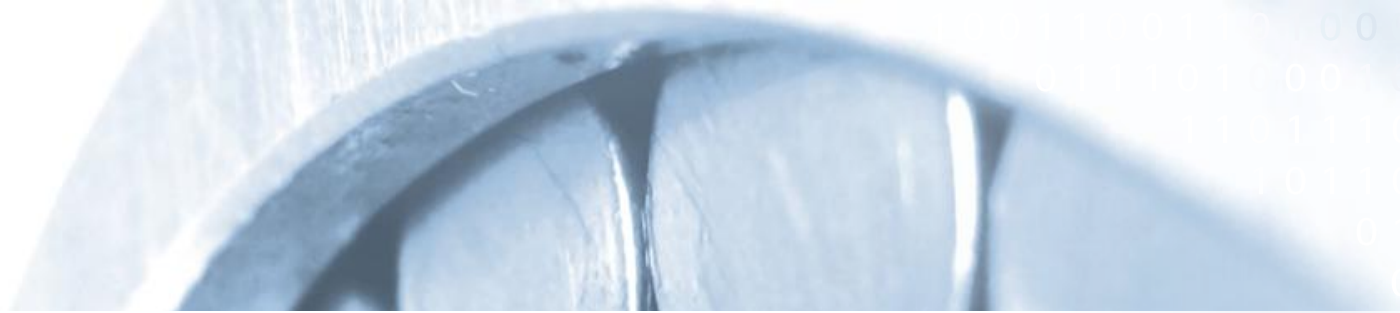


# A system approach to sensor-integrated machine elements (SiME): Platform-based integration for intelligent drive trains

J. Feldmann and D. Konopka



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## From passive components to SiME

- Advances in microsensor technology, miniaturization, and electronics
- Integration of sensors directly into machine components
- Measurement of local operating conditions directly at the relevant point of action
- Basis for improvements in condition monitoring (CMS) and predictive analysis

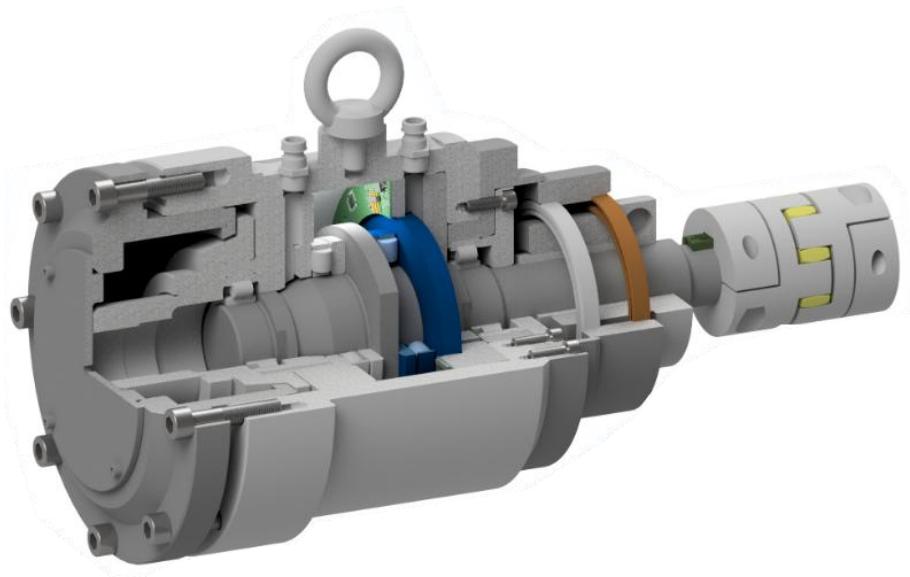
SKF Insight  
Sensor Bearing



Schaeffler Optime CMS System

Machine components no longer perform exclusively mechanical functions, but also provide information about their own operating status.

