

AIT AUSTRIAN INSTITUTE OF TECHNOLOGY

Intelligent, flexible and human-centric manufacturing systems

Cédric Jung, Florian Rötzer, **Stephan Strommer**



Dr. Bach & Prof. Kugi & Mag. Svejkovskj  AIT AUSTRIAN INSTITUTE OF TECHNOLOGY

Energy

Health &
Bioresources

Digital Safety &
Security

Vision,
Automation &
Control

Transport
Technologies

Technology
Experience

Innovation
Systems &
Policy

Seibersdorf
Labor
GmbH

Nuclear
Engineering
Seibersdorf
GmbH

Ownership

49 %

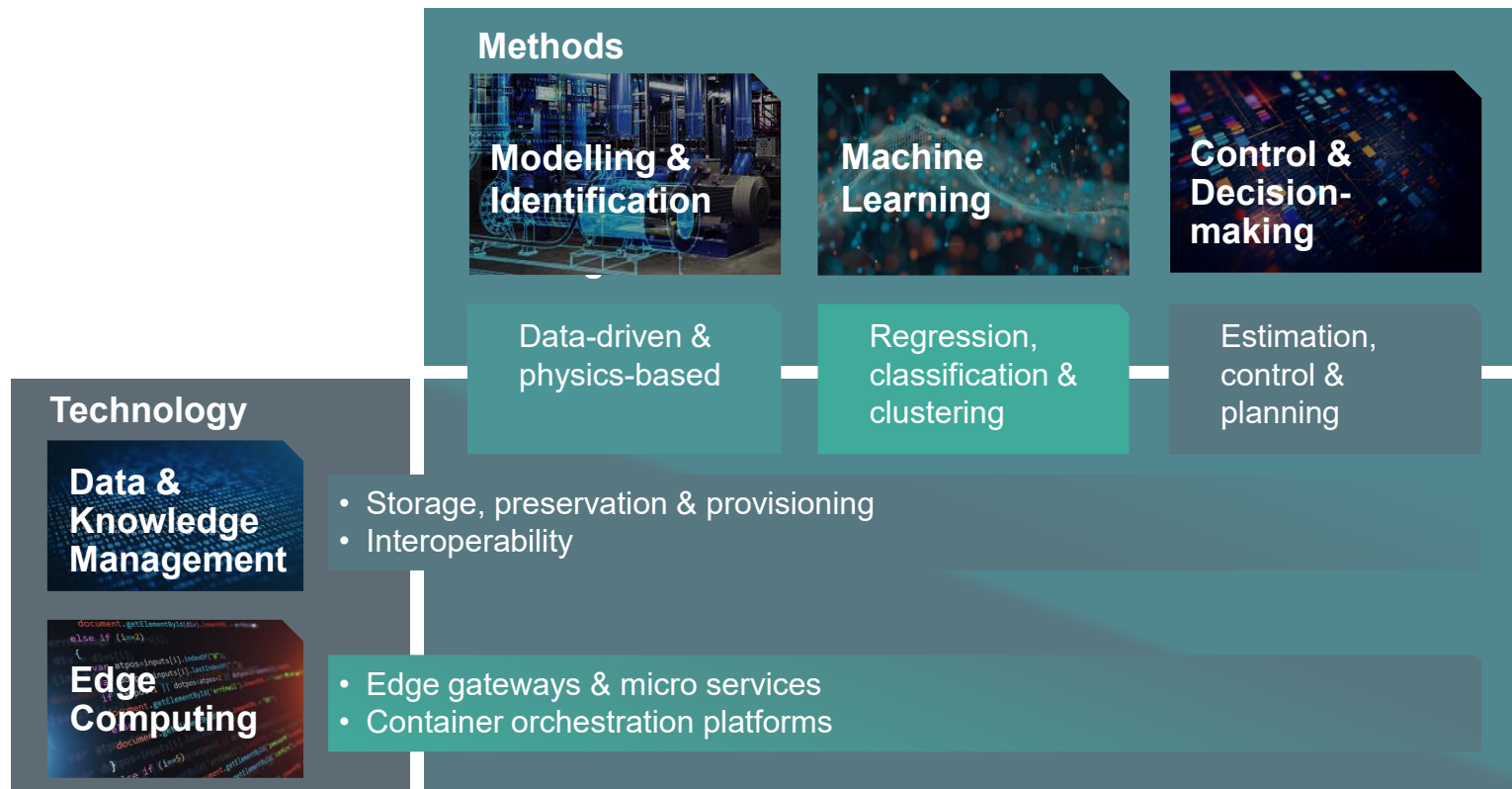
 **INDUSTRIELLEN
VEREINIGUNG**

51 %

 **Bundesministerium**
Klimaschutz, Umwelt,
Energie, Mobilität,
Innovation und Technologie

Center for Vision, Automation & Control DI Vrabl



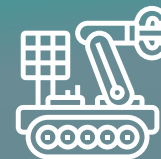


OUR SOLUTIONS



Intelligent
Process Automation

Cognitive
Robotics



Sustainable & Optimal
Process Control

- Casting, heat treatment & forming of metal products
- Injection molding



Learning & Adaptive
Mechatronics

- Electric, hydraulics & pneumatics drives
- Industrial robotics



Assistive & Cognitive
Large-Scale Robotics

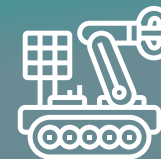
- Construction machinery
- Cranes
- Off-road vehicles

OUR SOLUTIONS



Intelligent
Process Automation

Cognitive
Robotics



Sustainable & Optimal
Process Control



Learning & Adaptive
Mechatronics



Assistive & Cognitive
Large-Scale Robotics

voestalpine
ONE STEP AHEAD.

PLANSEE

SIEMENS

ENGEL

TCG UNITECH
AUTOMOTIVE COMPONENTS

CERATIZIT
GROUP

MAGNA

FESTO



BOSCH

rexroth
A Bosch Company

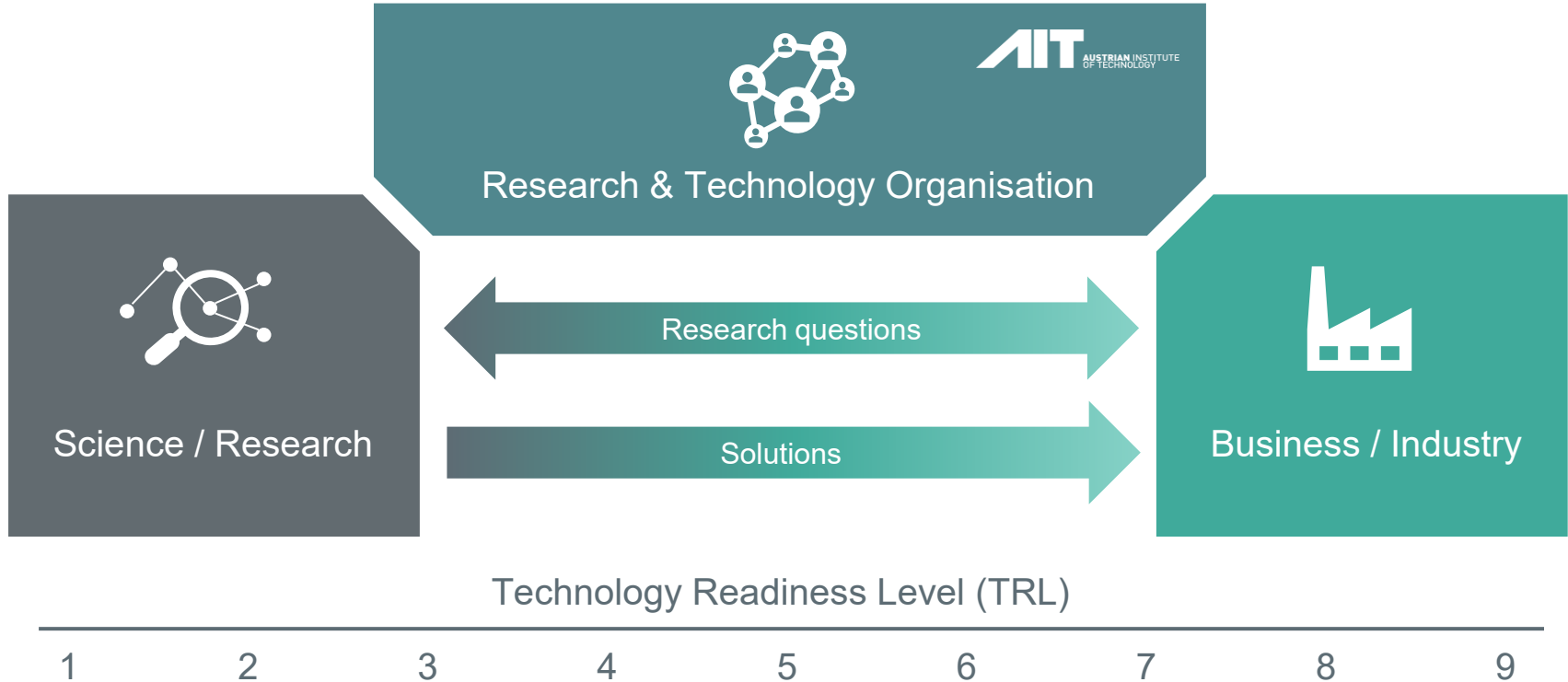
rexroth
A Bosch Company

LIEBHERR

SCHWING

PALFINGER

AIT CONNECTS RESEARCH AND BUSINESS



Core-Funded Research Projects

- Internal research agenda
- Strategic & exploratory topics

Public Co-Funded Research Projects

- National & European funding programs
- Multi-partner consortia
- 40-70% funding rate

Direct Industry Partnerships

- Bilateral contract
- 100% industry-funded
- Flexible scope & timeline

Technology Readiness Level (TRL)

1 2 3 4 5 6 7 8 9

INTELLIGENT, FLEXIBLE AND HUMAN-CENTRIC MANUFACTURING SYSTEMS

Self-optimising manufacturing systems enabling zero-defect
manufacturing



ZERO-DEFECT MANUFACTURING

Production of components with **consistently high quality** while simultaneously **reducing waste** and the **use of resources**.



