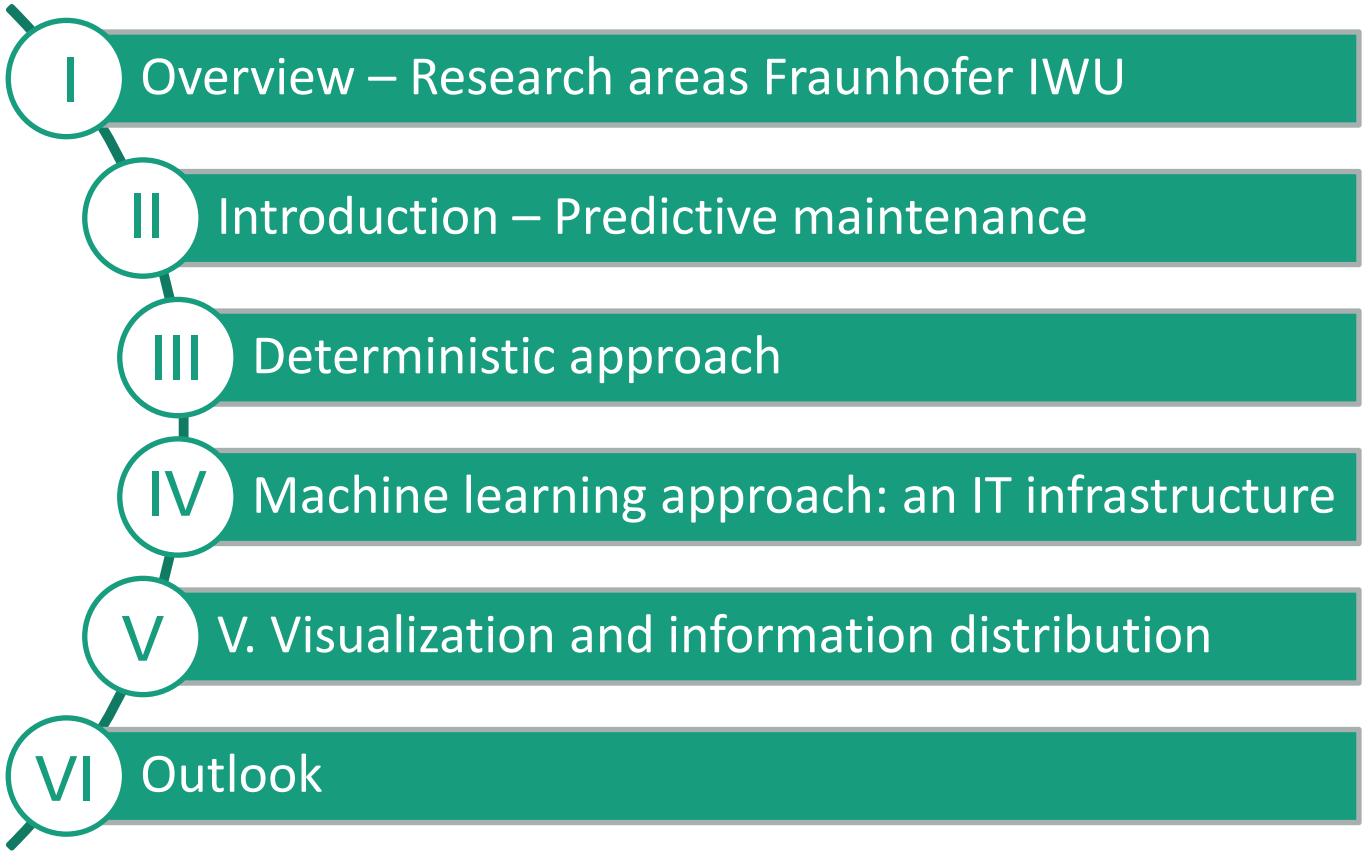
I.P.A. International Packaging Association Meeting

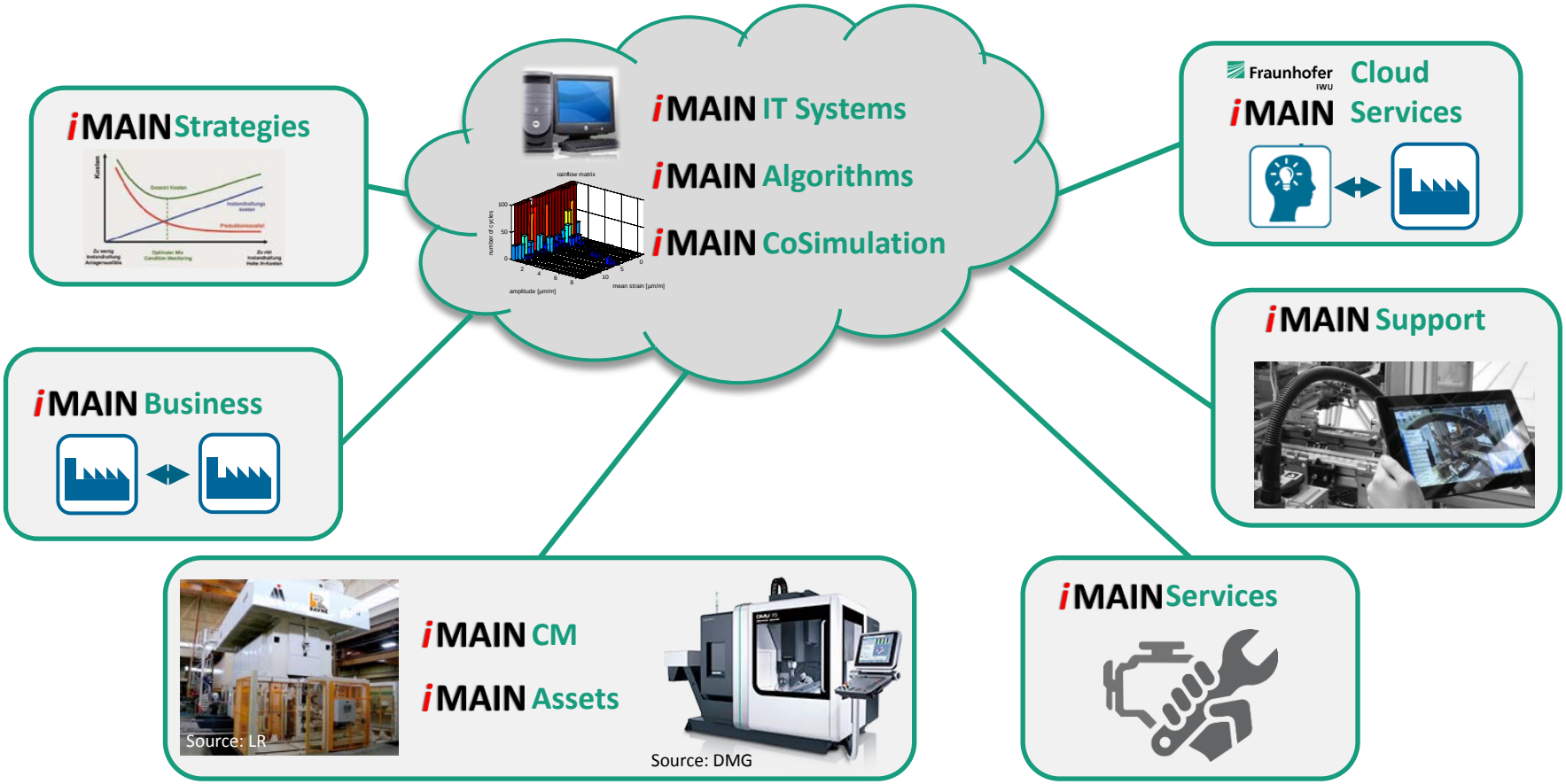
Berlin 18/10/2016

AGENDA


I
Overview – Research areas Fraunhofer IWU
II
Introduction – Predictive maintenance
III
Deterministic approach
IV
Machine learning approach: an IT infrastructure
V
V. Visualization and information distribution
VI
Outlook

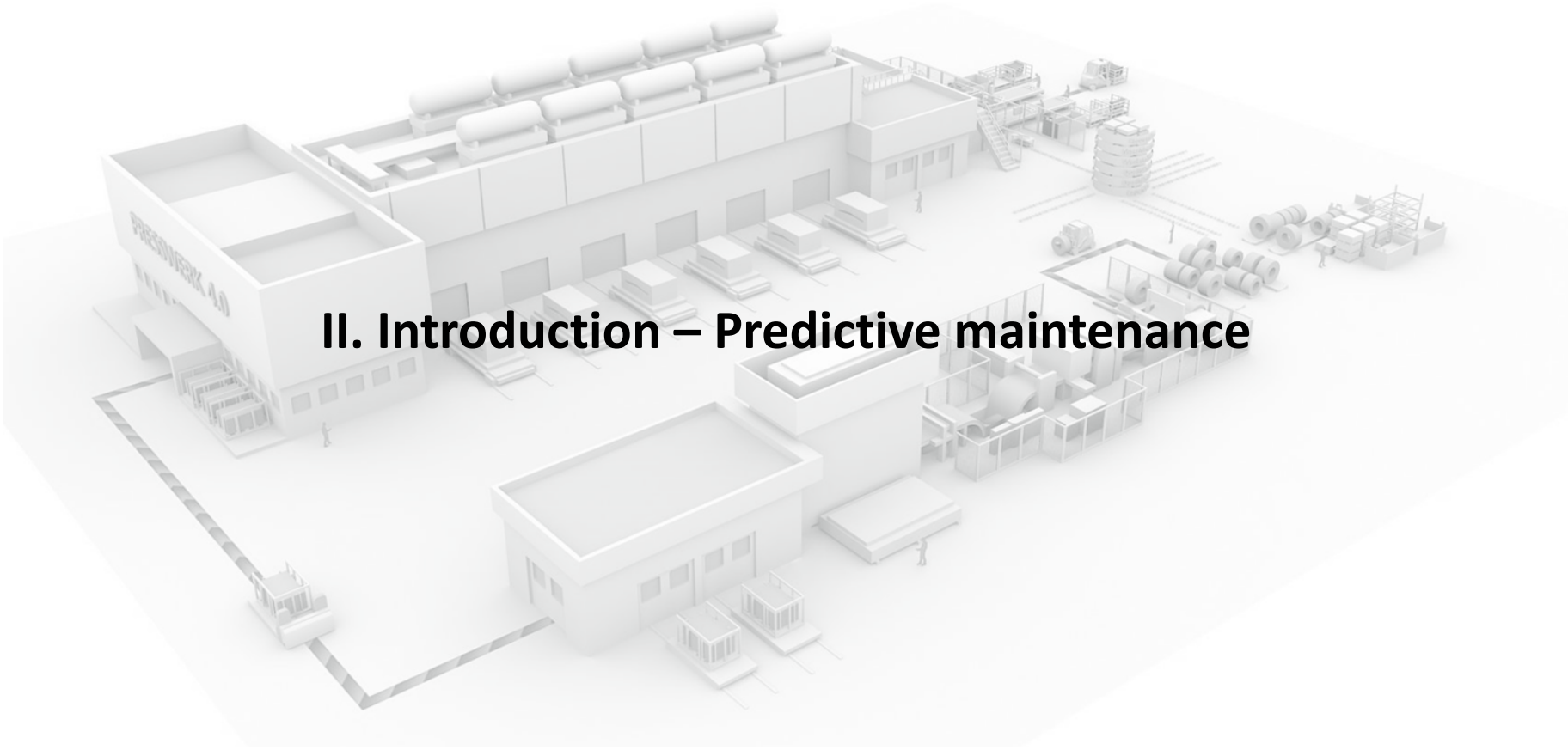
I. Overview – Research areas Fraunhofer IWU (I)

