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Modelling and Digital Twins for Water Distribution Systems

Faculty of Engineering

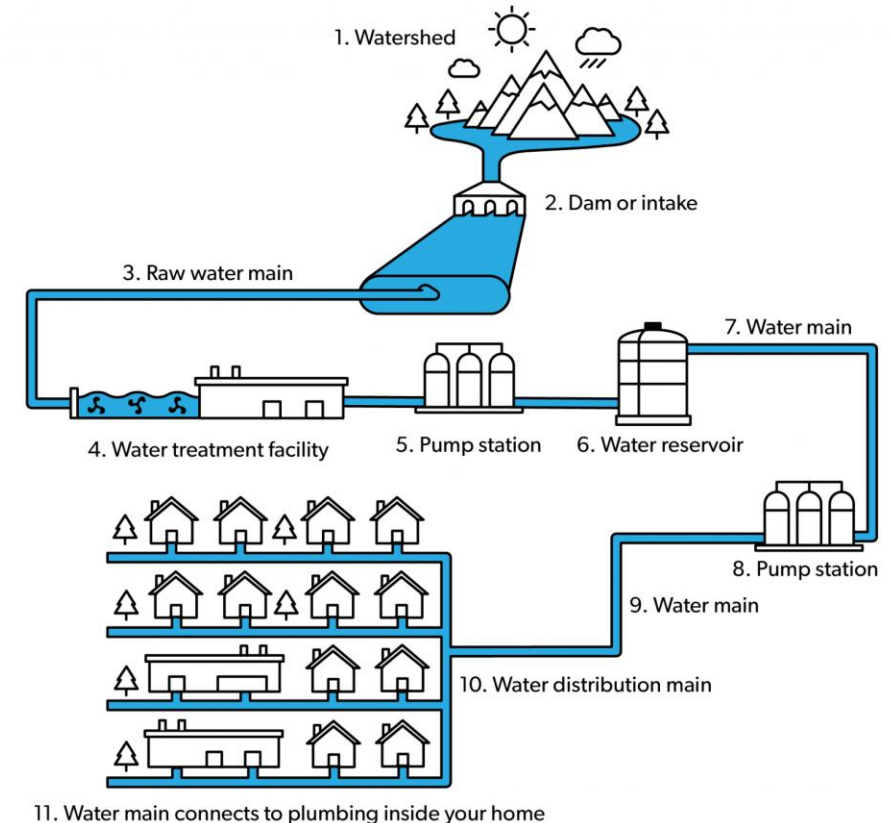
Industry Showcase 2025

Prof Anton Basson
Prof Pieter Rousseau

Department of Mechanical and Mechatronic Engineering

What are Digital Twins?

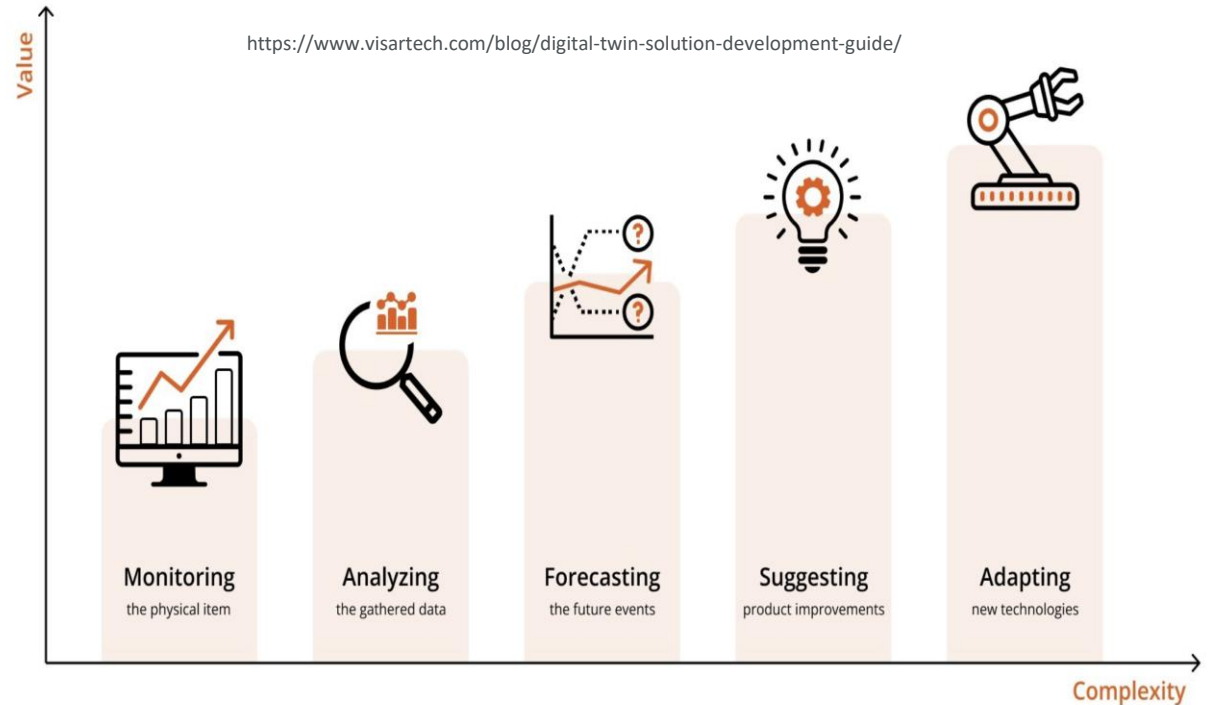
- Real-time, virtual replicas of physical products, systems, or processes.
- Merge **sensor data**, **modelling**, and **analytics** to mirror real-world behaviour.
- Provides real-time tracking, analysis, and virtual representation of complex systems.
- Enables operational optimization, predictive maintenance, and rapid scenario testing.
- Leads to enhanced efficiency and sustainability in critical infrastructure.