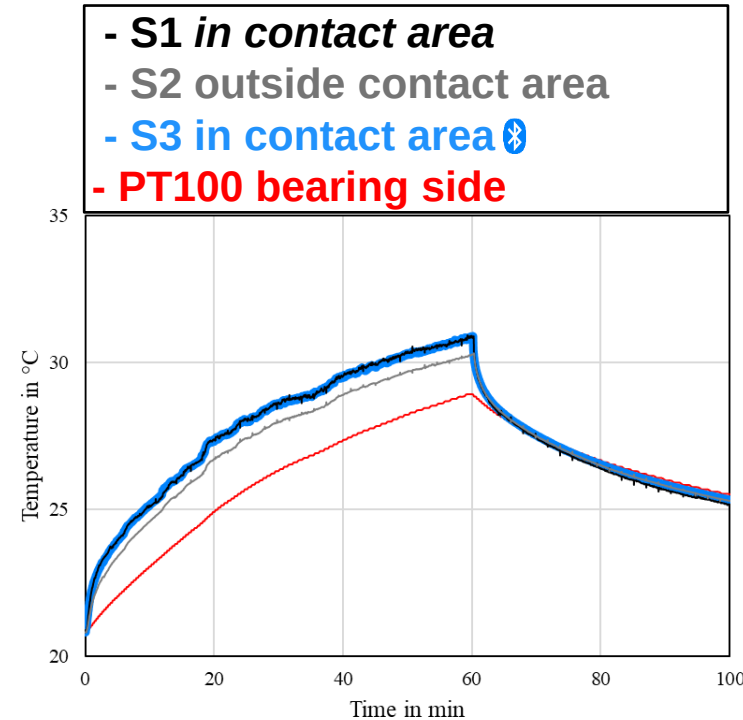
# Outline



- Introduction
- Test rig and integration of several SiME
- Gateway Development
- Experimental and Results
- Summary

## Local measured variables for advanced CMS

- Critical operating conditions often occur locally within a machine cor
- External sensors sometimes detect these conditions only indirectly
- Sensor integration enables the local detection of relevant measurement parameters
- Early identification of overload, temperature increases and wear
- Potential to increase service life and system availability



**Temperature Measurements**



Source: DOI 10.1007/s10010-025-00857-4

# The goal of the demonstrator



## Cross-System Integration

- Combining multiple sensor-integrated machine components
- Joint experimental investigation on a test bench
- Processing different measurement signals
- Using the data in a shared condition monitoring system
- Investigating horizontal integration at the system level

Motor-Pump Unit



<https://new.abb.com/news/de/detail/108787/elektrische-motorantriebe>

**Temperature Sensors**  
PT100 or Thermocouple

**Pressure Gauge**  
suction and discharge sides

**Flow rate**

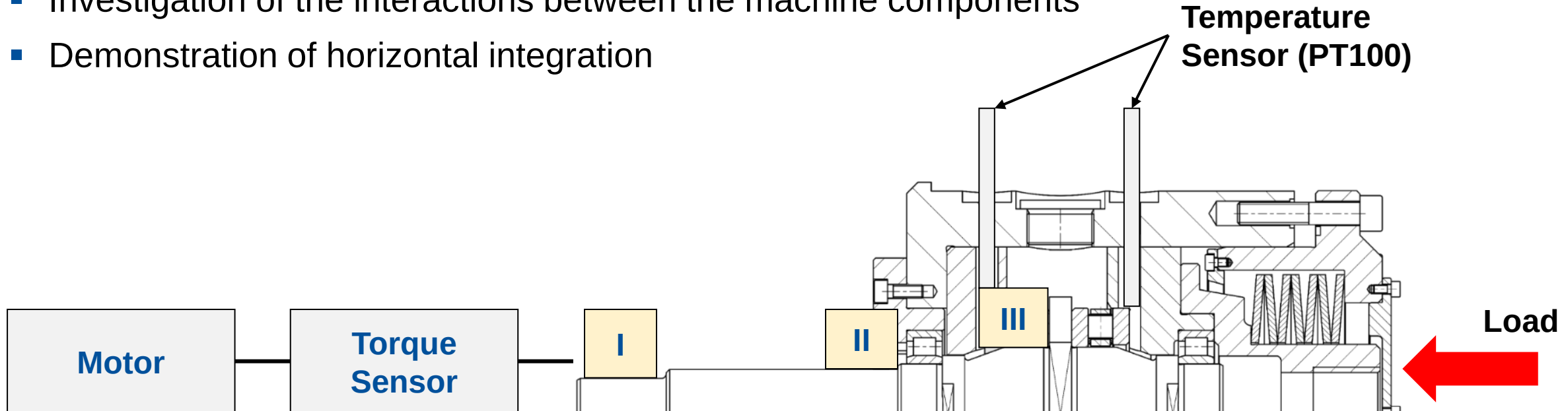
**Vibration sensors**  
on the pump and bearing  
 housings