- **Maintenance**: is the combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to, a state in which it can perform the required function ISO 13306:2010



I. Overview – Research areas Fraunhofer IWU (II)

*i*MAIN Strategies	Development of maintenance strategies for manufacturing assets
*i*MAIN CM	Planning and installation of condition monitoring systems
*i*MAIN Assets	Analysis of failure causes and proactive asset planning
*i*MAIN IT Systems	Cloud-based IT systems for data analysis
*i*MAIN Algorithms	Algorithms for predictive maintenance
*i*MAIN CoSimulation	Model-based information enhancement and virtual sensors
*i*MAIN Support	AR-Technologies, User Interfaces, Information distribution
*i*MAIN Business	Development of business models for I4.0 maintenance
*i*MAIN Services	***i*MAINTENANCE CLOUD** research and service platform



II. Introduction – Predictive maintenance

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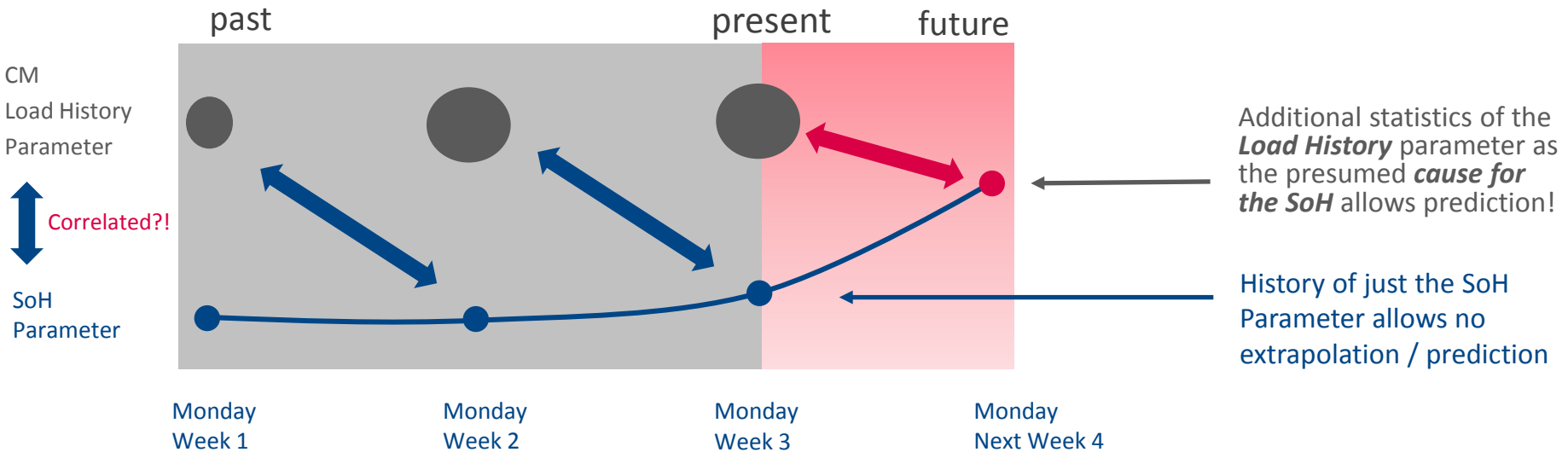
What is predictive maintenance?

➢ **Prediction** (lat. praedicere ‚predict' ‚prognosticate' ‚forecast')



Finding correlations → SoH vs. Load History data

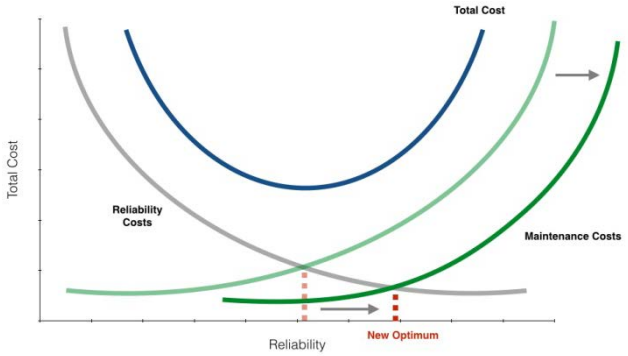
Condition monitoring
+ Load history
+ Prognosis

II. Introduction – Predictive maintenance

What are the advantages of predictive maintenance?

Aim: Make maintenance plannable – with the following characteristics:

- Estimation of future failures dates / remaining useful life (RUL)
- Optimal usage of RUL in real production



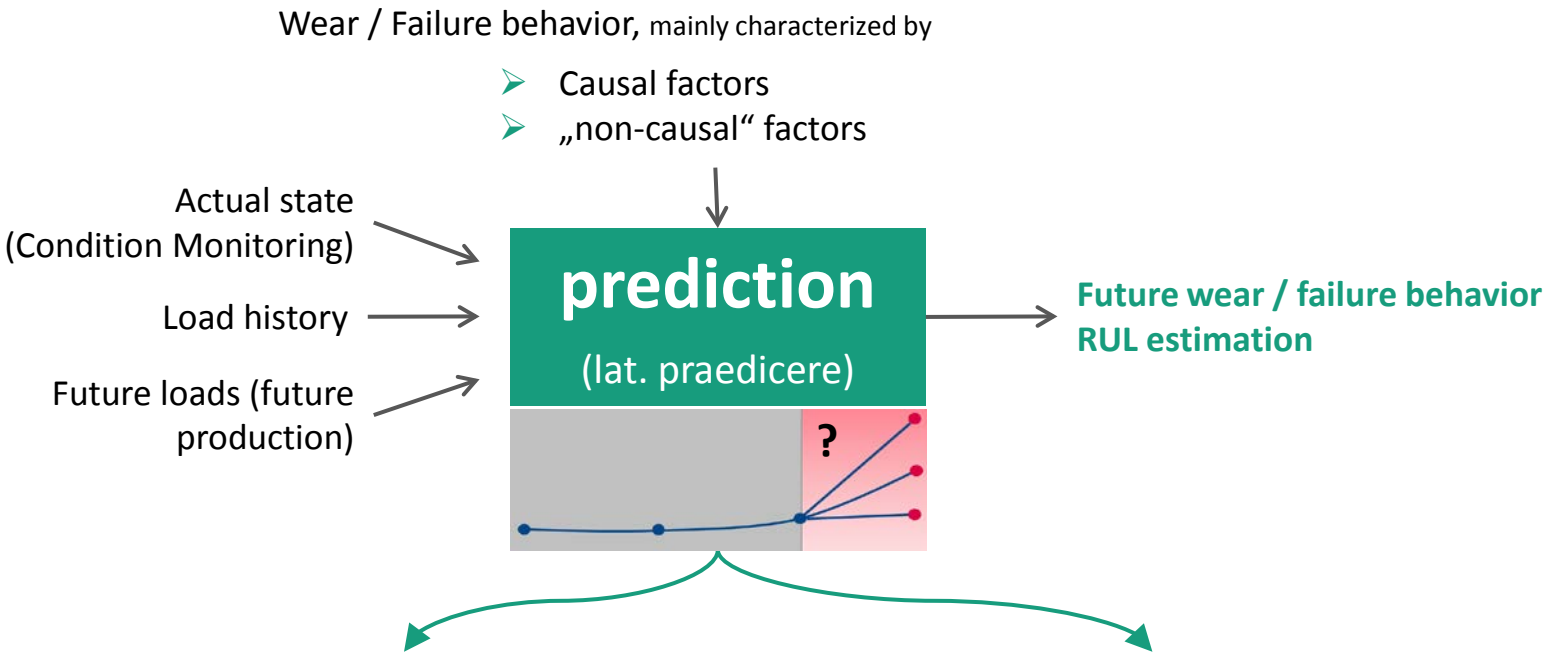
Advantages for manufacturers:

- **Avoiding** of expensive and unplanned **down times**
- Improved ERP: **assets** and **human resources**
- Minimizing **costs** for repair, insurance, production shifting,…
- Increasing **productivity**
- To guarantee **manufacturing quality**
- Increasing **customer satisfaction** (e.g. in just-in-time supply chains)
- New service-based **business opportunities** (e.g. I4.0 based)

Increasing efficiency / decreasing costs in maintenance

II. Introduction – Predictive maintenance

What are the challenges in predictive maintenance?

