ESTEP
European Steel Technology Platform

ESTEP Focus Group Smart Factory

AI for Steel
ESTEP Workshop

Overview, recent developments and future trends

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Live Congress,
Leoben
Austria

PROCTWIN

BFI Excellence in Applied Research

celsa GLOBAL STEEL WIRE

Surface quality control for steel long products via digital twins, new sensors and AI

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mcl

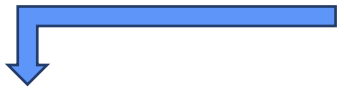
K1 MET
metallurgical competence center

PRIMETALS TECHNOLOGIES

voestalpine
ONE STEP AHEAD.

The ProcTwin project

- ProcTwin aims to develop a demonstration platform to predict and visualize best use of multiple processing steps in a steel manufacturing chain.
- Integration of sensor technology, digital twins and AI for cross-process monitoring and control.
- 2 industrial use cases: Plate quenching and wire rolling
- Led by Swerim, duration: 2025 – 2028.



Focus of this presentation

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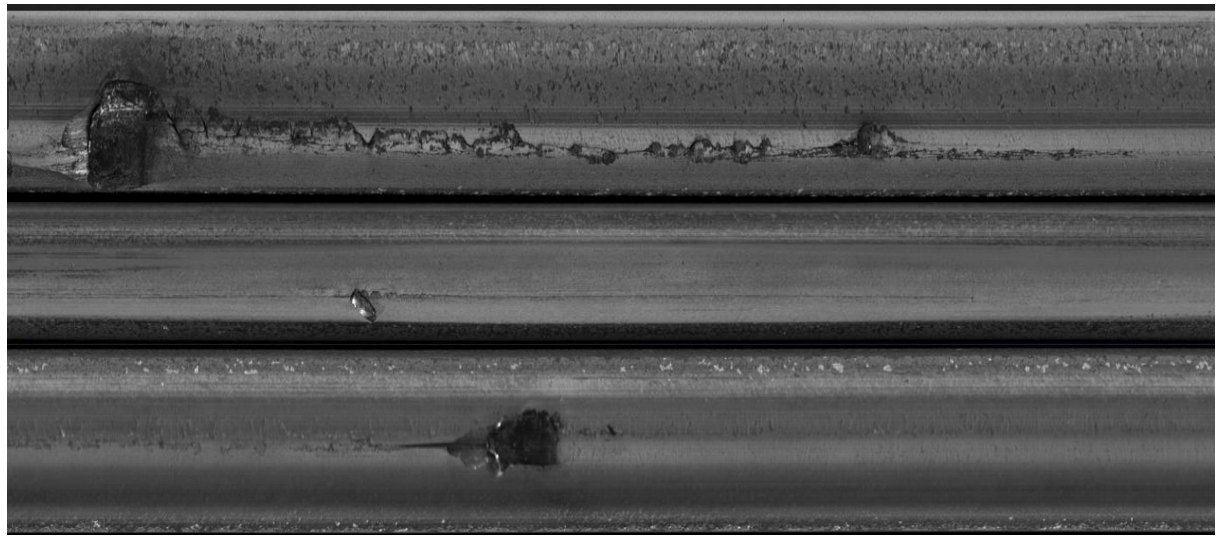
Surface defects on steel long products

- Surface defects are a major steel quality problem. They come in different types:
  - Transverse cracks
  - Longitudinal cracks
  - Slivers
  - Slag defects
  - …