**Torque**

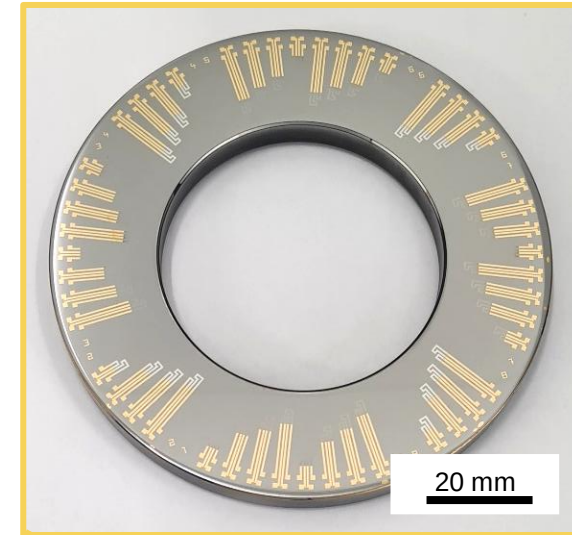
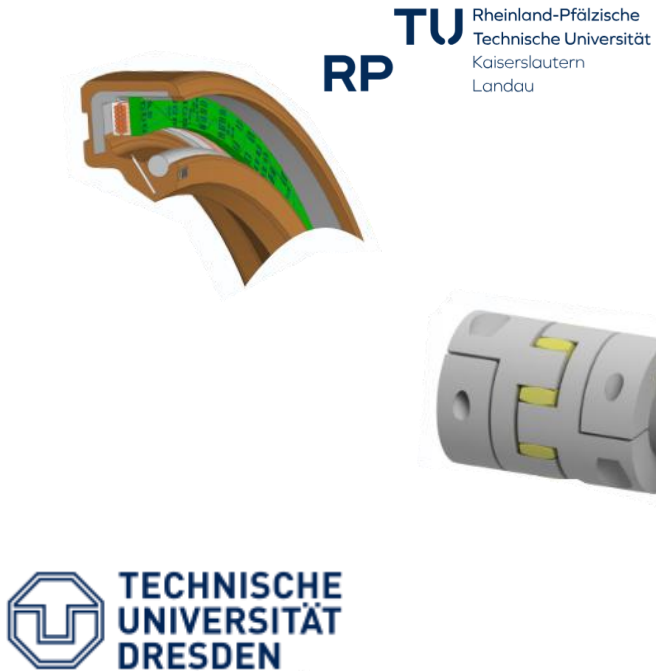
**Rotational speed**

## Joint technology platform

- Integration of the SiME into a joint test rig
  - Modified FE8 test head – for axial cylindrical roller bearings
  - Specified parameters for speed, load, and operating conditions
  - Joint experimental testing
- 
- Investigation of the interactions between the machine components
  - Demonstration of horizontal integration