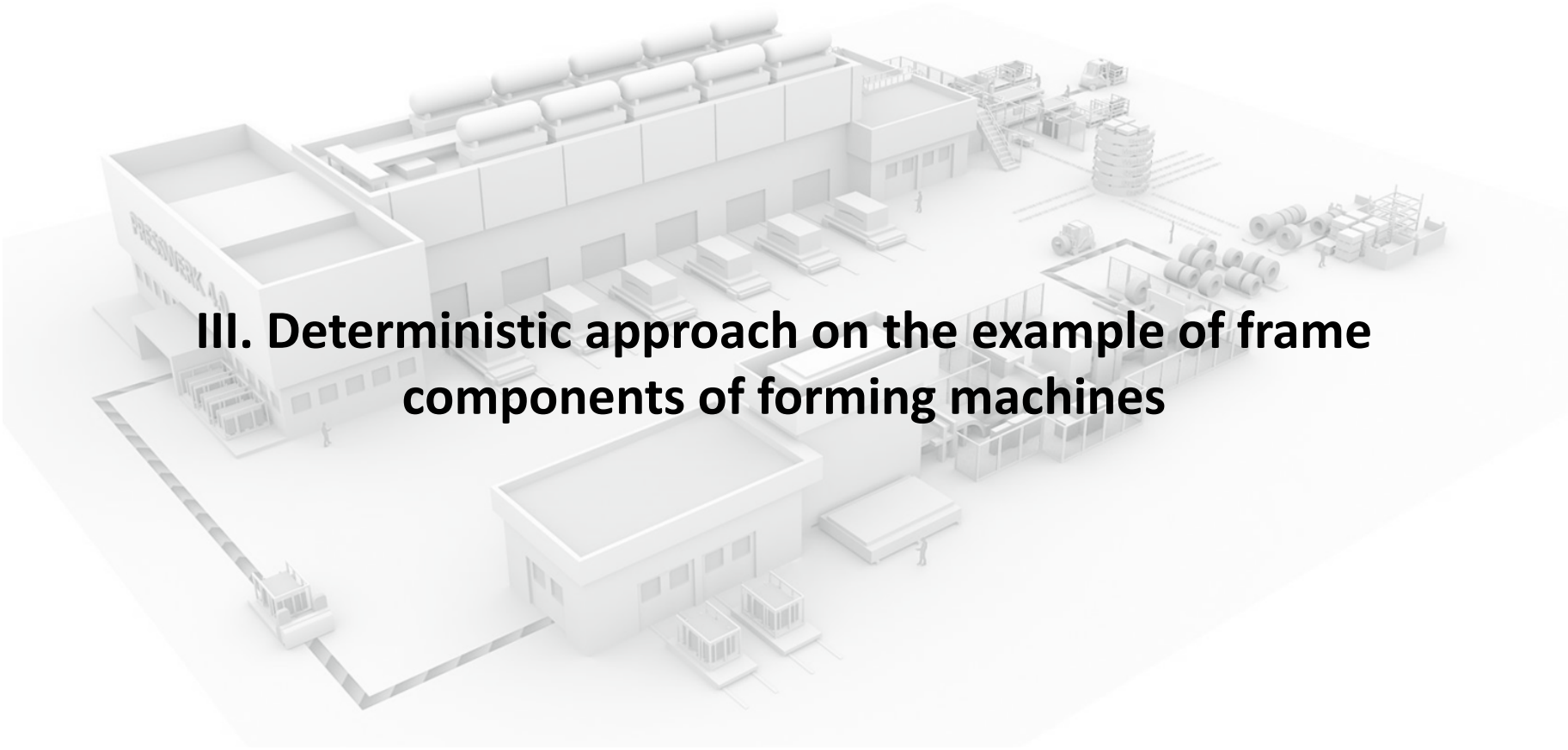


Deterministic description of load - failure - relation (➔ models)

- quality of the model and the input parameters essential
- even for unique systems possible

Pattern recognition, Data-mining, Machine learning,… (➔ artificial generation of knowledge)

- „learning“ from the history
- **large data base necessary**



III. Deterministic approach on the example of frame components of forming machines

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Initial situation

Fatigue cracks on frame components of forming presses

- Press crown, table, ram
- Hydroforming components

High costs caused by

- Undetected cracks → change of press characteristics → product quality!
- Production shifting
- Costly & time consuming repair → long down times!
  - Welding (if possible) often only a temporary solution
  - Manufacturing of new components

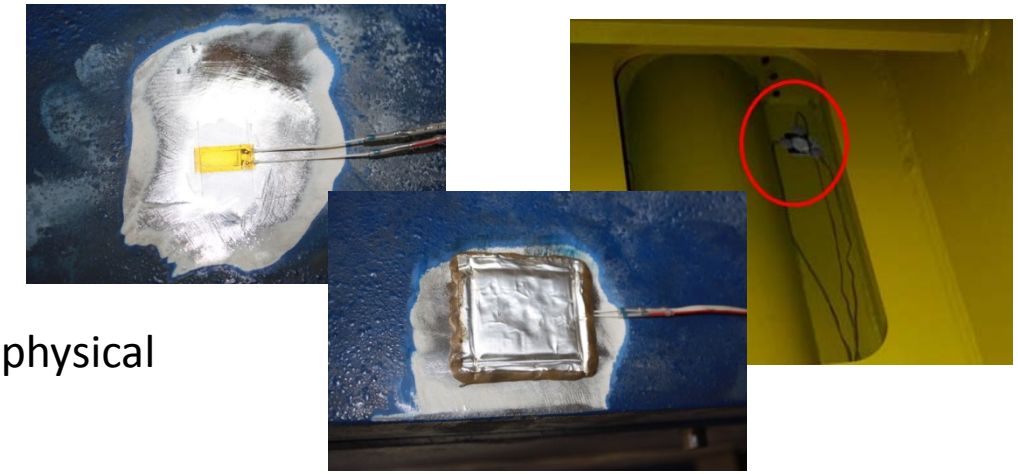
Automated monitoring and accumulation of mechanical stresses for the early detection of overloads and for the avoidance of fatigue cracks recommended

III. Deterministic approach on the example of frame components of forming machines

Monitoring of mechanical stresses

Challenges in the stress monitoring by strain gauges

- Definition of critical spots under real loads is difficult
- Strain gauge application often problematically
  - Limited accessibility (corners, inner structures)
  - High number of sensors necessary (cost of instrumentation, cables!)
  - Calibration of sensors!
  - Lifetime of sensors!



Approach

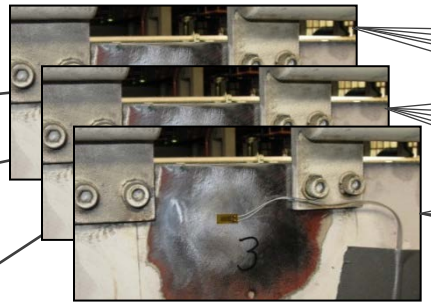
- Combination of real sensors and und physical models (**„Virtual Sensory“**)

III. Deterministic approach on the example of frame components of forming machines

Principle of Virtual Sensory for stress monitoring in mechanical components

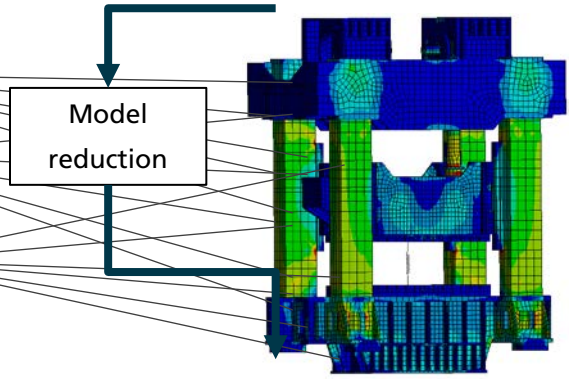
Forming press

Real sensors



- local selective assessment
- critical zones inaccessible (i.e. indentations)
- **limited information**

Virtual sensors

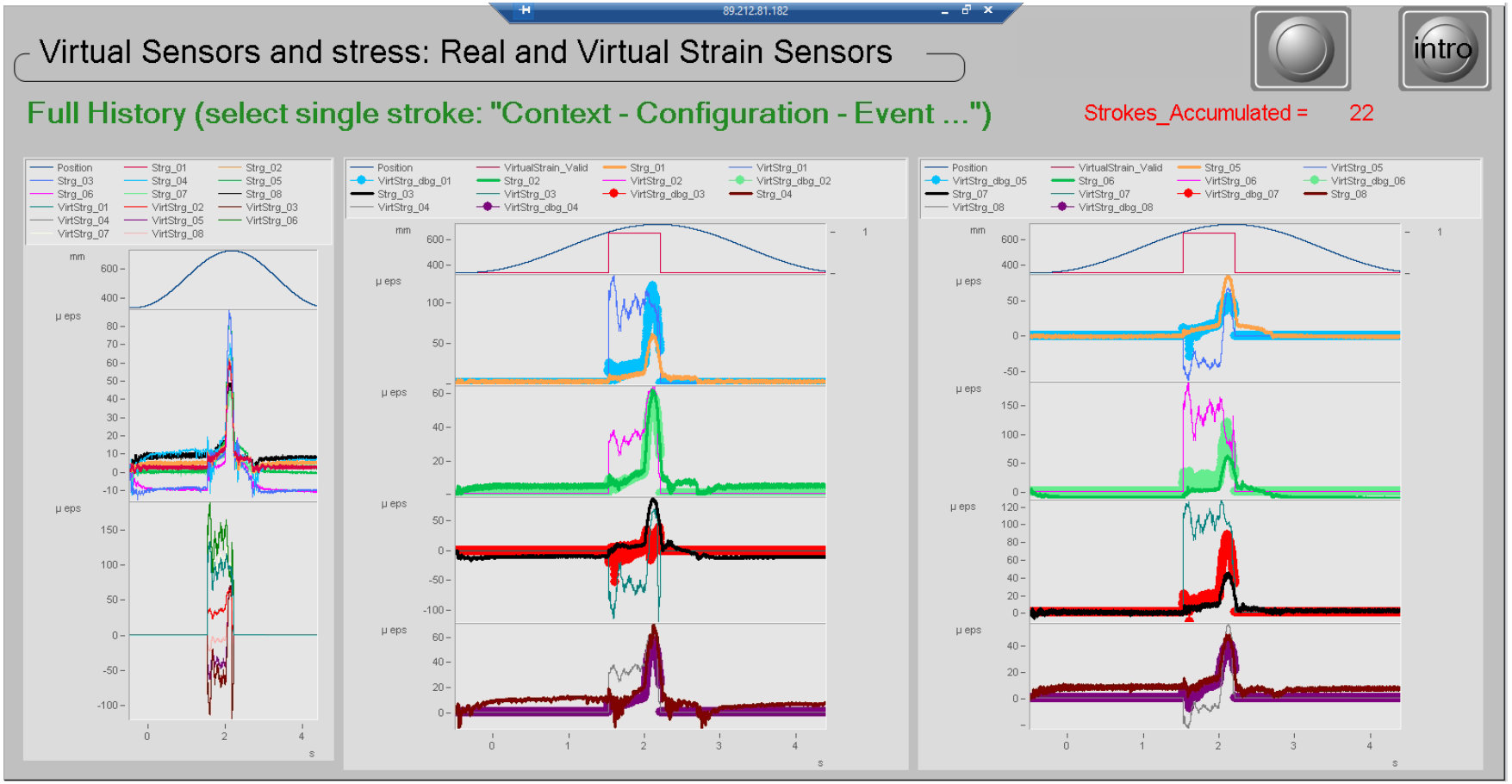


- global assessment of complex structures
- cover critical zones
- **"unlimited" information**