**Die
Casting**



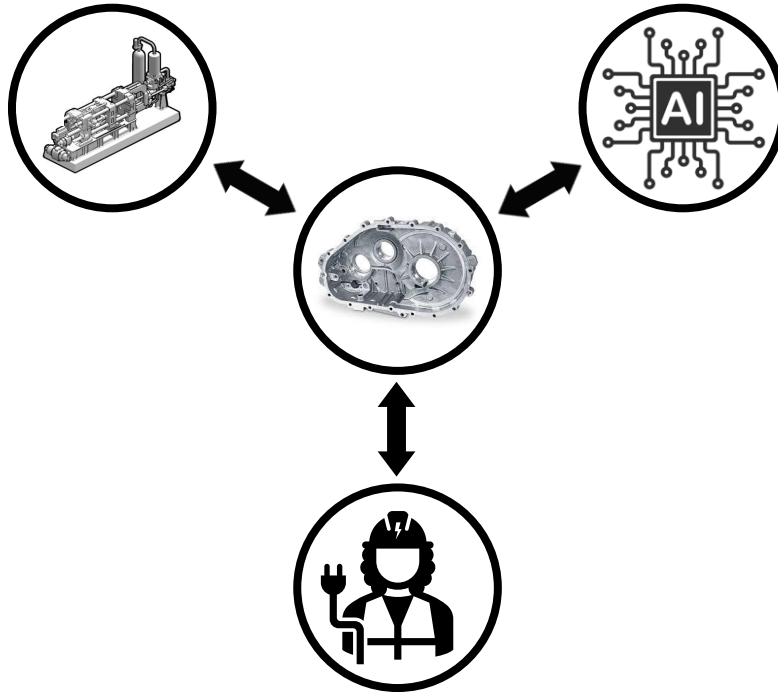
**Injection
Moulding**

BÜHLER

TCG UNITECH
GNUTTI CARLO GROUP

ENGEL





Die casting:

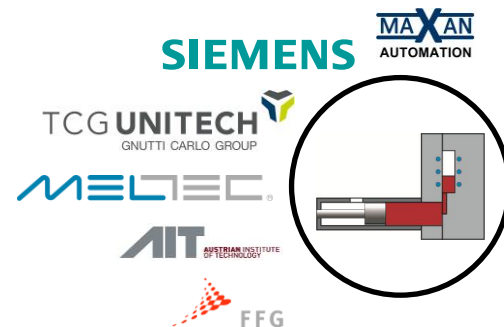
1. Human-centred assistance system
2. Shot-to-shot improvement
3. Control of the mould temperature
4. Robotic-assisted inspection

Injection moulding:

1. Quality inspection
2. Automatic machine settings

INTELLIGENT, FLEXIBLE AND HUMAN-CENTRIC MANUFACTURING SYSTEMS

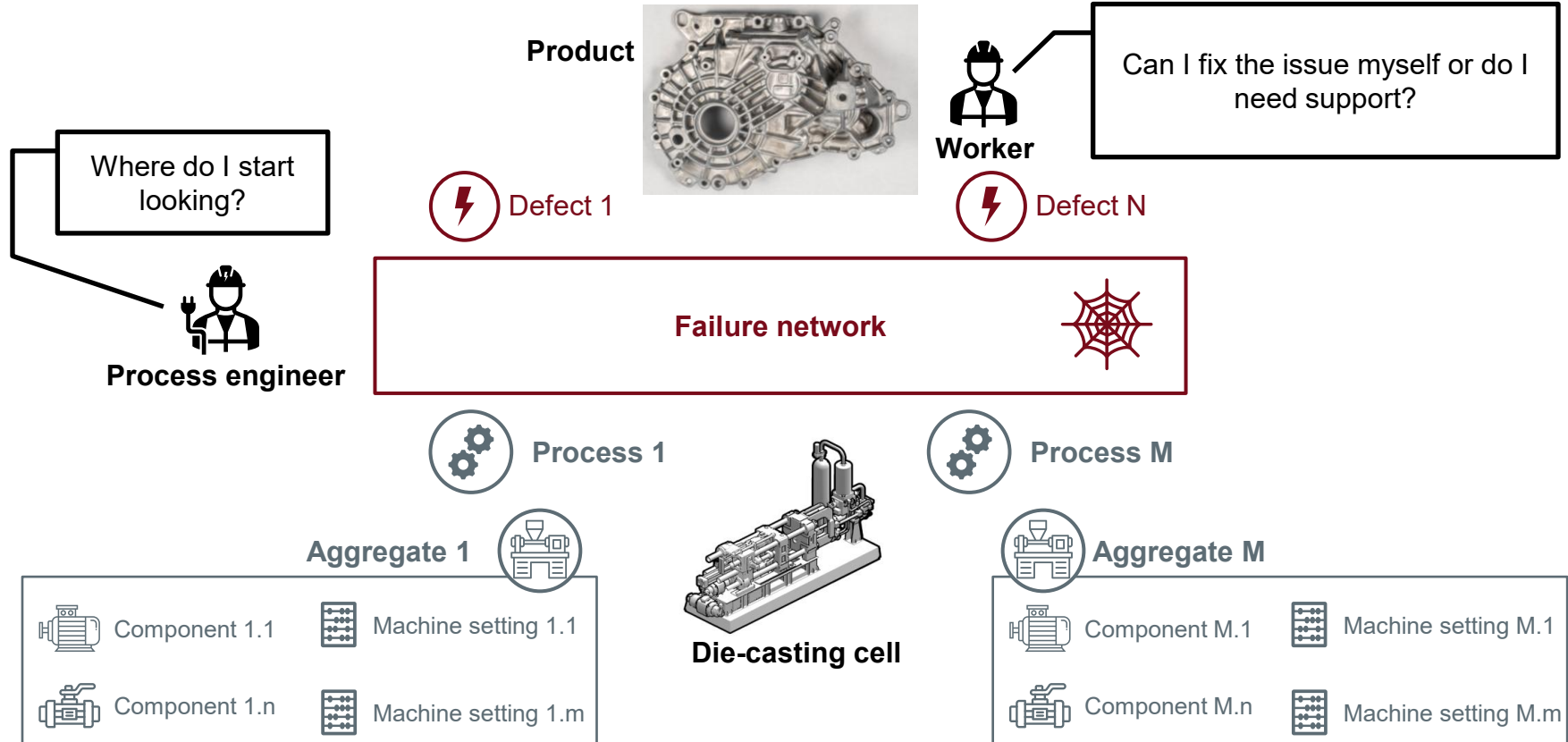
Human-centred, AI-assisted assistance system



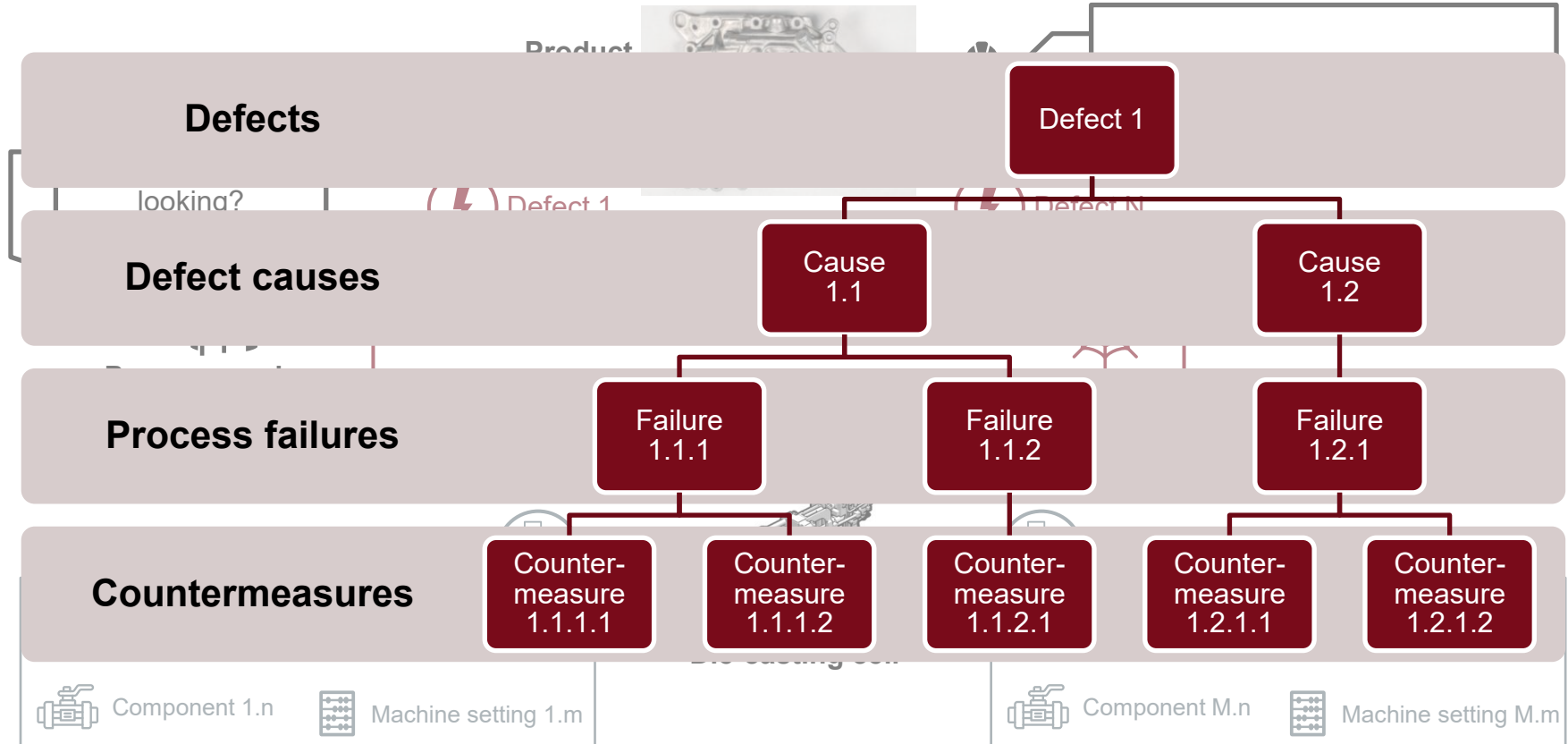
MOTIVATION – DIE-CASTING PROCESS



MOTIVATION – ROOT-CAUSE-ANALYSIS



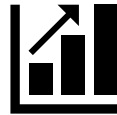
MOTIVATION – ROOT-CAUSE-ANALYSIS



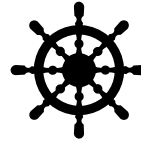
Development of a **human-centred assistance system** that turns complex decision-making into a guided, knowledge- and data-driven process