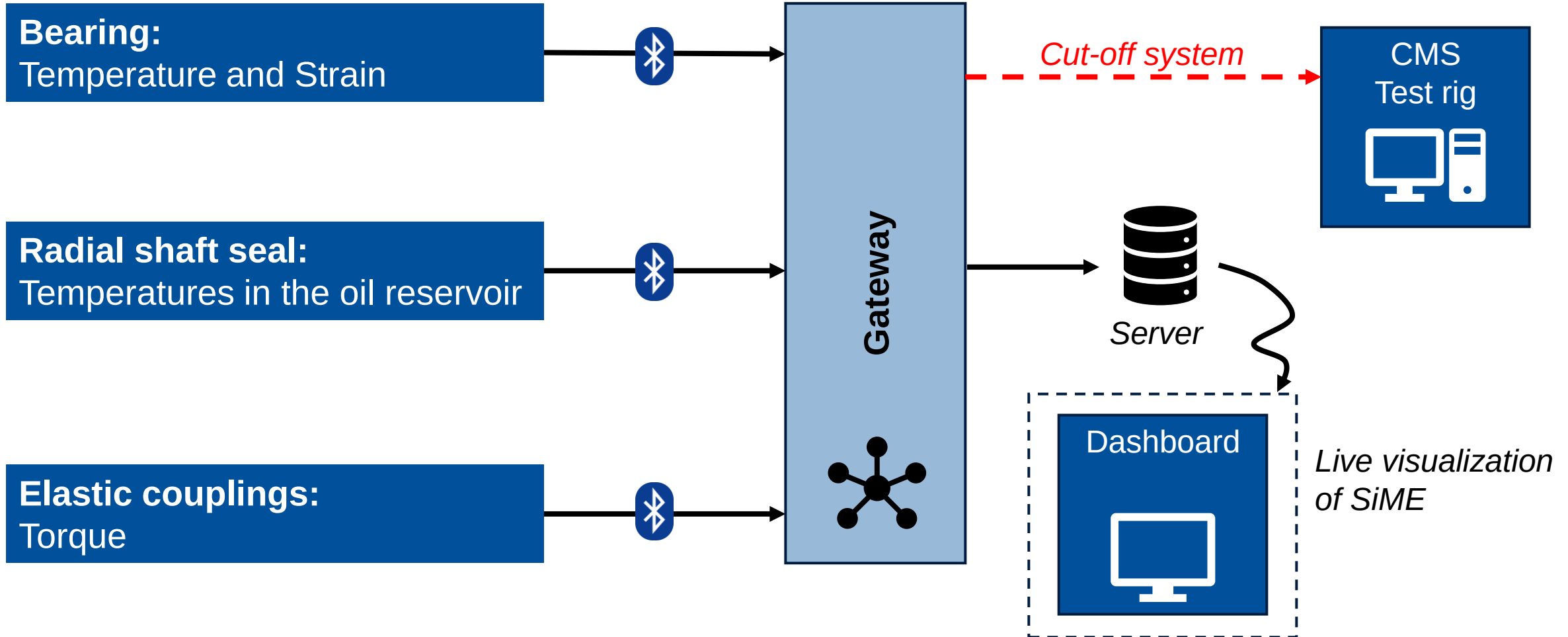


## Overview of the Integration



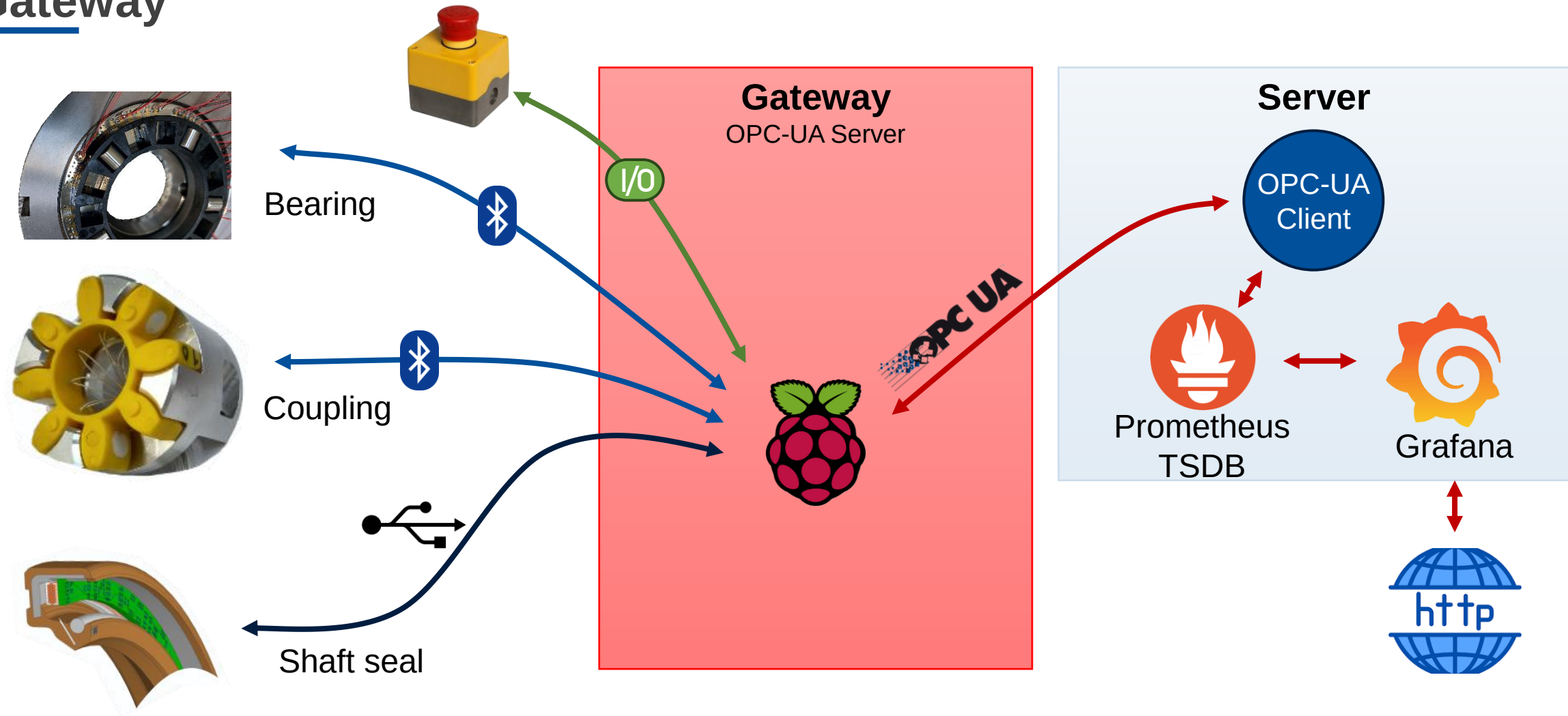
Sensor-Integrated bearing washer

## Measurement Systems with Joint Communication



# System Integration

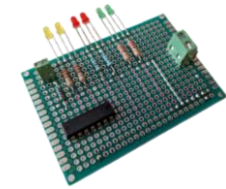
## Gateway



## Gateway

- Hardware
  - Raspberry Pi 5
  - Powered via IEEE PoE Plus
  - Custom IO: LEDs, Emergency Stop
- Software
  - Plain C99 implementation
  - OPC-UA: open62541\*
  - Bluetooth: bluez\_inc†
    - Data via notifications
  - Emergency Stop
    - Adjustable limits
    - 1 Hz signal (watchdog)

Custom I/O Head



Waveshare M.2 HAT+  
PoE and PCIe to M.2