Also: „Secondary usage" of design data / models

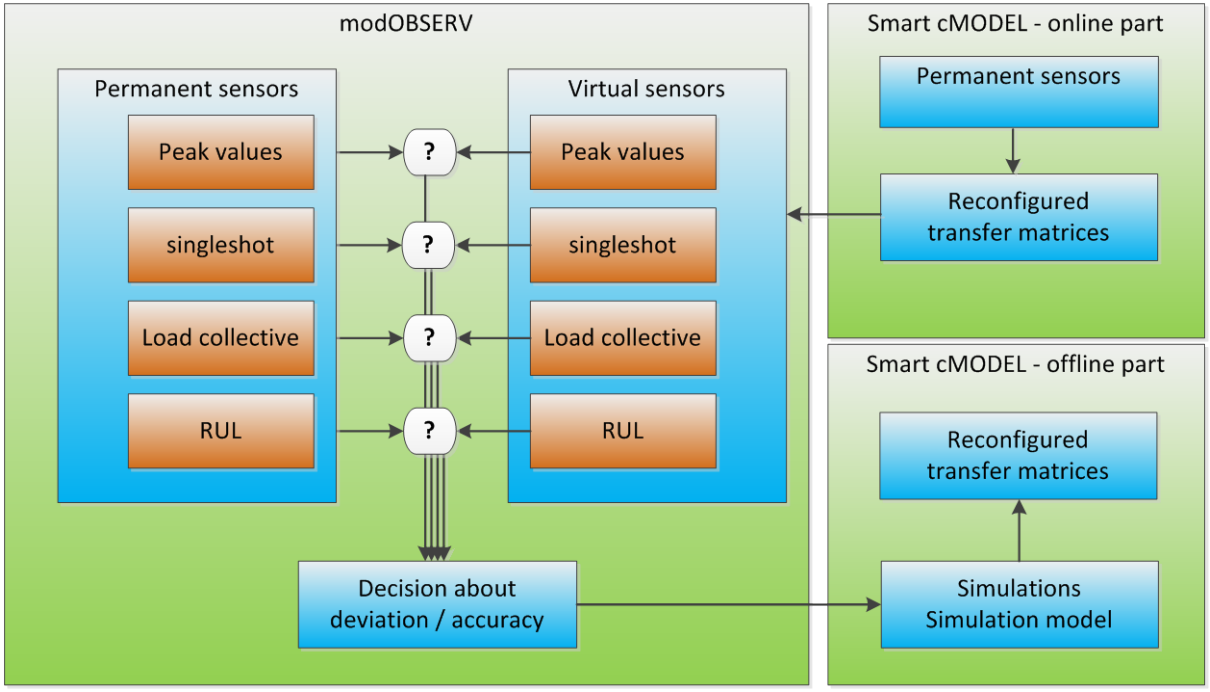
III. Deterministic approach on the example of frame components of forming machines

Monitoring mechanical strains and stresses in time domain



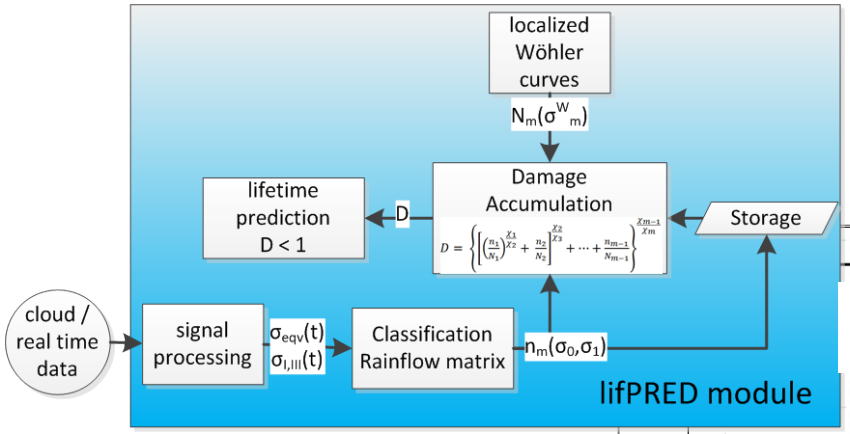
III. Deterministic approach on the example of frame components of forming machines

Accuracy monitoring of the Virtual Sensors (modOBSERV)



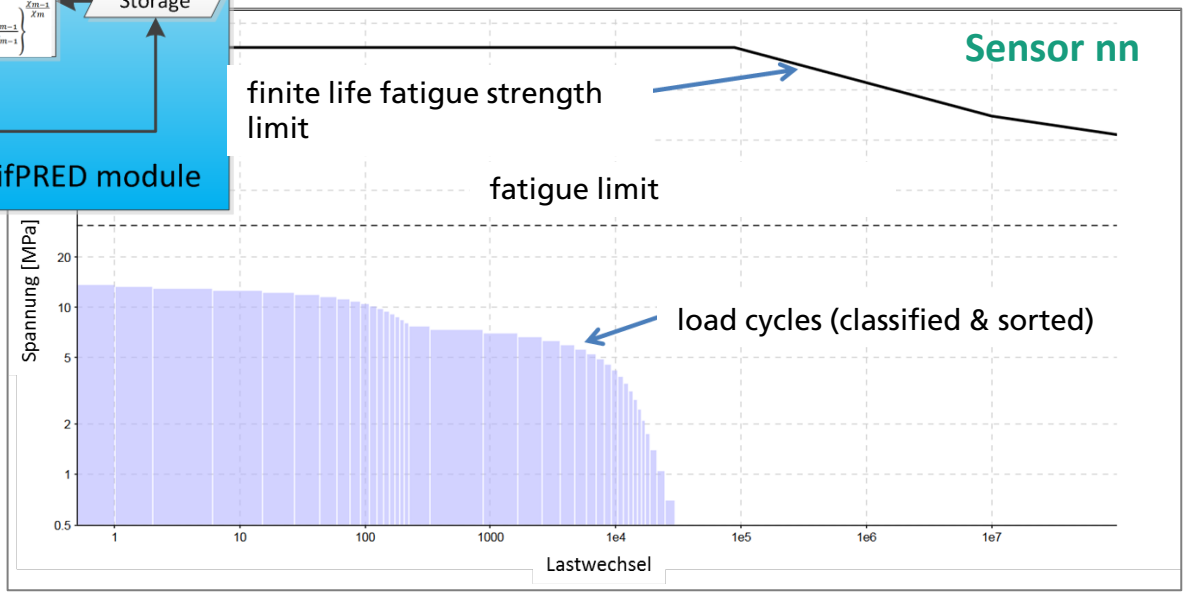
III. Deterministic approach on the example of frame components of forming machines

Evaluation regarding fatigue strength and RUL

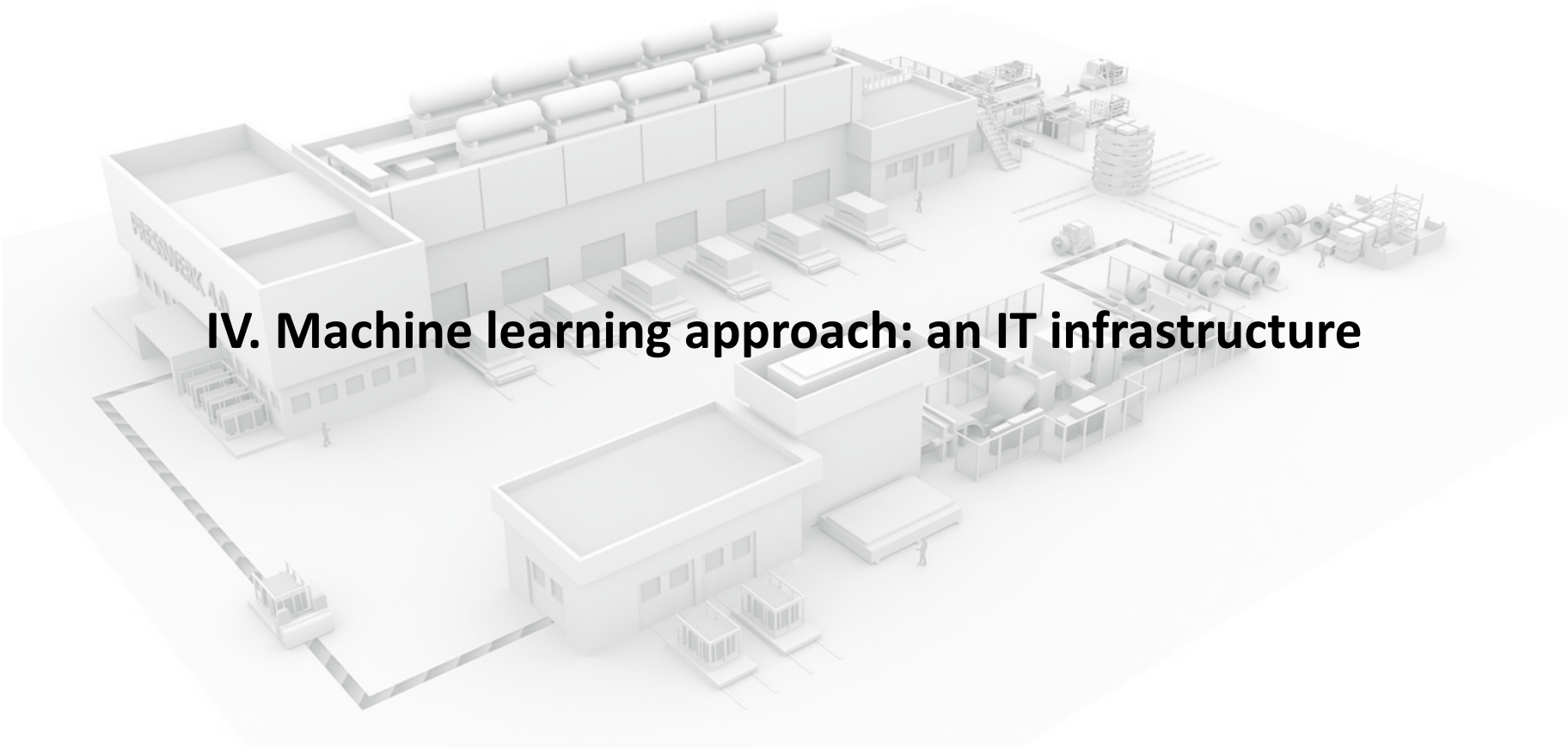


Methodology

Application of the linear cumulative damage hypothesis



RUL estimation: Evaluation of the distance between real stresses and finite life fatigue strength limit [in number of load cycles]