Reduced
scrap



Increased
productivity



Simplified
operability

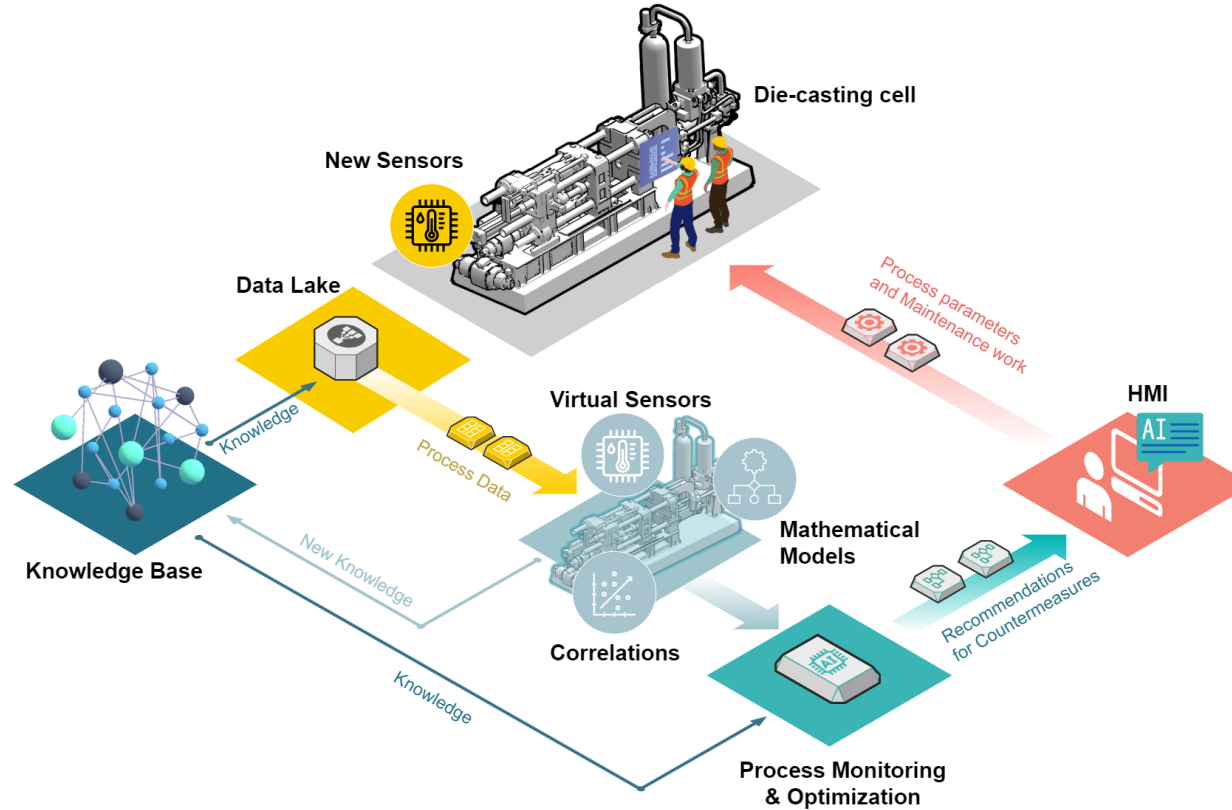


Improved
Transparency

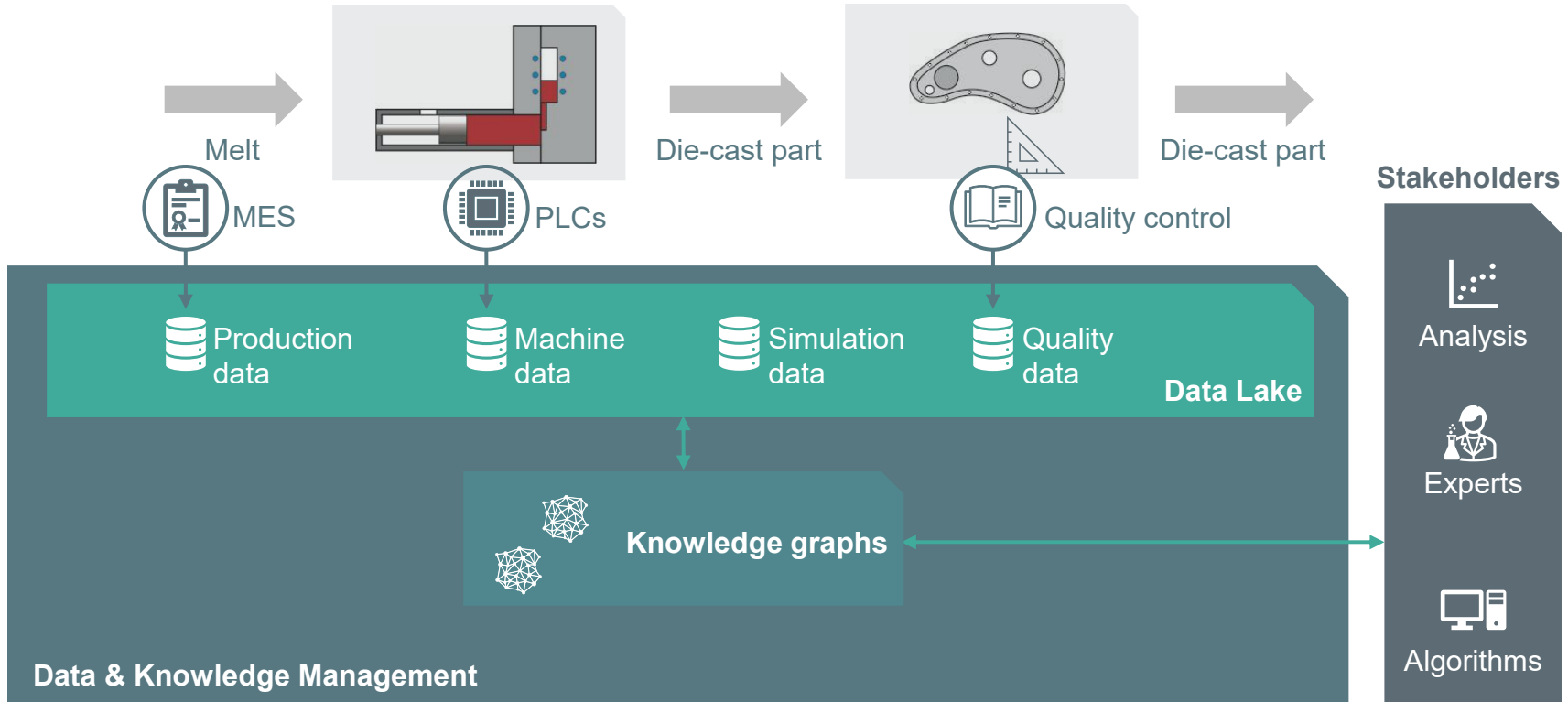


Reduced use
of resources

HUMAN-CENTRIC ASSISTANCE SYSTEM

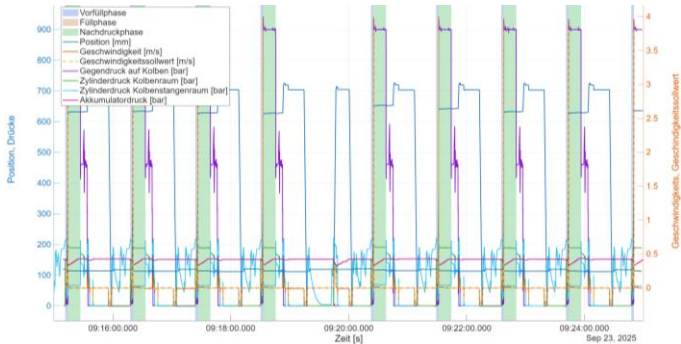


DATA LAKE

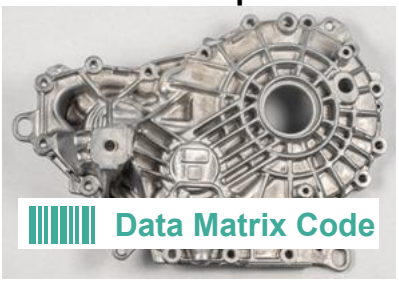


DATA LAKE

Auftragsnr.	Startzeitpunkt	Materialnr.	Werkzeugnr.	Kostenstelle
31113186	20/05/2025, 09:32:12	I900800RT/J	1-3827D1	11002024
41002024	02/09/2025, 22:13:44	I900800RT/J	1-3827D1	11002024

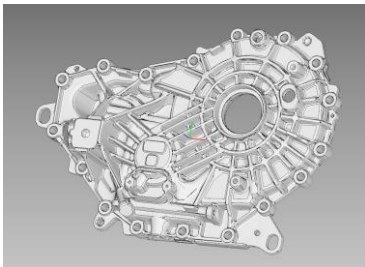
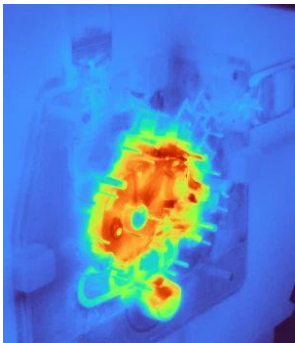
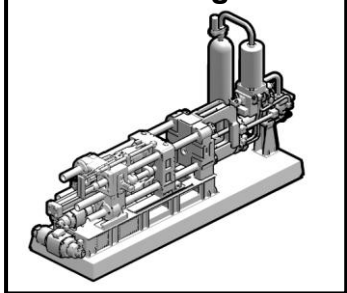


Die-cast part



 **Data Matrix Code**

Die-casting cell



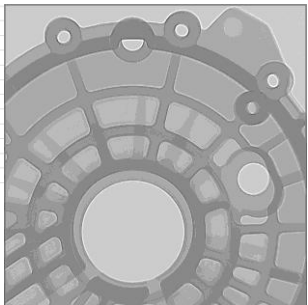
TCGUNITECH
BRUNNEN GROUP

Material Nr. I900800_M
Material Bez. I900800000_RHT
Zeichnung 9 845 182
Proj. I900800000_RHT
Kunde RT_Rohrleit
Arbeitsgang WLF_MF_Epilon
Hersteller 13235961
Teil

WMS Nr. 212273 - PRIMO2
Datum / Uhrzeit 03.11.2025 12:38:24
Seite 1 von 6

Erzeugnis Form / Name A / 3
Maschine / Sp. 1105-DG4115 / -
Teile Nr. 2530700019_9008000_41151
Auftrag
Polstername
Abteil
Anzahl Messwerte 61
Anzahl Abweichungen 6
Anzahl Wangenverformungen 3

Name	Messwert	Minwert	Maxwert	Unterschied	Abweichung	+	-
V-Wert_Pumpe07	-7,116	-7,300	0,000	-0,500	0,184	0,184	0,000
V-Wert_Pumpe15	-0,000	0,000	0,000	-0,000	-0,000	0,000	0,000
V-Wert_Pumpe13	-0,004	0,000	0,000	-0,500	-0,004	0,000	0,000
V-Wert_Pumpe12	-0,004	-7,300	0,000	-0,500	0,004	0,000	0,000
W-Längen	0,075	7,000	0,200	-0,200	-0,025	0,000	0,000
Länge_Längen01	0,004	0,000	0,200	-0,200	-0,004	0,000	0,000
Stärke_Längen01	0,075	7,000	0,200	-0,200	-0,075	0,000	0,000
A1	-17,680	-17,300	0,000	-0,700	-0,380	0,000	0,000
A2	-17,532	-17,300	0,000	-0,700	-0,232	0,000	0,000
A3	-17,441	-17,300	0,000	-0,700	-0,141	0,000	0,000
A4	-17,615	-17,300	0,000	-0,700	-0,315	0,000	0,000
A5	-17,632	-17,300	0,000	-0,700	-0,132	0,000	0,000
A6	-17,534	-17,300	0,000	-0,700	-0,234	0,000	0,000
A7	-17,723	-17,300	0,000	-0,700	-0,423	0,000	0,000
A8	-17,723	-17,300	0,000	-0,700	-0,423	0,000	0,000
A9	-17,573	-17,300	0,000	-0,700	-0,273	0,000	0,000
A10	-17,702	-17,300	0,000	-0,700	-0,402	0,000	0,000
Elektro-Schalt	0,199	0,000	0,000	0,000	0,199	0,199	0,000
Elektro-Schalt1	0,179	0,000	0,000	0,000	0,179	0,179	0,000
Elektro-Schalt2	0,129	0,000	0,000	0,000	0,129	0,129	0,000
Durchmesser_Schalt	0,438	0,400	0,200	-0,200	0,038	0,000	0,000
Proben1.1	0,192	0,000	0,000	0,000	0,192	0,192	0,000
Proben1.2	0,225,175	0,225,200	0,000	-0,300	-0,025	0,000	0,000
Proben1.3	200,593	200,500	0,000	-0,300	0,093	0,000	0,000



Defect type	X	Y	Z	Status
DG Fließfehler	203,5	-130,0	153,1	IO
DG Risse	19,1	20,7	53,2	NIO