Raspberry Pi 5 B



\*) <https://github.com/open62541/open62541>

†) [https://github.com/weliem/bluez\\_inc](https://github.com/weliem/bluez_inc)

## Prometheus TSDB and OPC-UA Connector

- Prometheus Time Series DataBase
  - Data logging
  - Scheduling of Data Scraping Jobs
    - Name
    - Target (OPC-UA Connector)
    - Interval
- OPC-UA Connector
  - Receiving scrape events
  - Reading data via OPC-UA from Gateway
  - Answering event with read data

# System Integration

## Grafana

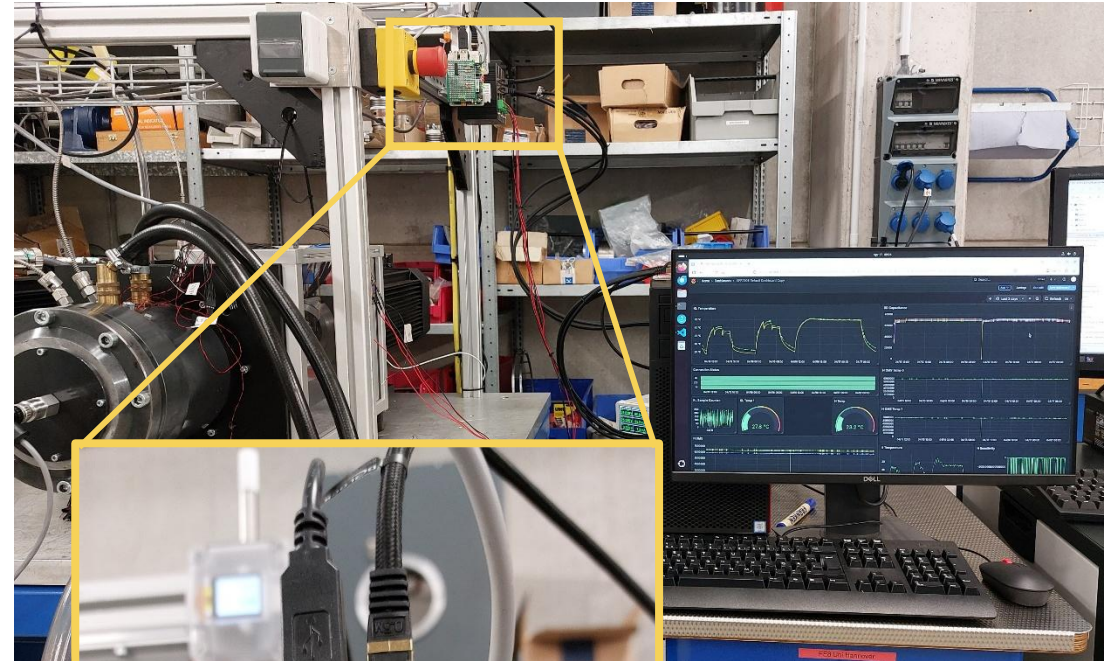
- Visualization
  - Live
  - History data
- Data Transformation
  - Filter, average, etc.
- Notifications / Alerting