IV. Machine learning approach: an IT infrastructure

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Initial situation

Additional critical components of forming machines

- Main drive (motor, bearing, flywheel, transmission, clutch)
- Crank assembly
- Press guide (slide guide)
- Tappet balancing
- Process media (oil, air)

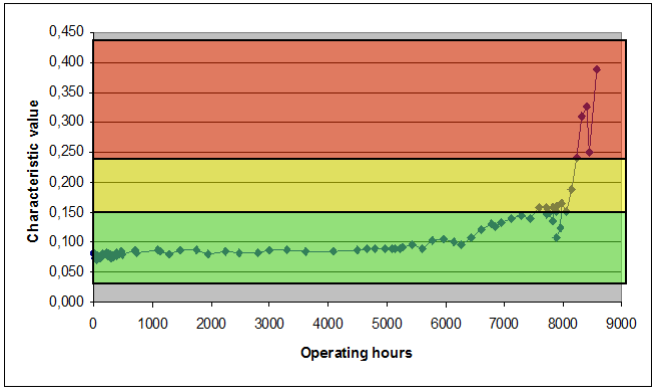
Wear models rarely/not available

SoA monitoring concepts

- Threshold definition
- Estimation of short-term trends

Challenges for prediction

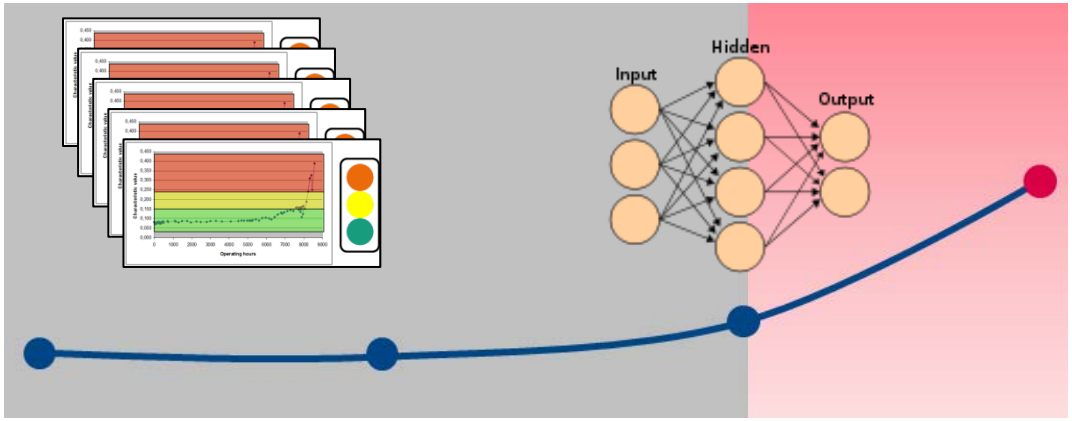
- Data base for „non-deterministic“ methods to small



IV. Machine learning approach: an IT infrastructure

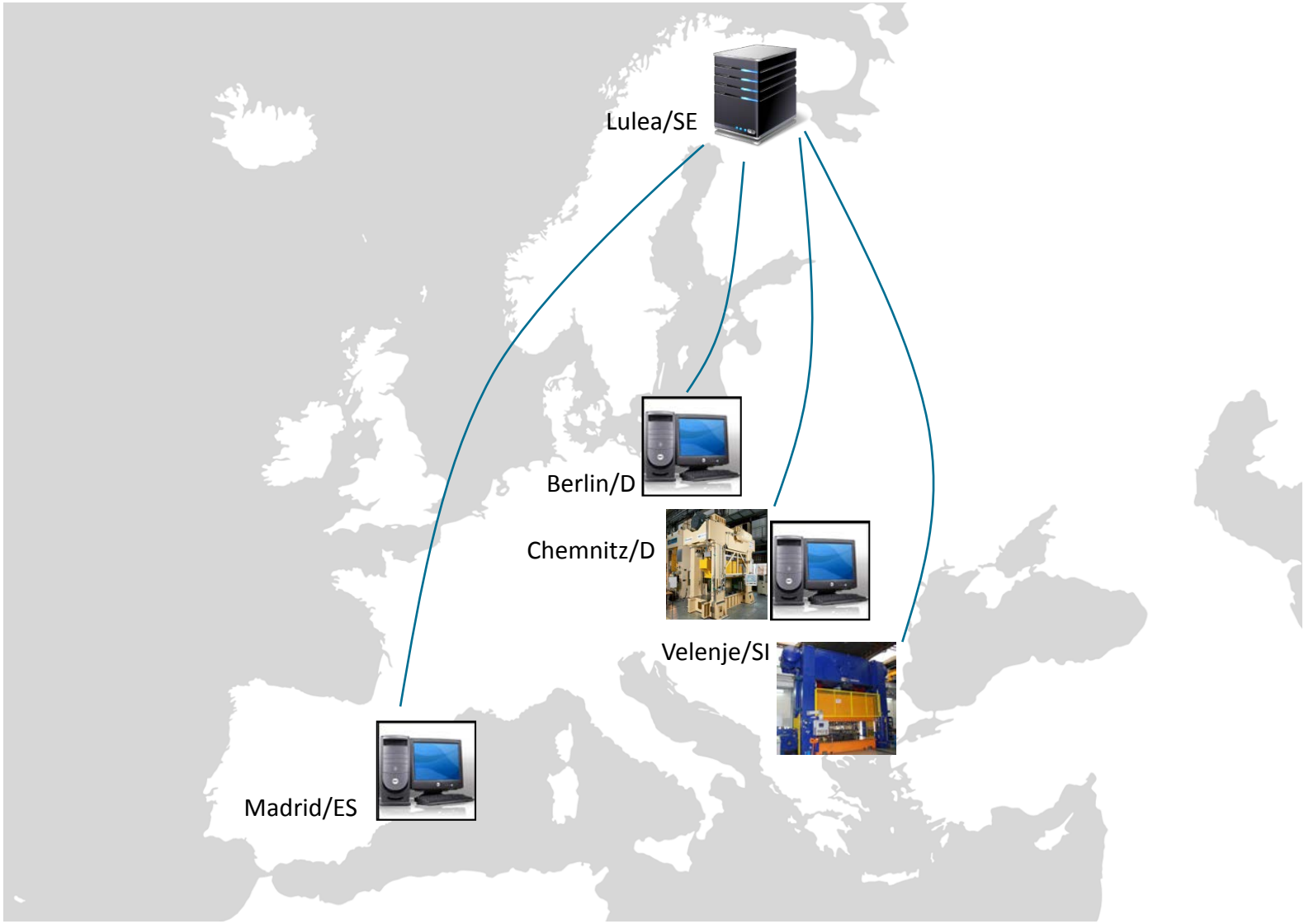
Approach

- Increasing data base by networking similar systems/machines
- Generation of added value from „conventional“ CM systems
- Learning from the history for the future



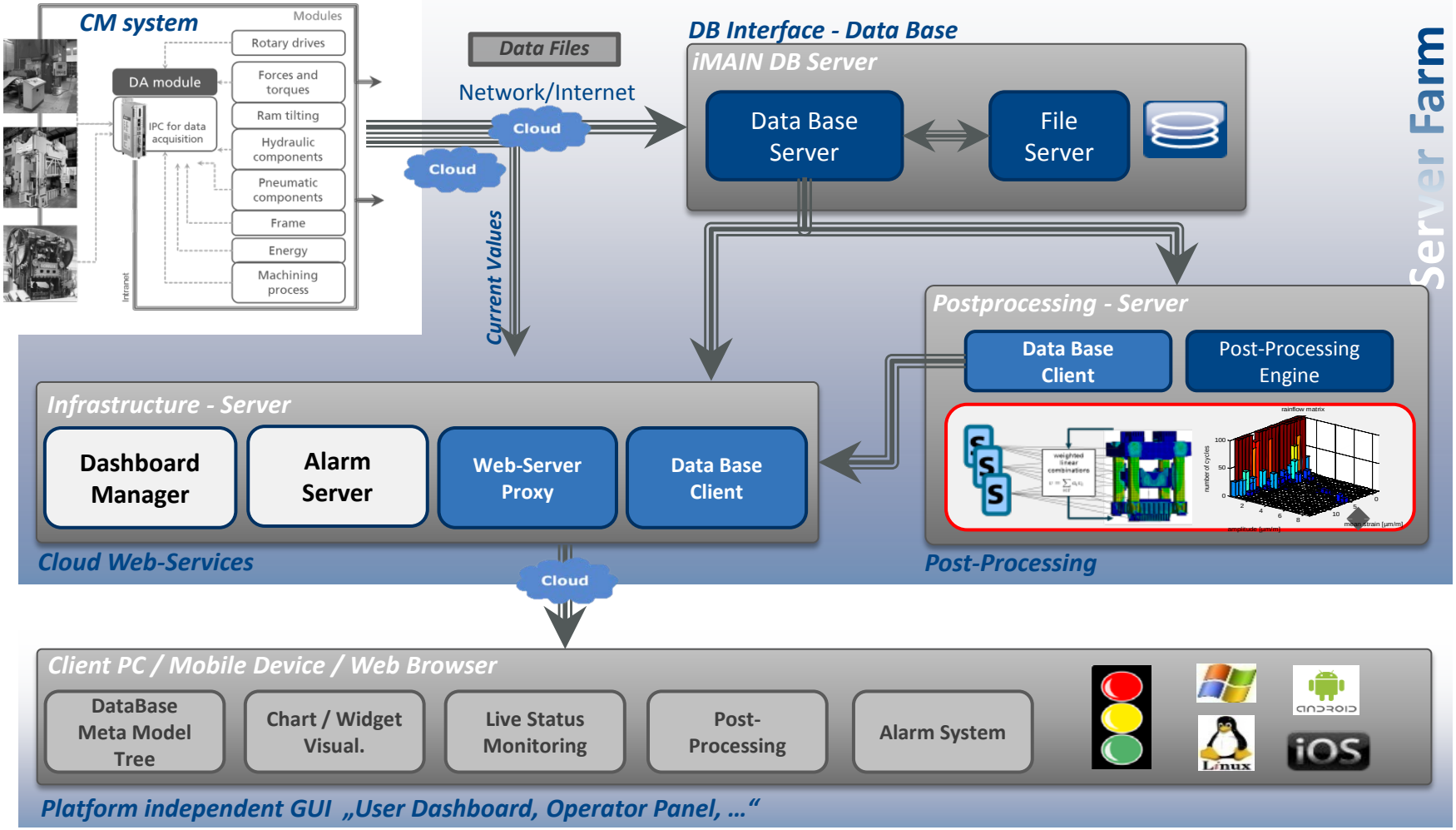
Development of an IT infrastructure for networked (and cooperative) maintenance