ROOT-CAUSE-ANALYSIS

Data lake



Knowledge base



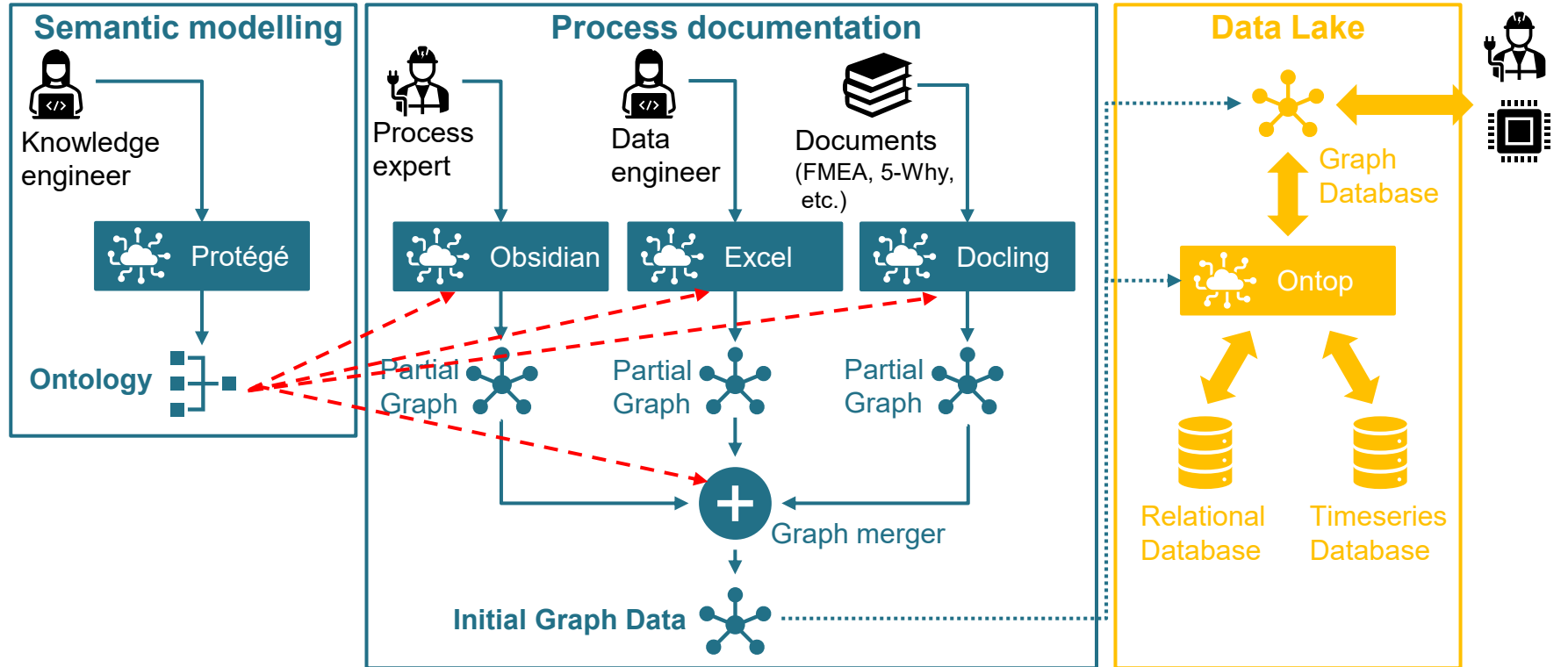
Defects

Defect causes

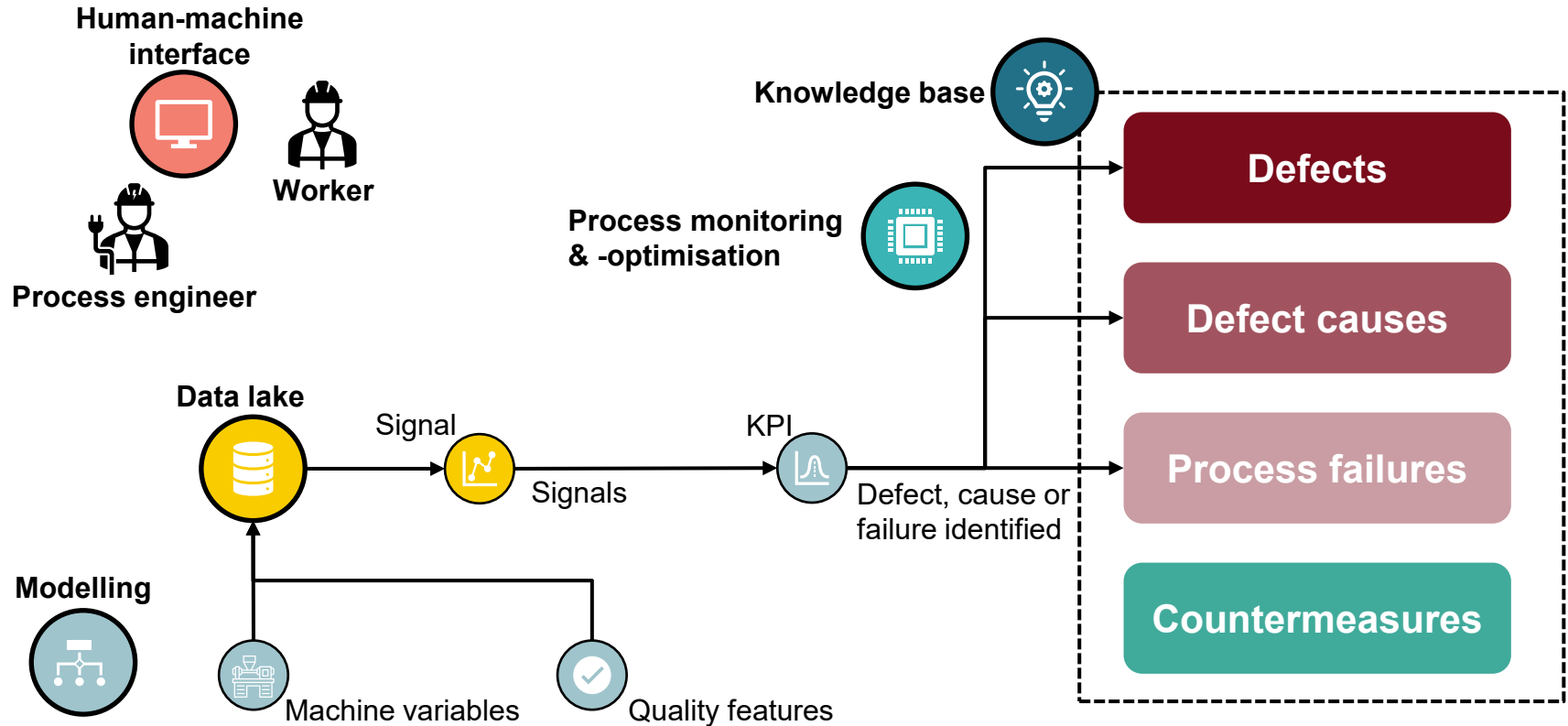
Process failures

Countermeasures

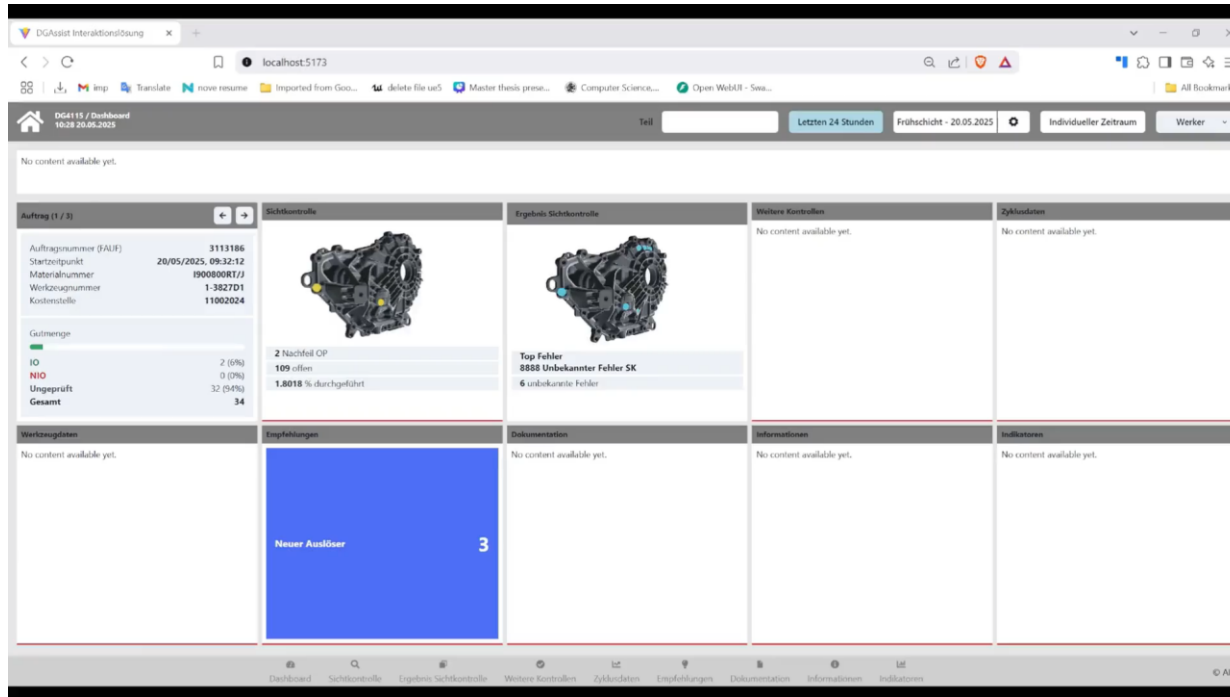
KNOWLEDGE PIPELINE



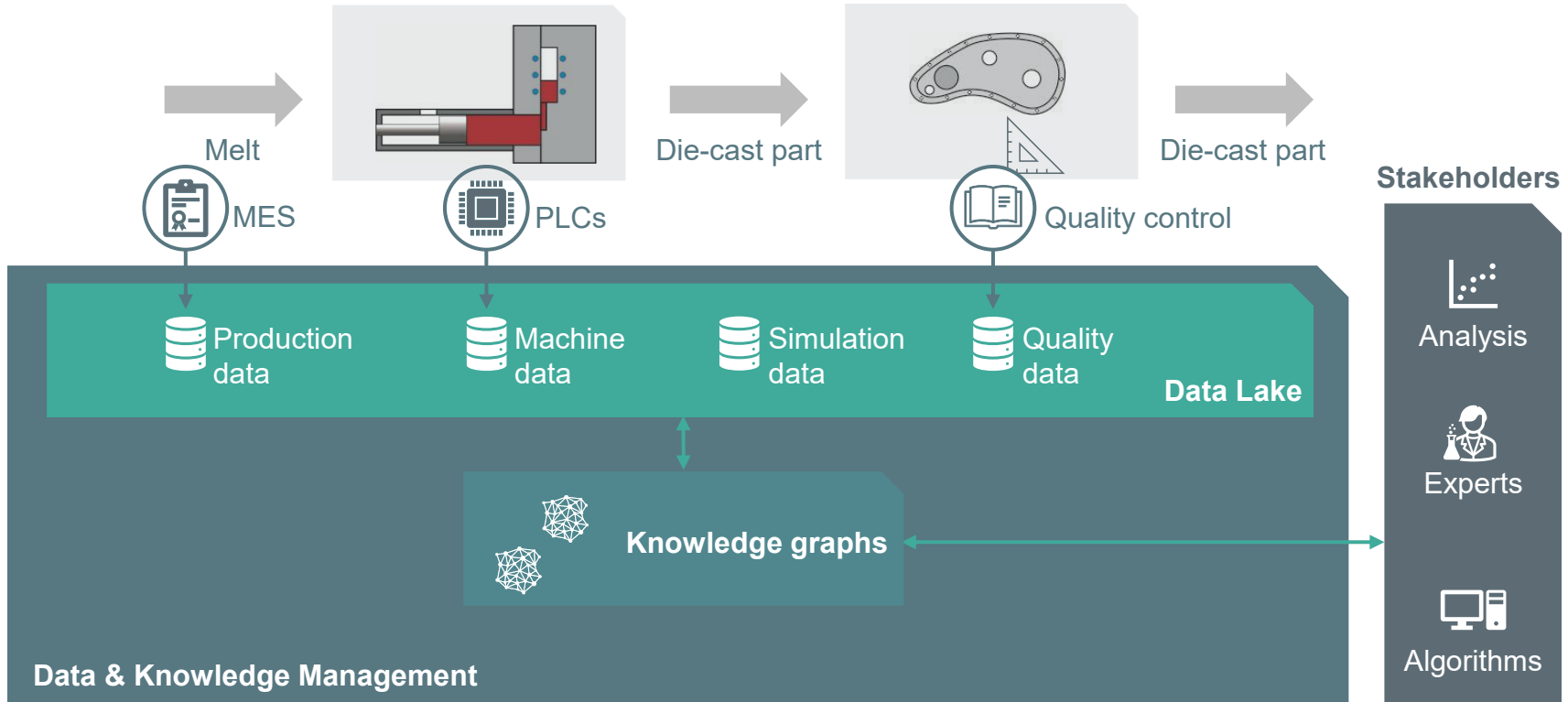
ROOT-CAUSE-ANALYSIS



HMI – DASHBOARD



DATA LAKE



APPLICATION „DATA EXPLORATION“



Provide signal metrics of 3 three parts with defect XY and their 3 good previous parts!