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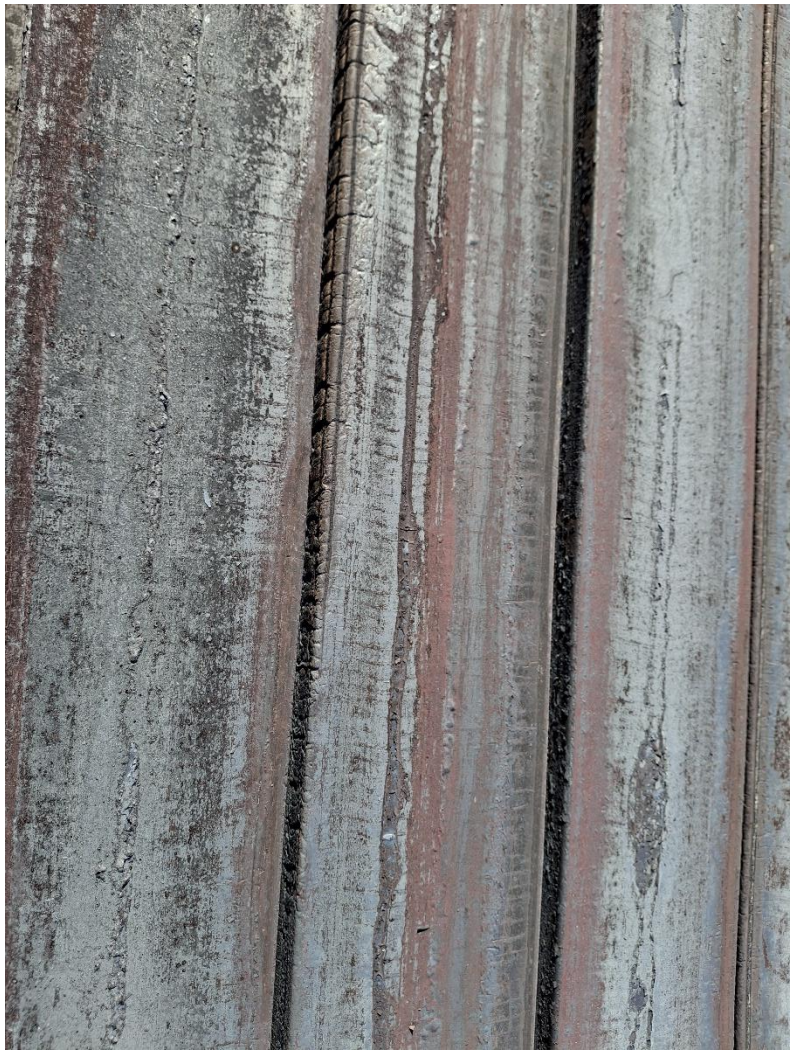
Surface defects on steel long products

- Some phenomena that can cause surface defects:
  - Inhomogeneous flow in the mould, leading to temperature gradients and causing stresses and strains
  - Oscillation marks caused by mould movement
  - Hot ductility trough at the straightener or the rolling process
  - „Hot shortness“: tramp element precipitates at grain boundaries
  - Non-metallic inclusions
  - Worn mill rolls



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Relevant parameters

Many factors impact the conditions that can lead to defects:

- Steel superheat
- Steel composition (e.g., C, Nb, V, N, Mn/S)
- Casting powder composition and spreading
- Mould oscillation rate and shape of oscillation curve
- Mould level variation
- Casting speed (mean and variation)
- Submerged entry nozzle design, clogging state & gas injection
- Cooling rates (primary, secondary cooling rate, nozzles design, …)
- Application of electromagnetic stirring, soft reduction, …
- Caster geometry, straightening forces

- Phenomenological defect predictions are possible, but complex and specific to individual steel grades
- AI promises to simplify the creation of defect predictors

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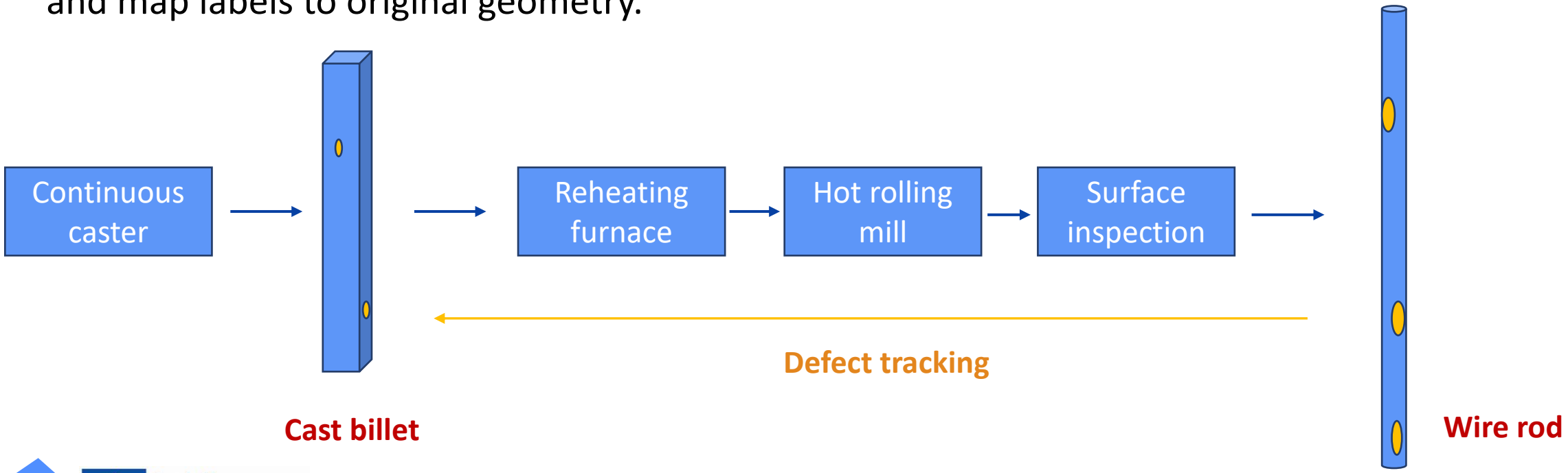
Challenges of data-driven casting defect predictors