IV. Machine learning approach: an IT infrastructure



IV. Machine learning approach: an IT infrastructure

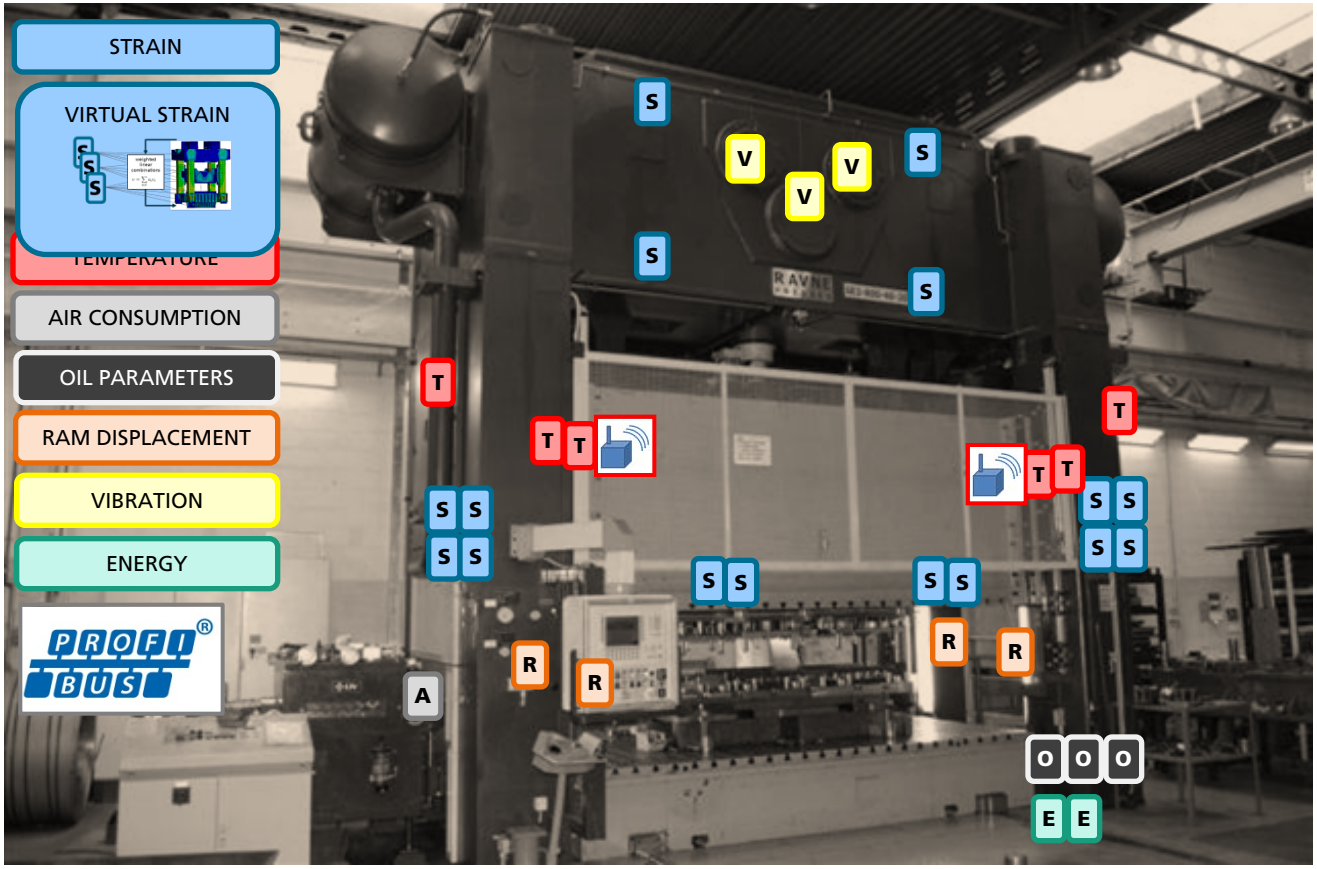
Solution example (EU Project iMAIN)



Fraunhofer IWU

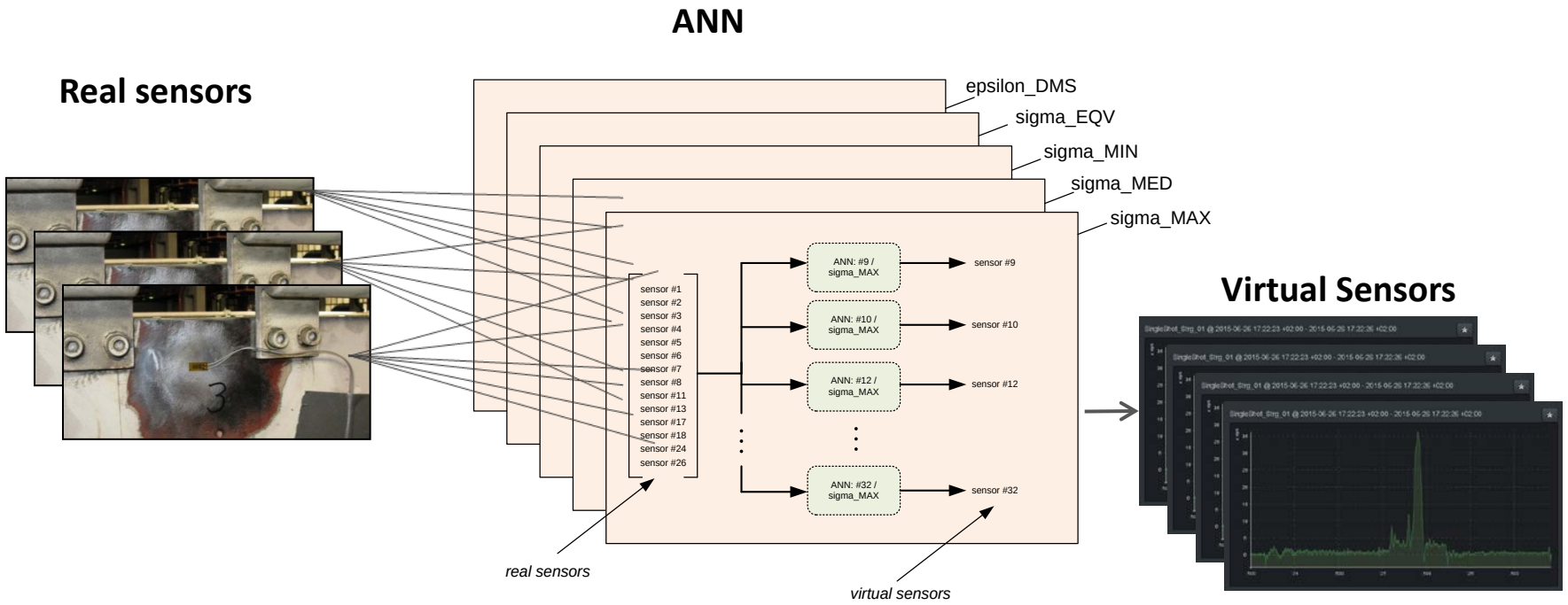
IV. Machine learning approach: an IT infrastructure

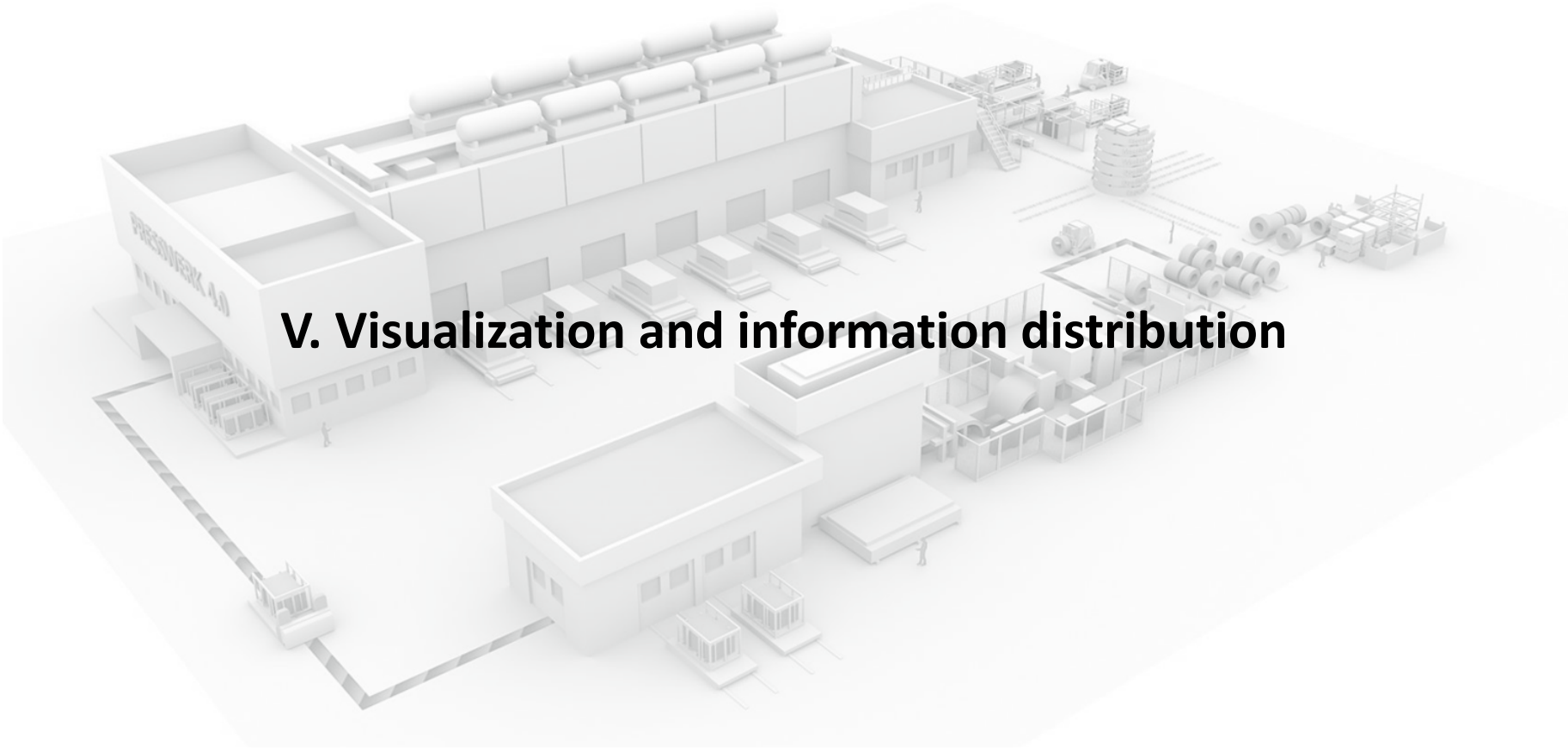
Data acquisition Slovenia



IV. Machine learning approach: an IT infrastructure

Test example: Artificial intelligence (AI):
Model reduction and development of Virtual Sensory by artificial neural networks (ANN)