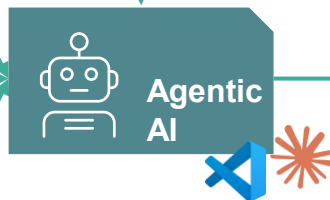
**Knowledge Graph
(Semantic Backbone)**



**Relational DB
(Quality data)**



**Time Series DB
(Process data)**



Analyse: 3 Formausbruch-Teile mit Vorgängern + Transparente Quellenzuordnung

Verfügbare Daten (GRÜN = aus den Graphen)

12-Teil-Serie möglich: **X**

- Defekt-Teile: 3 Formausbruch-Teile (1124) verfügbar ✓
- Vorgänger-Teile: Nur 3 zusätzliche Gut-Teile mit Phase-Daten vorhanden

Arbeite mit verfügbarem Dataset:

- 5 Gut-Teile mit vollständigen Phase-Zeiträumen (32745-32749)
- Nachdruckphase-Metriken erfolgreich abgerufen

Ergebnisse: Metriken der 3 Gut-Teile (Nachdruckphase)

Signal	Part 32745	Part 32746	Part 32747	Δ Trend
cmdval_ctrl_temp_mold_holdfur (Spritzform °C)				
MAX	32.55	-	-	↓
MIN	32.55	-	-	stabil
AVG	32.55	-	-	stabil
cmdval_ctrl_temp_ceil_holdfur (Deckel °C)				
MAX	27.69	70.85	55.13	▲ +156%
MIN	23.71	57.60	44.93	▲ +143%
AVG	26.32	63.31	50.03	▲ +141%
height_mold_dcm (Formhöhe mm)				
MAX	-	1008.31	1008.32	stabil
MIN	-	1008.31	1008.32	stabil
AVG	-	1008.31	1008.32	stabil

Schlussfolgerungen: QUELLE AUFGESCHLÜSSELT

✓ Aus den Graphen (konkrete Messdaten):

1. Temperaturanomalie bei Part 32746:
 - Deckelteil-Temperatur +143-156% über Baseline
 - Wert: 63.31°C vs. 26.32°C (37°C Differenz)
 - Quelle: `sgg_float_stable` Signal `cmdval_ctrl_temp_ceil_holdfur` [Zeit 18:45:17-18:45:36]
2. Formhöhe stabil:
 - `height_mold_dcm` konstant bei 1008.31 mm
 - Ausschluss von mechanischen Verschleißproblemen
 - Quelle: `sgg_float_stable` Signal `height_mold_dcm` [Datenbank]
3. Teilzeitpunkte und Sequenz:
 - Part 32745: 2025-09-22T10:44:48.133Z (Gut)
 - Part 32746: 2025-09-22T10:45:53.332Z (Gut, +1m 5s)
 - Part 32747: 2025-09-22T10:46:59.926Z (Gut, +1m 6s)
 - Quelle: `part` Tabelle `ts_shot_prt` [SQL]

• LLM Domänenwissen (nicht aus den Graphen):

1. Ursache-Folge "Temperatur → Formausbruch":
 - Erhöhte Deckelteperaturen führen zu thermischen Spannungen
 - Thermische Spannungen können zu Formrissen und Ausbrüchen führen
 - **NICHT in den Daten:** Kein direkter Messwert für "thermische Spannung" oder "Materialbelastung"
 - Quelle: Werkstoffkunde/Druckgussfachlichkeit (LLM Training)
2. Hypothesen zu Fehlerursachen:

COOPERATION AIT AND ENGEL

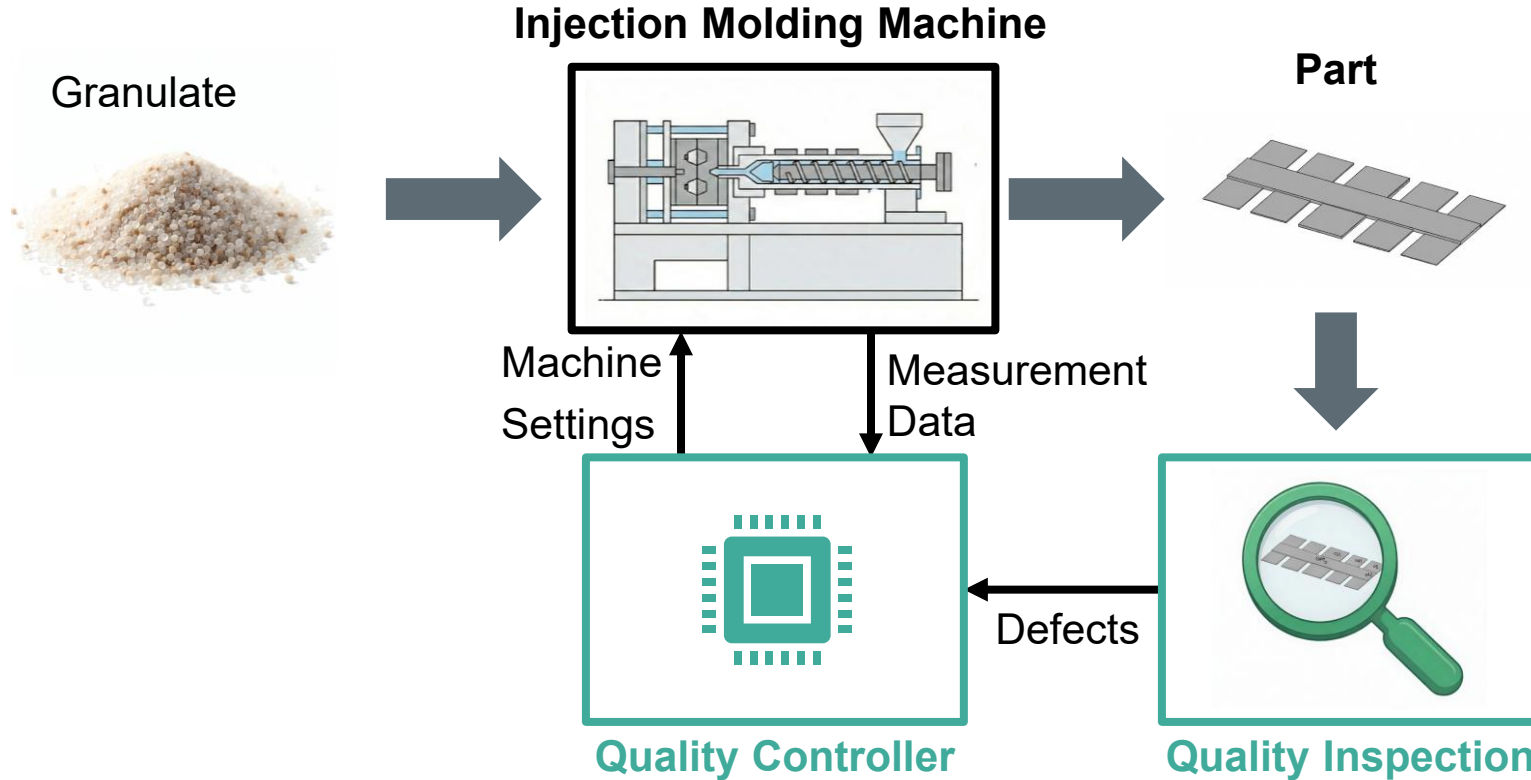
Autonomous System Operation: Quality Control & Inspection in
Injection Molding



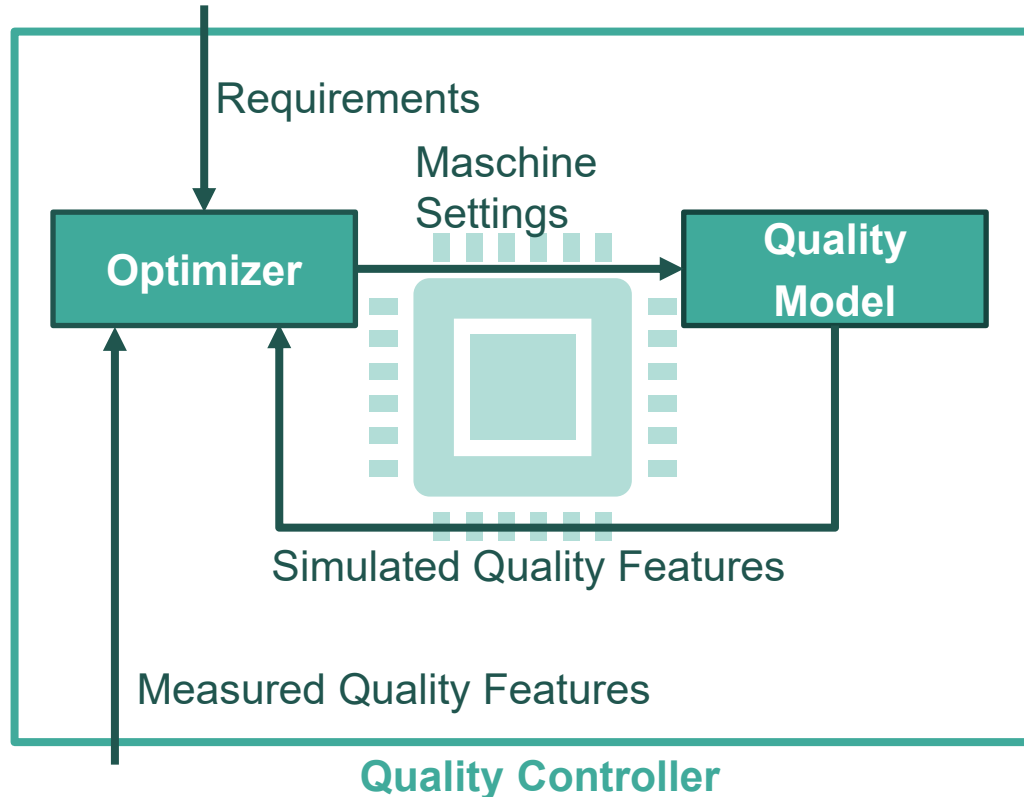
ENGEL



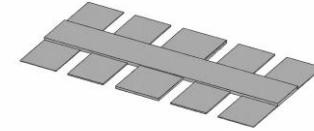
AUTONOMOUS SYSTEM OPERATION



AUTONOMOUS SYSTEM OPERATION



Part



Quality features:

- Weight
- Short shot
- Burrs

QUALITY MODEL

Machine settings u

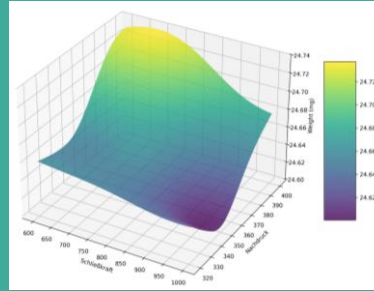
Switchover volume

Holding pressure

Clamping force

Injection velocity

Quality Model



Neural Network
(3 layers)

Gradient G

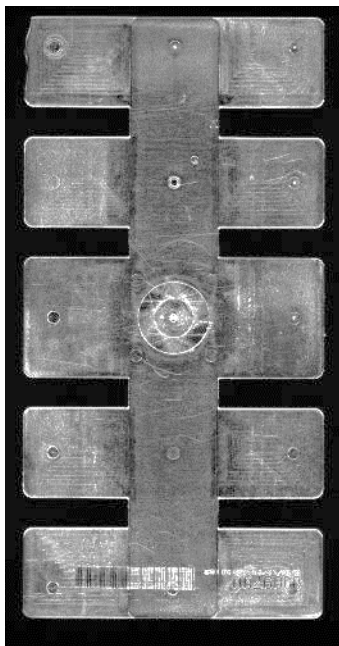
Quality features y

Weight

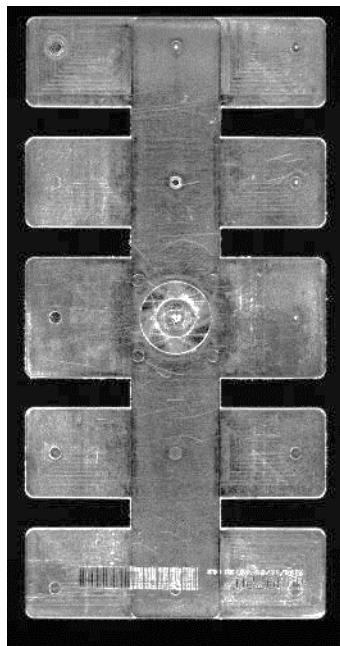
Short Shot

Burrs

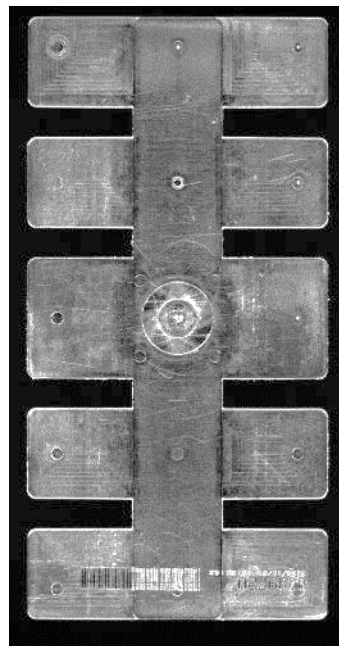
EXPERIMENT



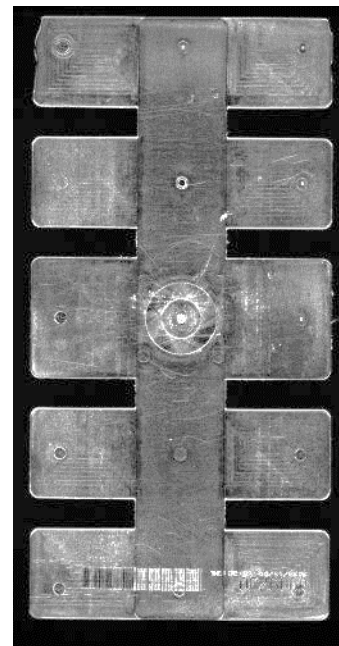
$k = 1$
99.86%



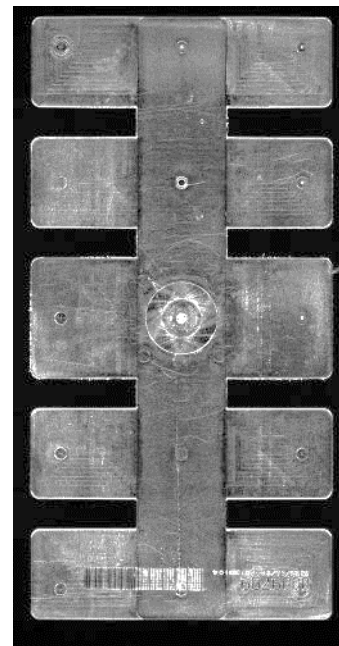
$k = 12$
100%



$k = 20$
100%



$k = 30$
99.70%



$k = 40$
100%

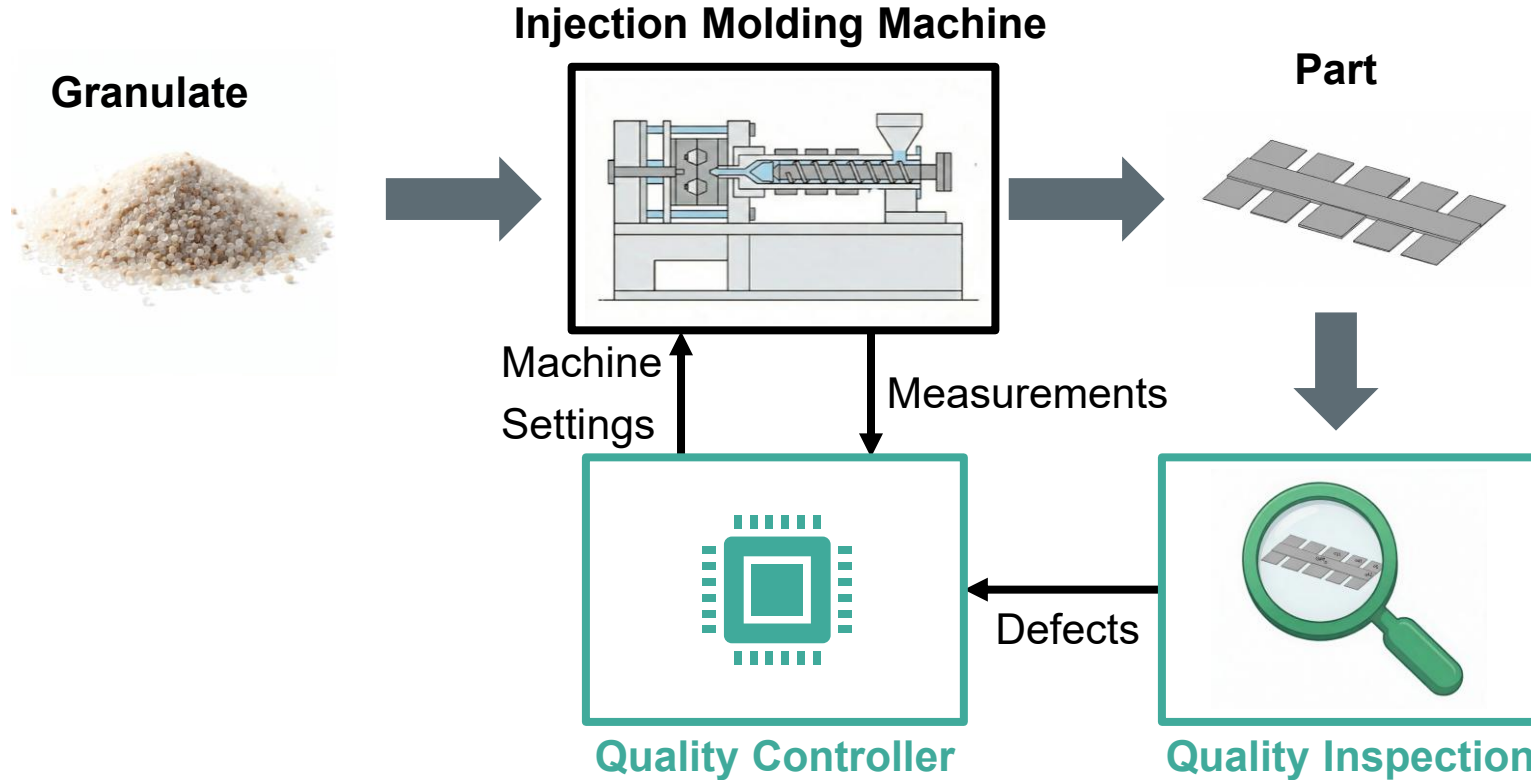


Disturbance (Material change)