- **Missing features**: relevant features cannot or are not measured, such as temperature gradients in liquid steel, or casting powder consumption.
- **Multi-process impact**: casting, reheating, and rolling can all impact the defect creation.
- **Material tracking for training data generation**: quality inspection is usually performed after rolling, changing the geometry of the cast semi-products. Need to track material ids and map labels to original geometry.



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Challenges of data-driven casting defect predictors

- **Data imbalance**: severe defects are usually strongly underrepresented in the dataset.
- **Heterogeneity**: many different steel grades can be produced in the melt shop, and they may be processed to different geometries in the rolling mill, each with distinct defect characteristics.
- **Sparse sampling**: the high-dimensional feature space can only be explored in narrow ranges.

⇒ Large amounts of training data needed for data-driven models

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⇨ Large amounts of training data needed for data-driven models

- **Changing conditions**: equipment wear, maintenance, or adaptation of operational practices can all invalidate a data-driven model.

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Sensors

- Relevant process data is a prerequisite for the application of AI methods to predict and control product quality
- Traditional process monitoring does not capture all relevant process parameters in continuous casting. For instance:
  - The flow of liquid steel and the solidification process itself are not amenable to measurements
  - The temperature field in the strand surface is usually only known from a few individual measurements, if at all. Temperature inhomogeneities lead to uneven solidification, stresses, etc.
  - Mould powder covering, consumption, etc., are not monitored consistently.
  - Some surface defects could be detected already after casting.

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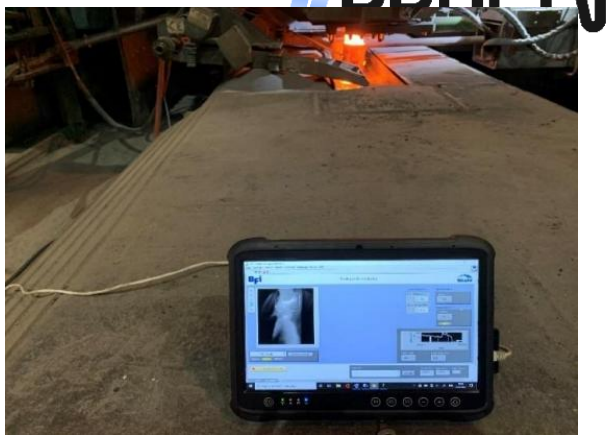
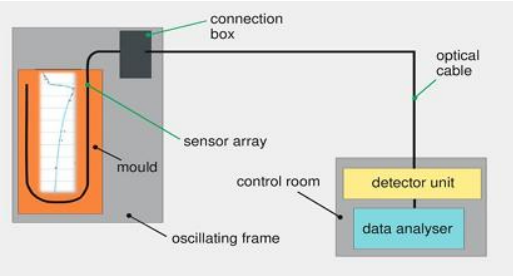
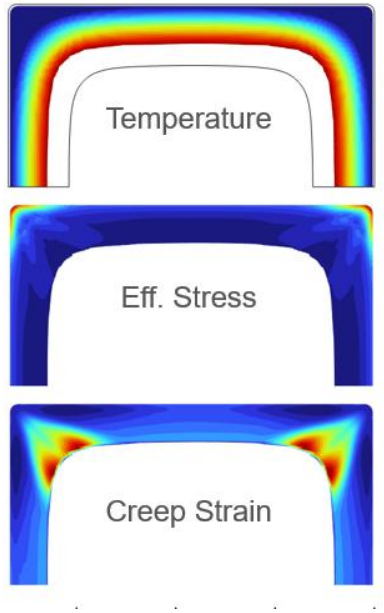
ProcTwin: new mould sensors