V. Visualization and information distribution

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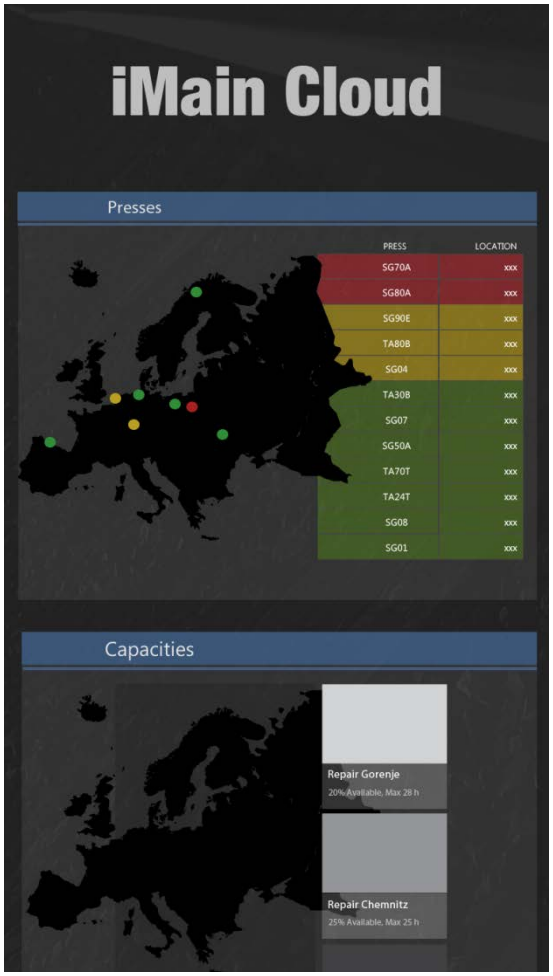
Information and Alerts:* *at the right time, at the right place



Information access with access control

- Web Browser
- Mobiles (Web Browser, App, SMS)
- Interfacing to ERP
- Interfacing to SAP

Alerts and Status

- Next to the machine
- via Email
- via SMS
- Browser-based dashboard

V. Visualization and information distribution

Example GUI: browser based

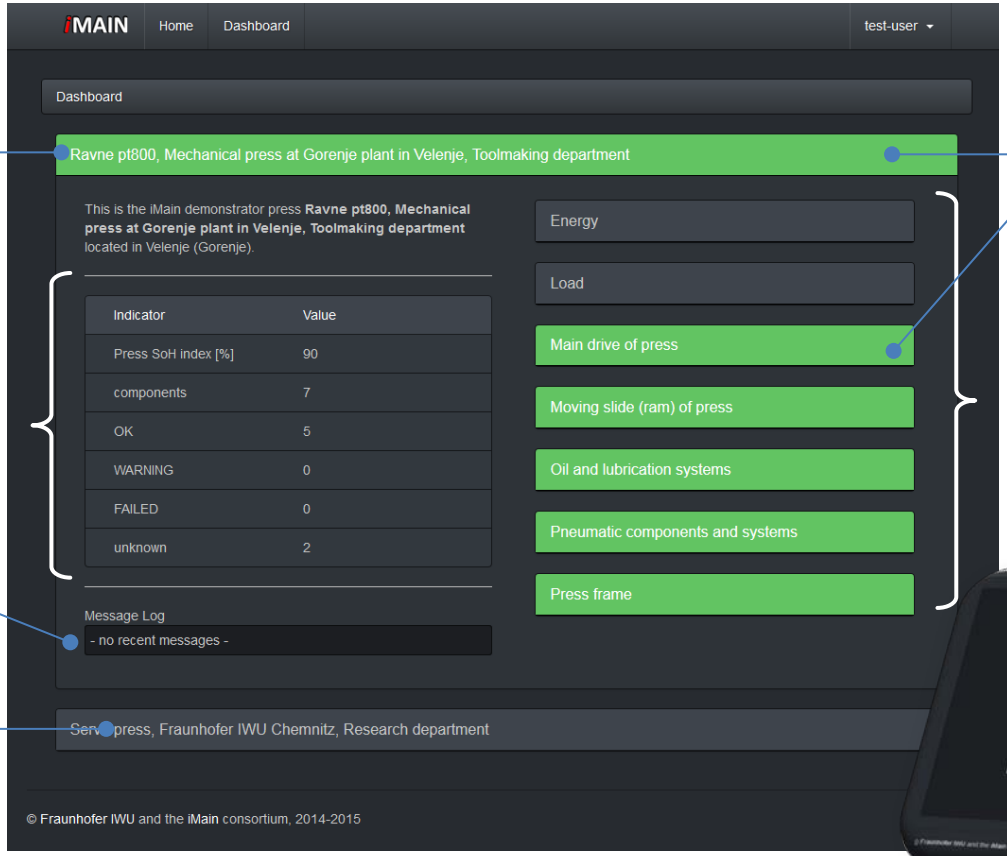
First page after login

Object selection:
Press 1

Key Performance Indicators **(KPI)**

Alarm messages

Object selection:
Press 2
Press n



Color: health status of
(a) Press machine
(b) Main groups

Main component groups

Dashboard login page

V. Visualization and information distribution

Example GUI: Monitoring of mechanical stresses and load history

Full resolution: „SingleShot“

Reduced to „Peak per Stroke“ → trends

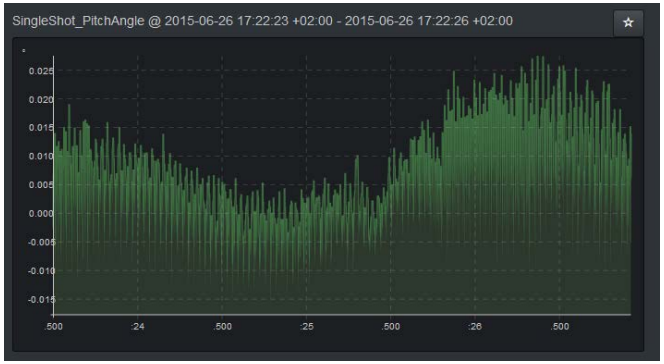
Rainflow ClassCounting

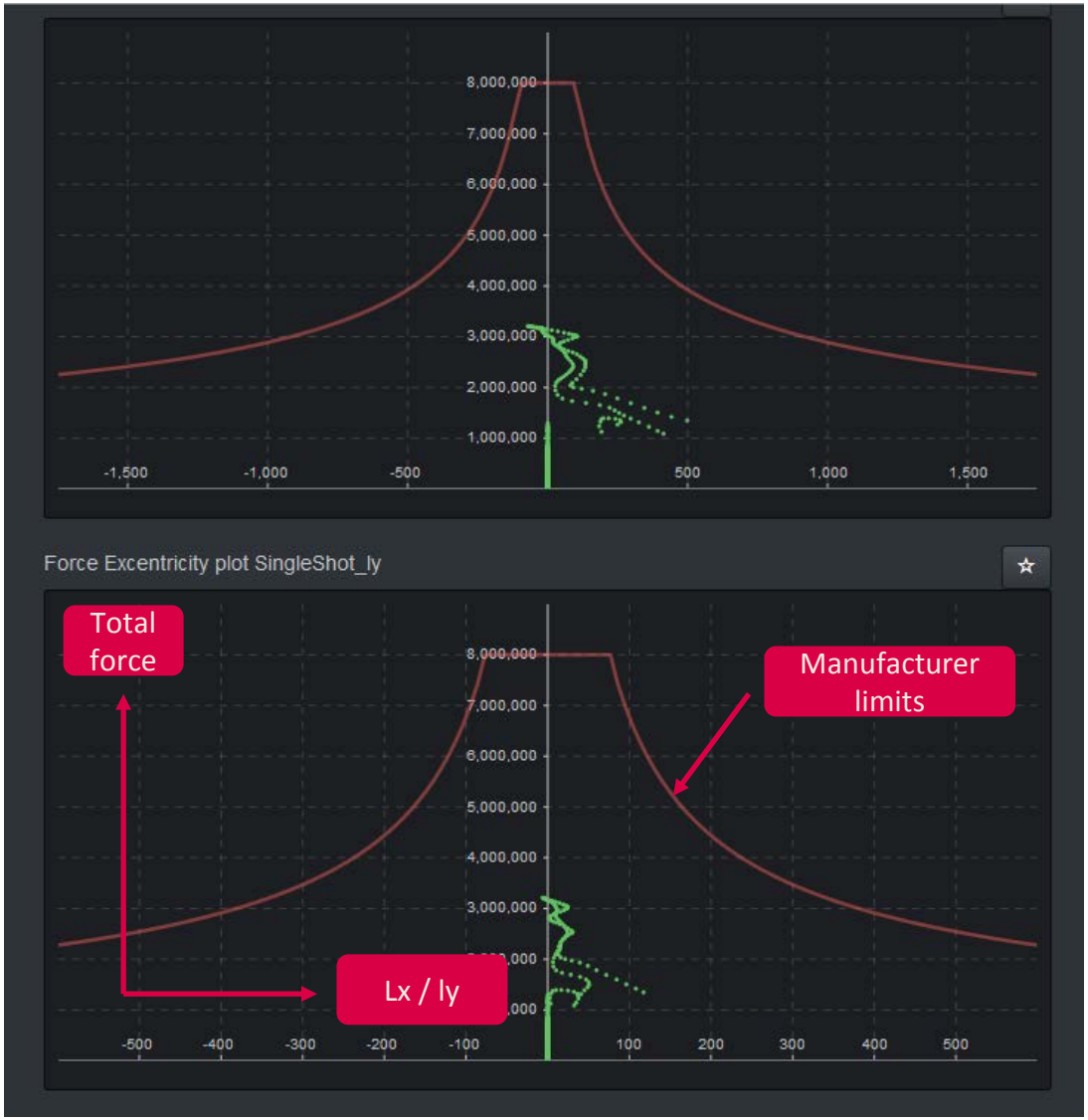
Accumulated load history (Wöhler)