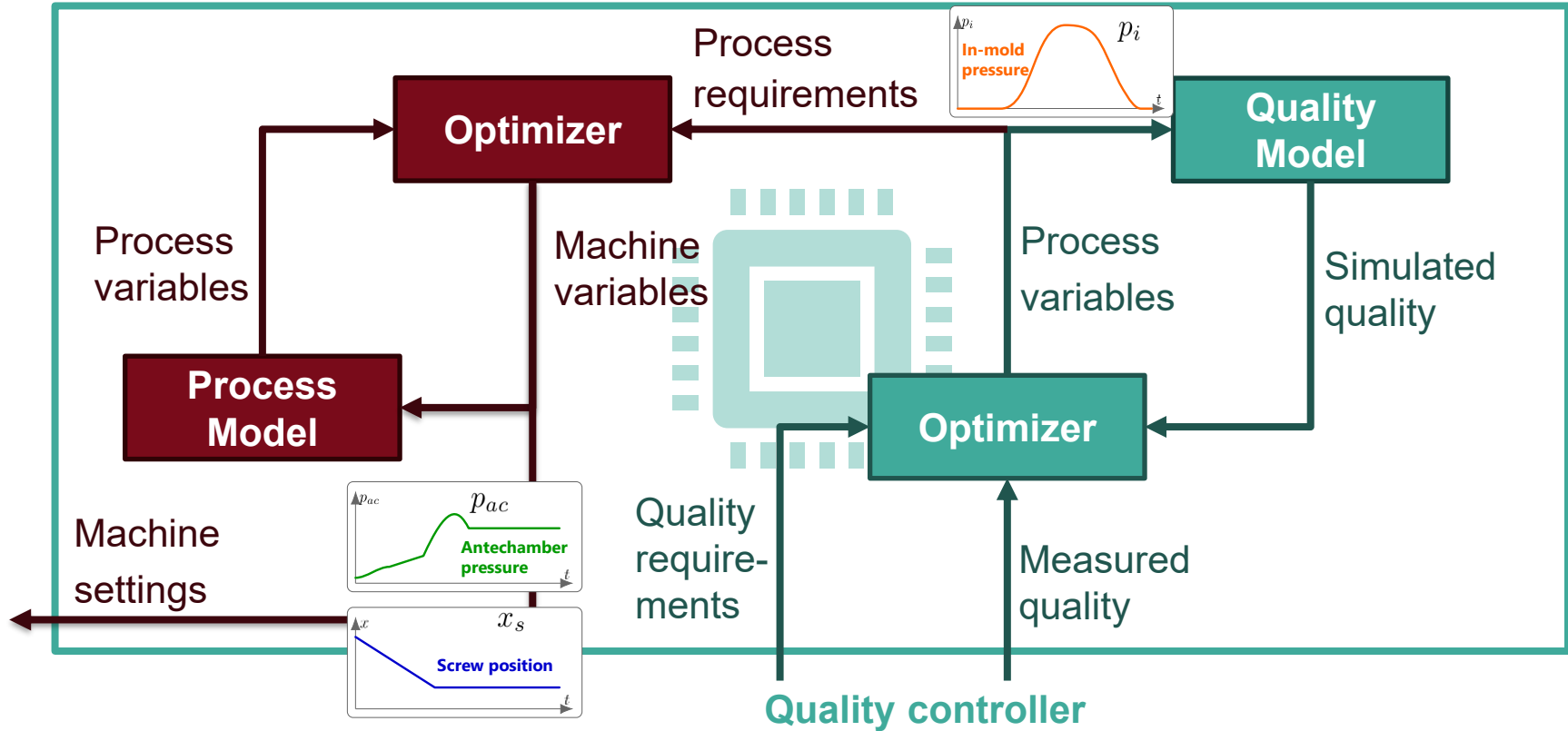
PP + Wax 3%

PP

AUTONOMOUS SYSTEM OPERATION

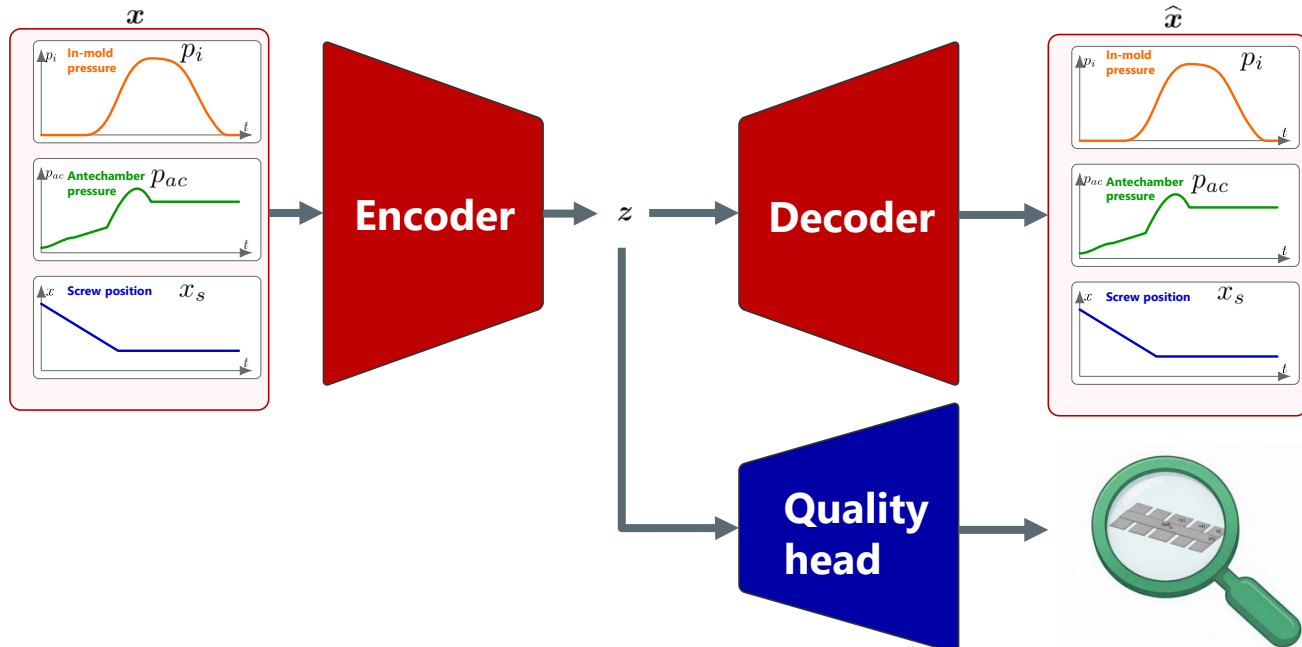


AUTONOMOUS SYSTEM OPERATION

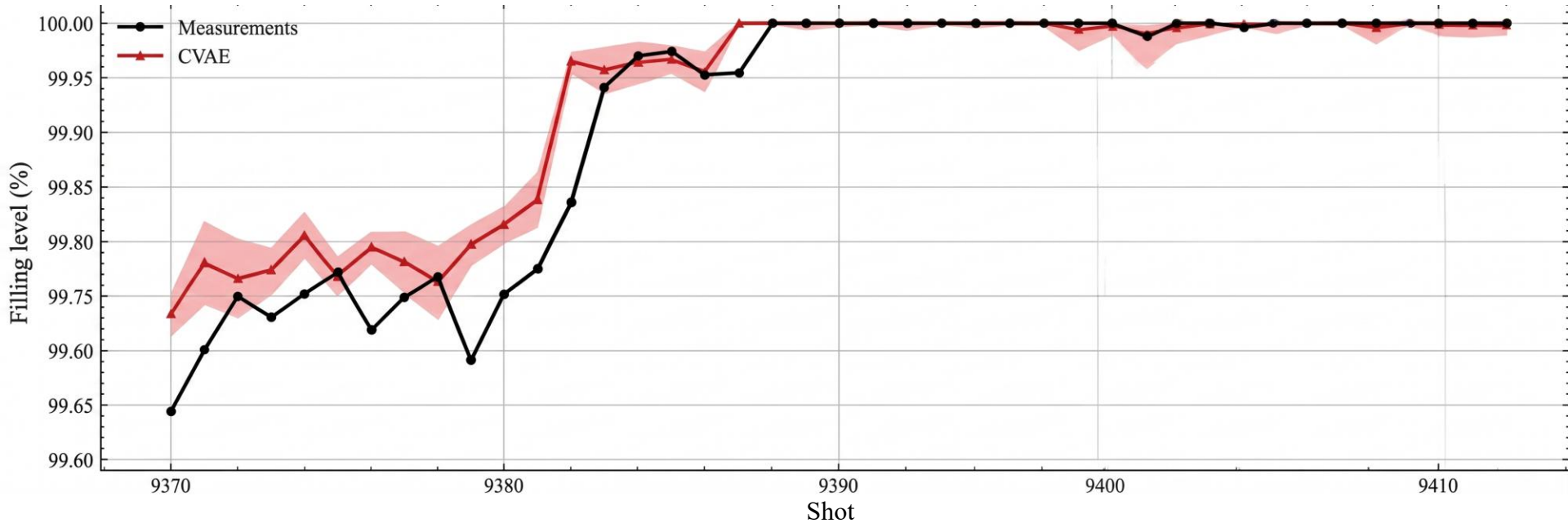


ANOMALY DETECTION AND CONTROL THROUGH AUTOENCODER

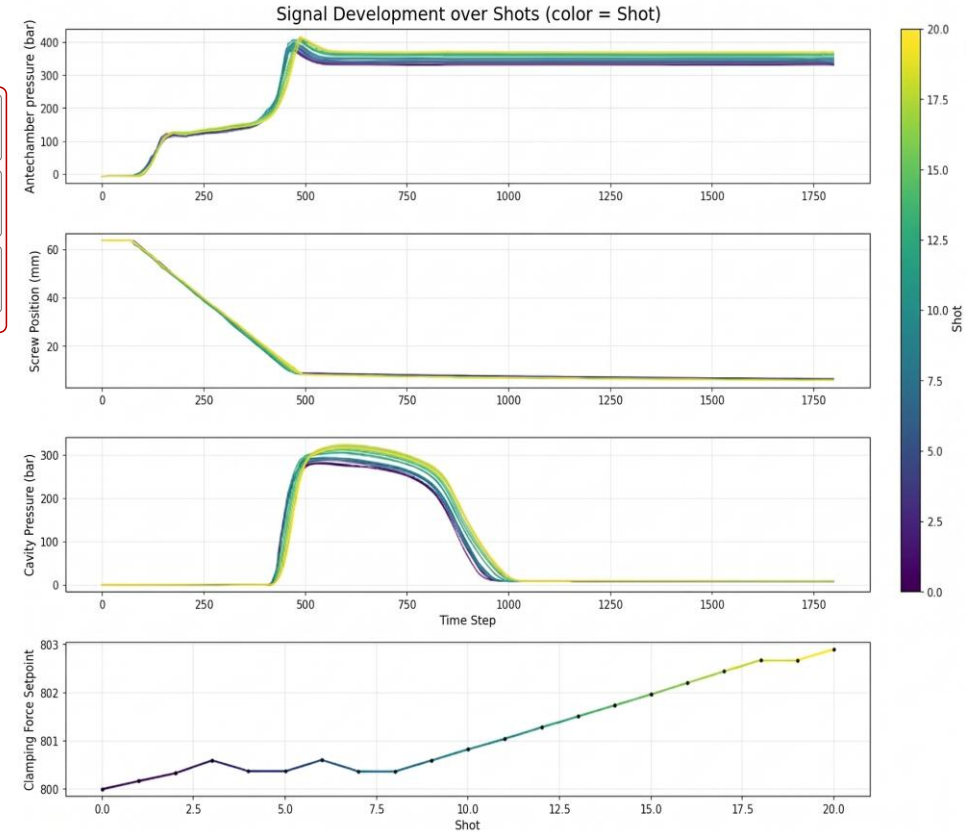
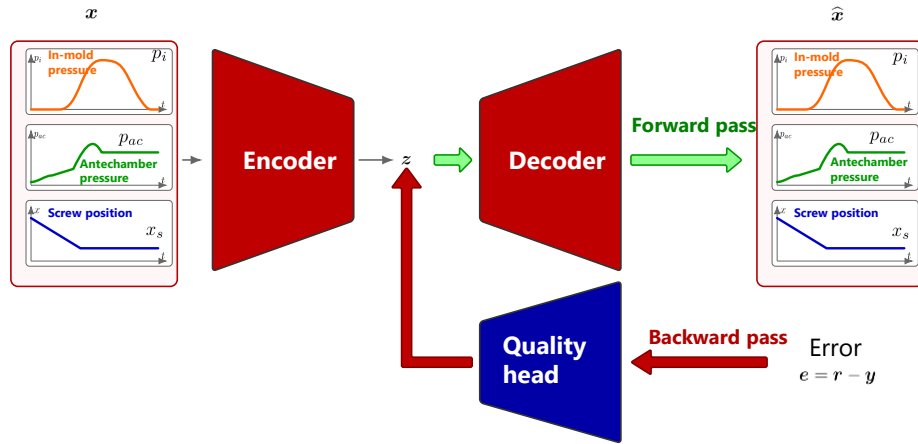
The process curves are compressed into a **low-dimensional latent space**, enabling **anomaly detection and precise process control**.