- Mould powder supervision
  - Camera-based
  - Challenges: dusty, hot environment, limited space
- Mould temperature supervision
  - Optical fibre based
  - Requires instrumentation of the mould; moulds are changed frequently (~once per week)
- Steel flow simulation
  - CFD simulation
  - Long execution times, offline mode only
  - Surrogate model for online operation envisioned







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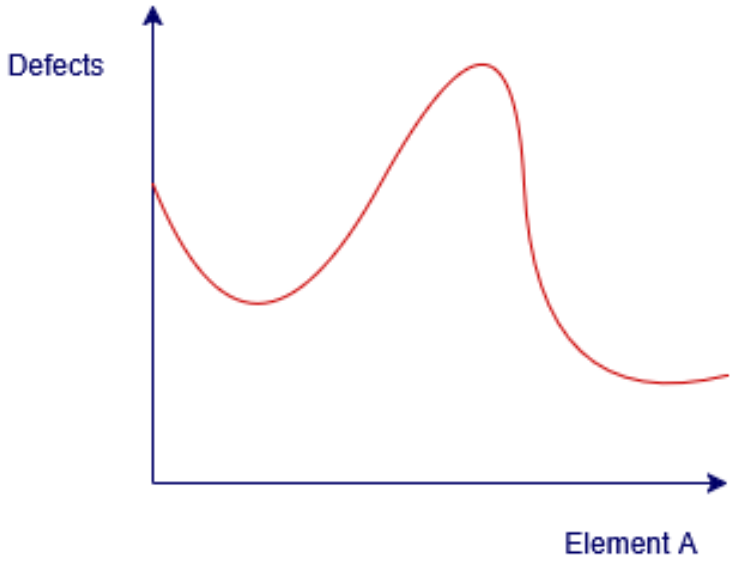
Selected initial results

- Based on 6 months training dataset, fixed set of steel grades and diameters
- Complex dependency of surface quality on chemical composition and process parameters. Example:



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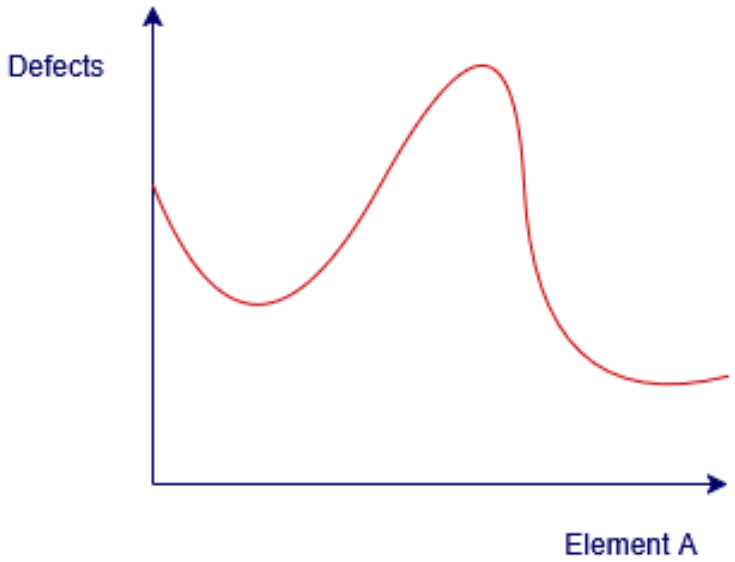

Questions:

- Correlation vs Causation?
- Are there alternative measures to reduce defects?