V. Visualization and information distribution

Monitoring ram tilting

Ram Tilt: Pitch angles



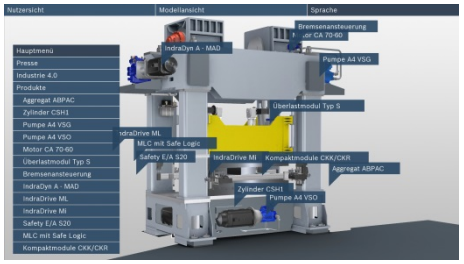


Excentric force injection:
XY plot :
Total force (Y) versus
off-center coordinates (X)

V. Visualization and information distribution

Virtual & Augmented Reality for Maintenance Support and Service

Virtual Reality (VR)
3D visualisation of assets



Augmented Reality (AR) /
Glasses

Applications
Intelligent HMI

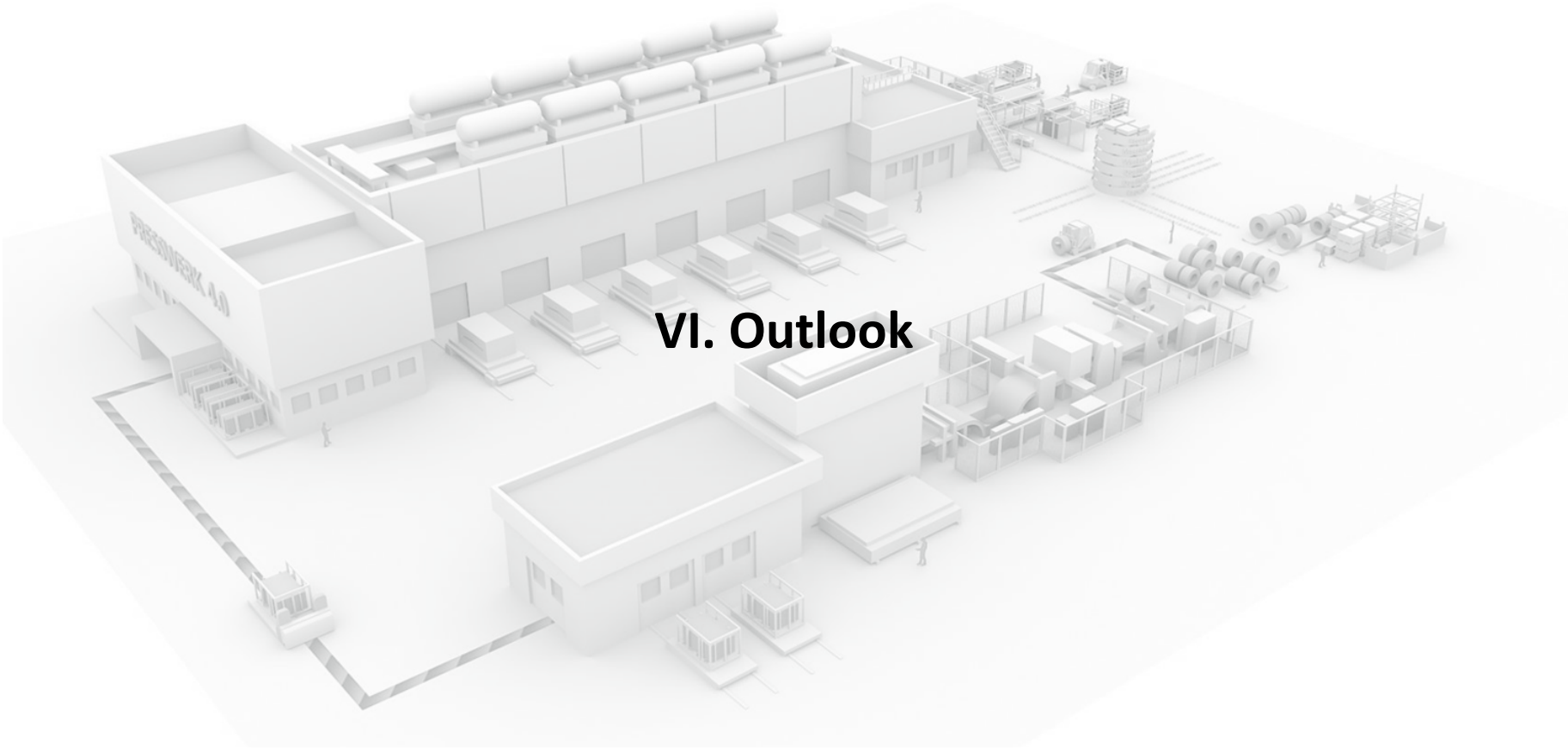
- Individualised information for every user
- Actual, relevant information locally
- Live-Condition-Monitoring
- Diagnosis/ failure causes
- Standardised control
- Service applications
- Energy flow visualisation
- Presentation

- Various systems: (3D-)Monitors, Tablets, Smartphones, -glasses, -watches

Overall system and networking

- Cloud-based data storage
- Intelligent data evaluation for generation of new information
- RUL estimation
- Optimisation of tracking and navigation in shop floors
- Online parameter optimisation of press drives

Improved Man-Machine-Interaction / Improvement of process quality / cost reduction



VI. Outlook

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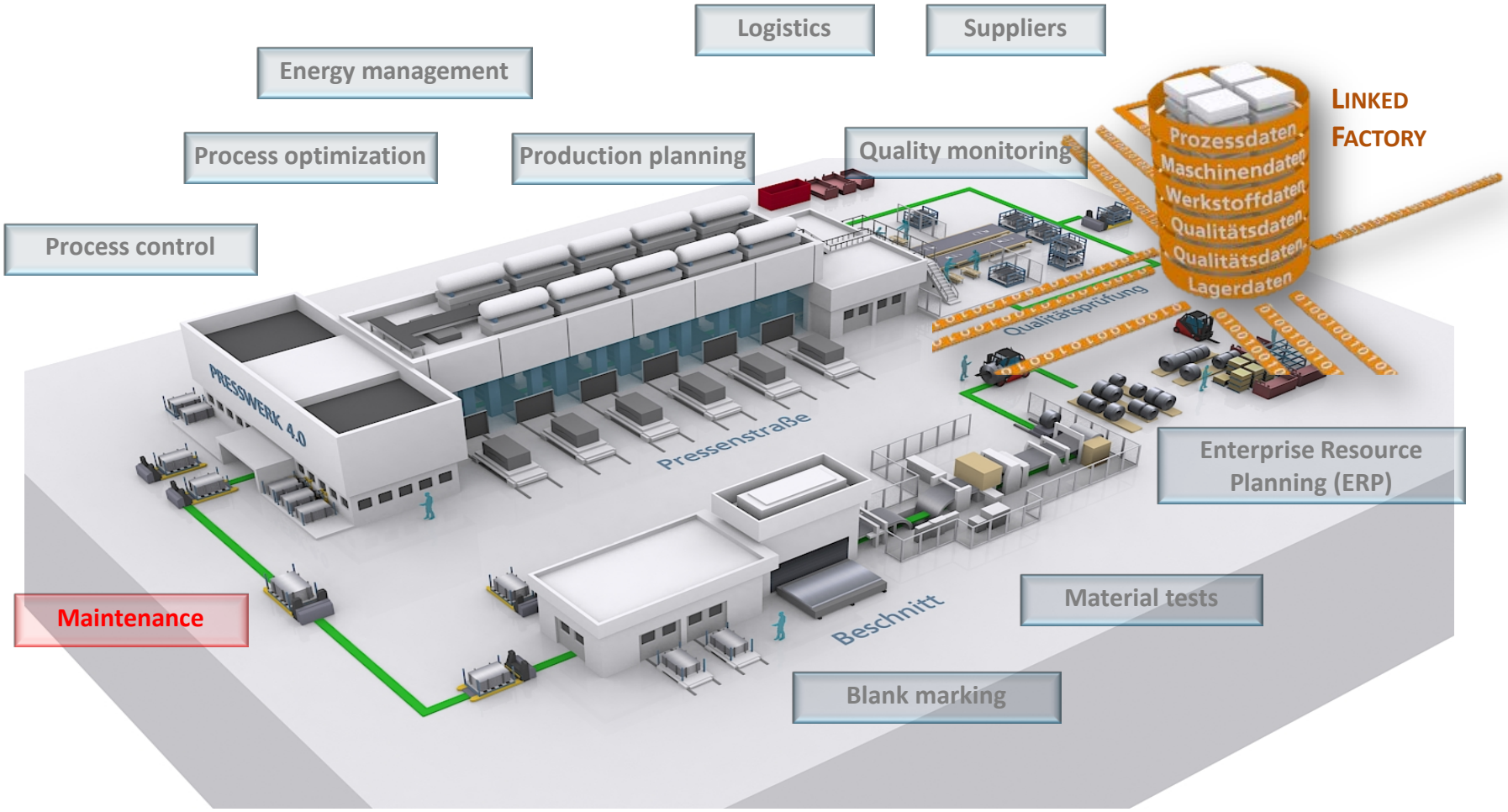
Press Shop 4.0 (Presswerk 4.0) – a strategic research frame



VI. Outlook

EU Cluster MAINTENANCE@FoF

MAINTENANCE in Factories of the Future

www.mainfof.eu

Horizon 2020
European Union Funding
for Research & Innovation

Partners und working areas

iMAIN	Machine tools (Forming presses), all other highly loaded mechanical systems
Power-OM	Machine tools (milling)
EASE-R³	Machine tools
T-REX	Machine tools, spindles, robotics, transport systems (lift trucks), batteries
SelSus	Manufacturing devices, assembly lines, fixtures
eFBorn	Machinery, Robotics, in-line manufacturing (AM)
whiteR	White rooms: Robots, effectors, transportation, dna fixturing systems
SUPREME	Paper industry

Cluster Expert Workshop to discuss and define EU research foci EU 2030

- Brussels, 15.-16. February 2016
- Roadmap will be published in October 2016
- Additional workshops & roadmaps: Zero Defect Manufacturing, Robotics, High Precision Manufacturing, Clean Factory

THANK YOU

FOR YOUR ATTENTION

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