ANOMALY DETECTION THROUGH AUTOENCODER

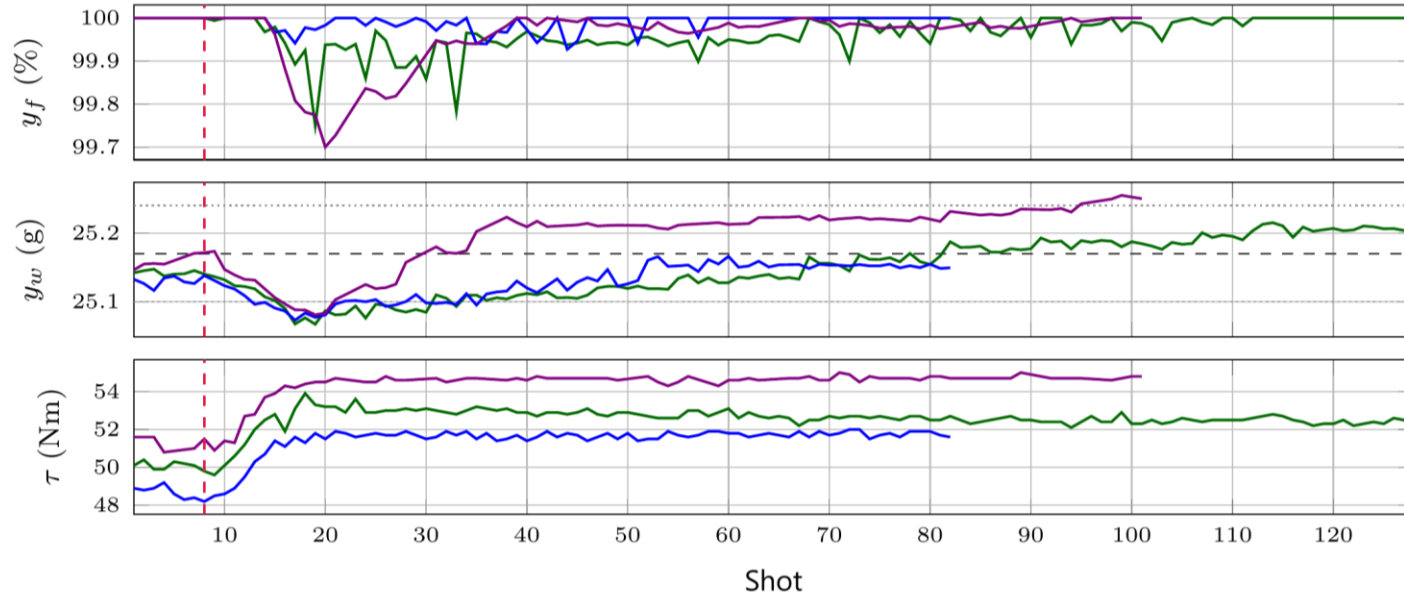


CONTROL THROUGH AUTOENCODER



CONTROL THROUGH AUTOENCODER

Enhancement of the stability through integration of in-mold pressure sensor and precise control.



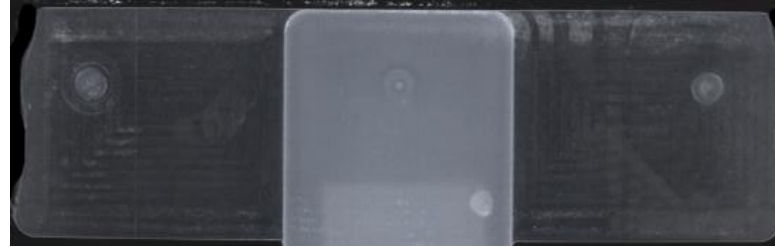
— Autoencoder with Antechamber pressure — Autoencoder with In-mold pressure
— Direct method - - - Material change at the screw tip: PP + 3 % → PP

CONTROL THROUGH AUTOENCODER

Comparison

With Direct Method :

Minimum filling: 99.70%



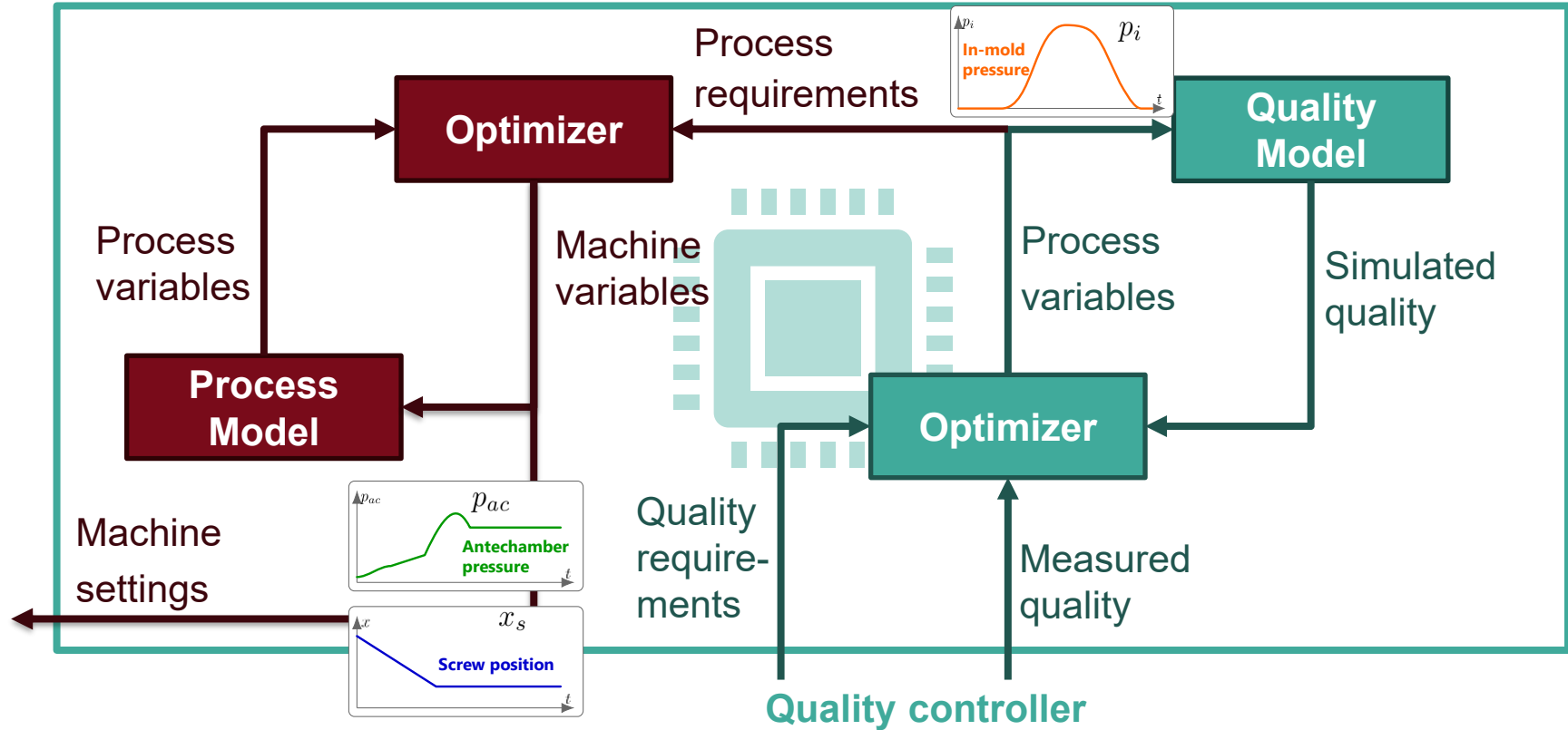
With Autoencoder Method :

Minimum filling: 99.97%



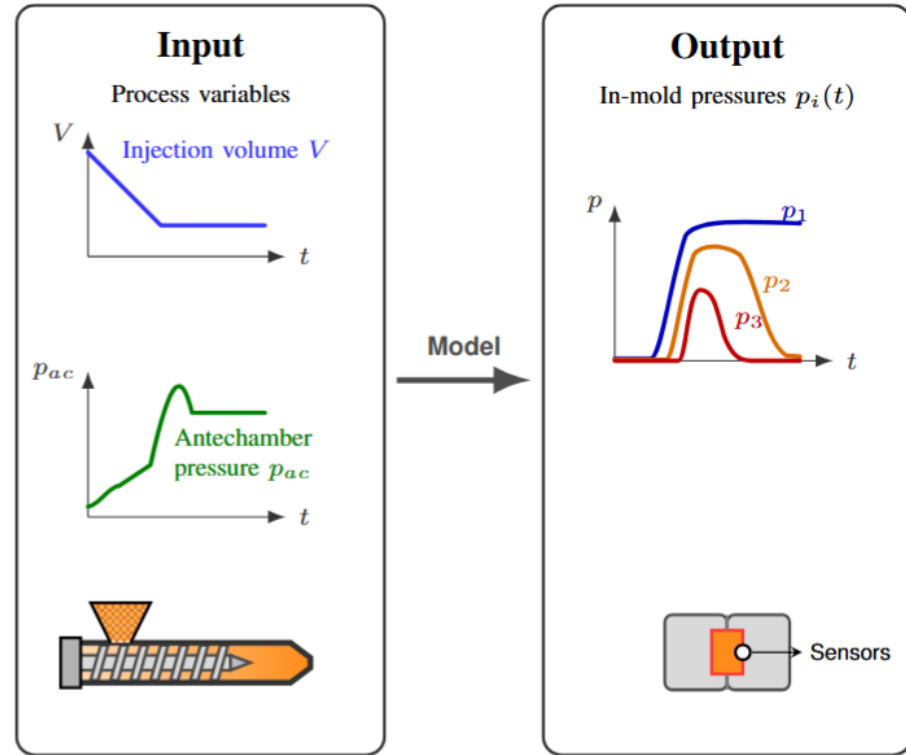
10 × lower filling deviation under
the same disturbance magnitude

PROCESS MODEL

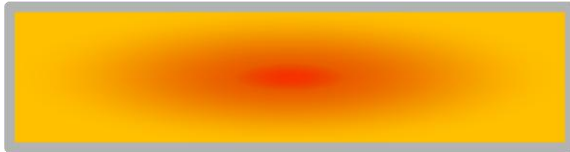


PROCESS MODEL THROUGH DEEP SEQUENCE MODELS

- **Learn nonlinear process dynamics** directly from data
- **Predict multiple cavity-pressure trajectories by LSTM and NSS** from machine-side signals
- **Real-time inference ($\sim 15 \mu\text{s}$)** enables predictive control



Temperature
measurement

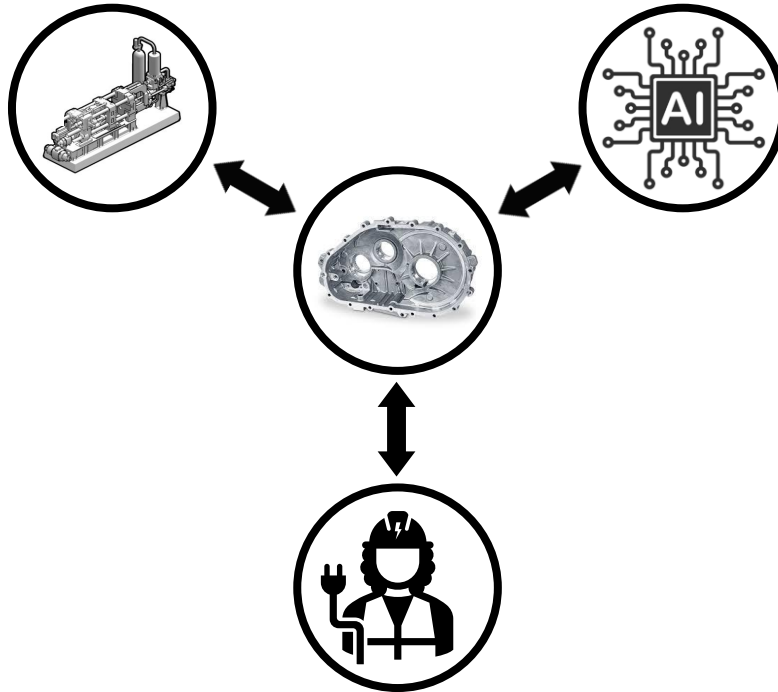


Slab

Heat conduction equation:

$$\begin{aligned} \rho c \frac{\partial T}{\partial t} &= \nabla(\lambda \nabla T) \\ -\lambda \nabla T &= \dot{q} \end{aligned}$$

- Distributed parameter systems and scarce measurements
- Data infrastructure
- Availability of big data
 - Mapping between data and product / process
 - Labelled data
 - Variation in process parameters
- Trust in AI
 - Action and feedback



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