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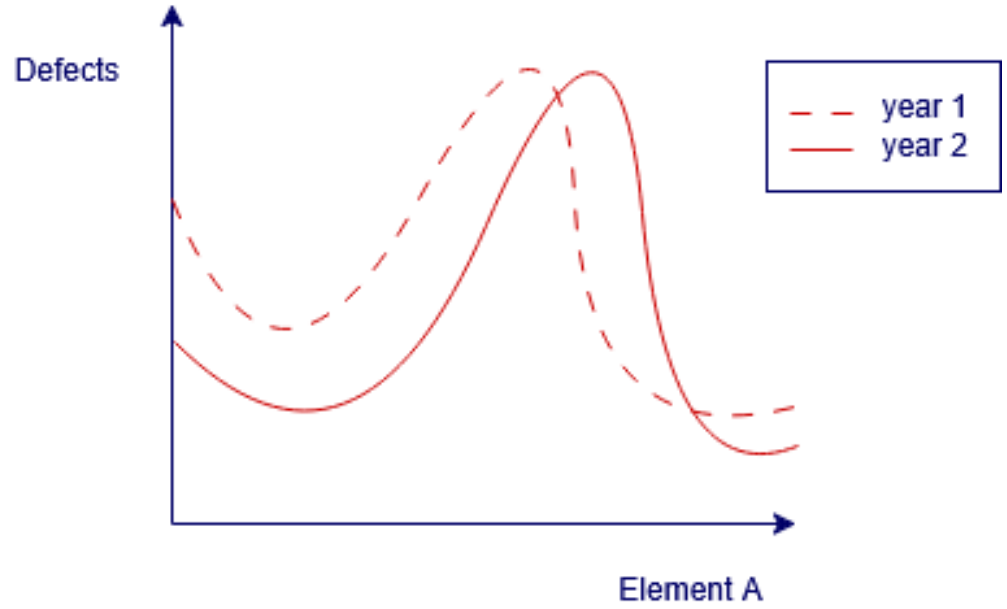
Selected initial results: drift

- Validation dataset: 6 months, 1 year later



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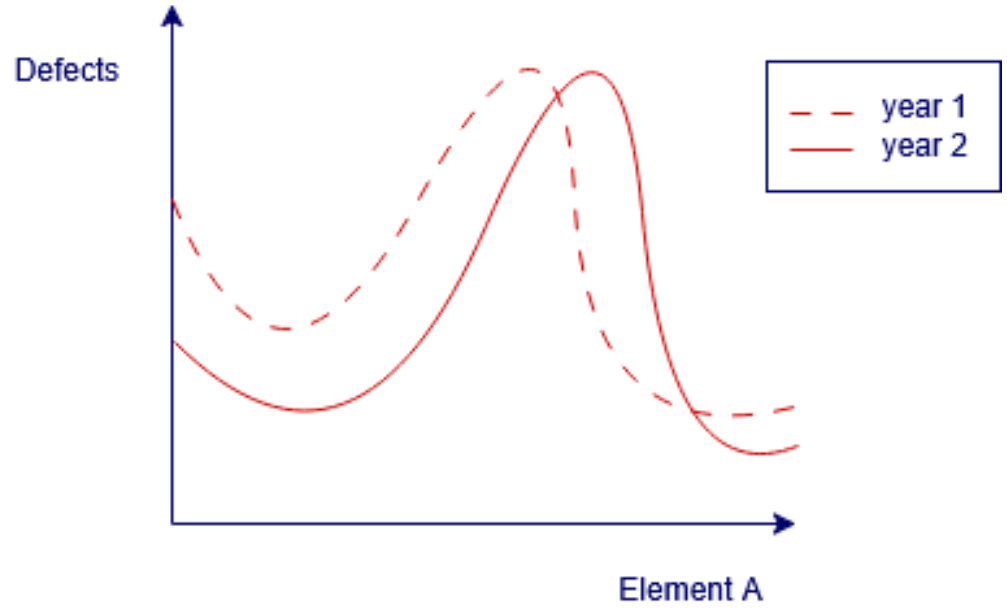

Questions:

- Drift root cause?
  - Operational settings
  - Machine wear
  - Equipment changes
  - …
- Projected future drift?

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AI application in ProcTwin

- Goal:
  - Predict and optimize the surface quality based on process parameters
- ProcTwin solution components:
  - New sensors for more comprehensive monitoring
  - Digital Twins: physics-based simulation models of critical processes
  - AI models based on timeseries process data, applying attention mechanism
  - Cross-process models capturing the interaction between casting, reheating and rolling
  - Drift-awareness and mitigation [e.g. adaptive windowing]
  - Explainability [e.g. SHAP, LIME]

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Selected research goals

- Quantify the impact of additional (soft) sensors on the predictability of surface defects
- Industrial-grade AI application
  - Cross-process consideration
  - Drift-aware
  - Correlation-aware
  - Explainable
  - Quantification of uncertainty
- Reduction of surface defects by cost-efficient measures

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THANK YOU !

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