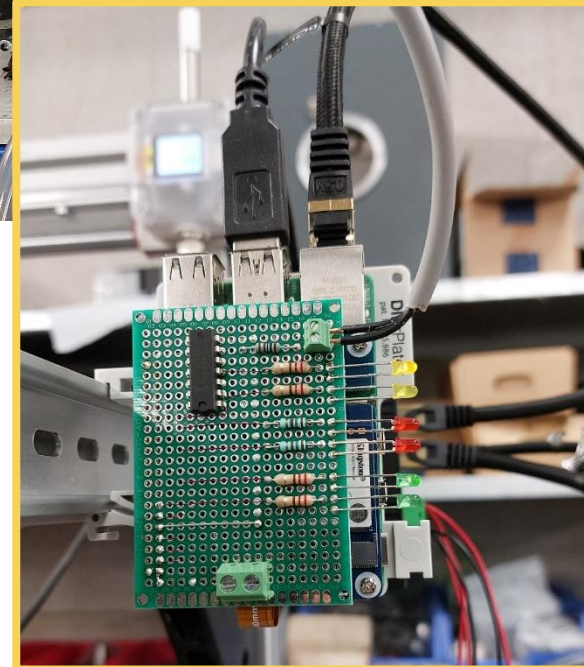
## Results

- 3 data sources
  - Rolling bearing
  - Coupling
  - Radial shaft seal
- 31 data channels
- 100 ms sample rate
- Continuous measurement over 4 days
- Live data visualization
- Conditional Emergency Stop
- Gateway: 4W via PoE

Test rig



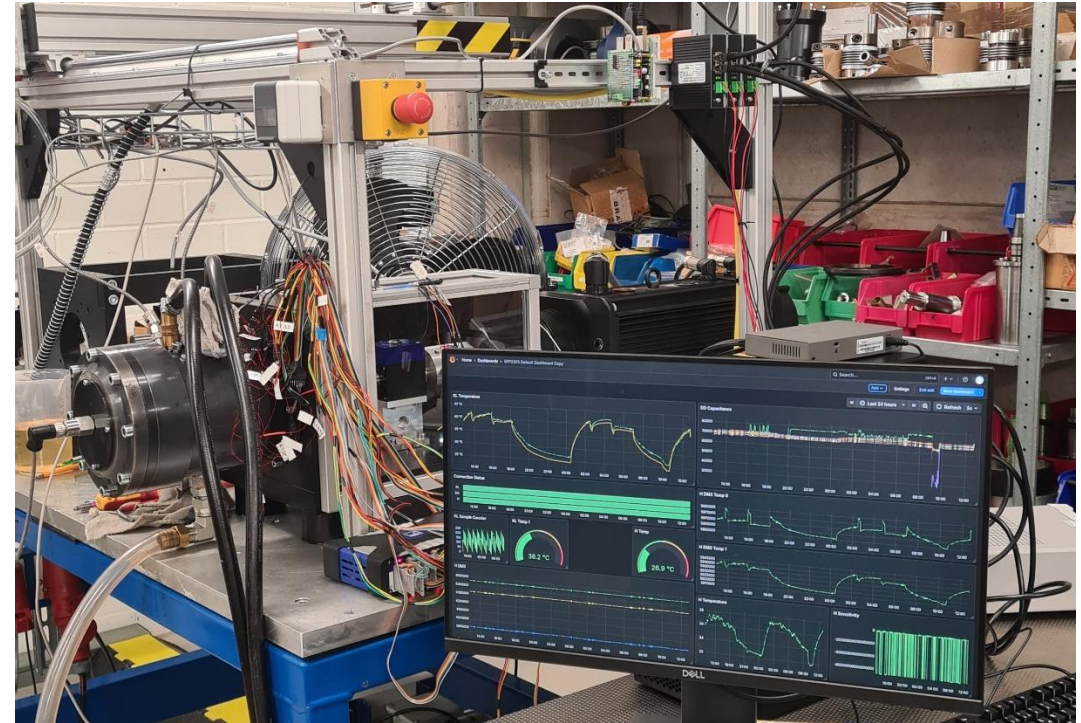
Dashboard



Gateway

## Scientific contribution

- Software Update for SiME
  - Default: Over-the-Air-Update (OTA)
  - Serial Recovery capabilities
- Time synchronization
  - To support burst data transfer
  - Gateway + SiME nodes
- Power management
  - Integration of wireless power supply
- Data integrity
  - Handling of SiME connection loss
  - Data buffering in case connection loss



# Thank you! Any questions?

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