<https://pressbooks.bccampus.ca/plumbing3b/chapter/describe-water-services/>

Functions of Digital Twins

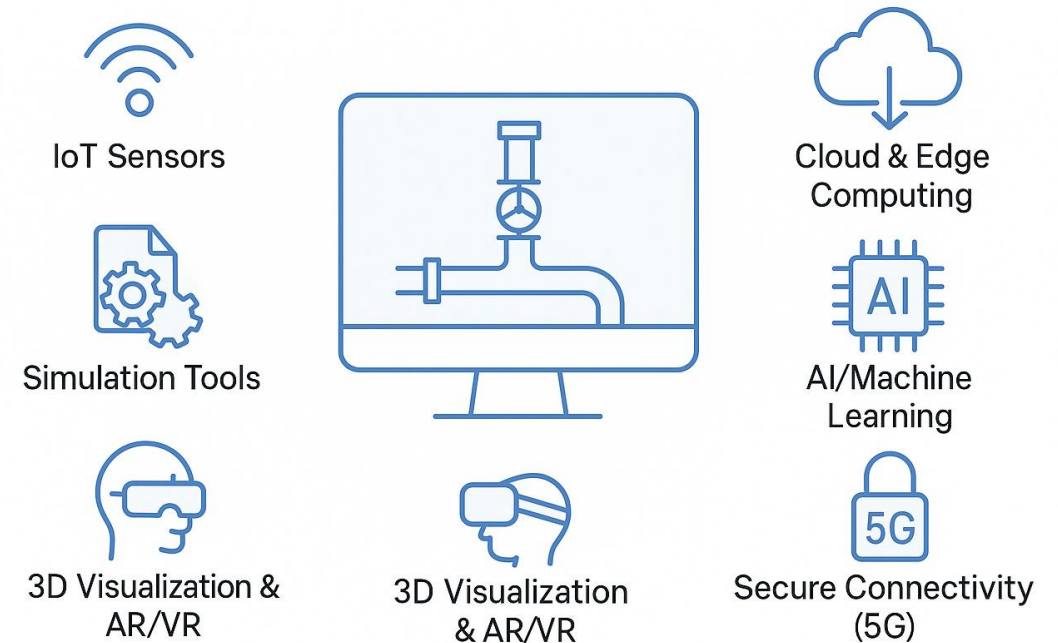
- **Monitoring** - Tracking physical characteristics, performance indicators, and environmental factors in real-time.
- **Analysis** - Leveraging built-in physics-based models, machine learning and analytical algorithms.
- **Forecasting** - Uses information to predict future events.
- **Advising** - Model what-if scenarios and generate suggestions to find optimal operating parameters.
- **Adapting** - Ability to incorporate new technologies for operational optimization.



Digital Twin ecosystem

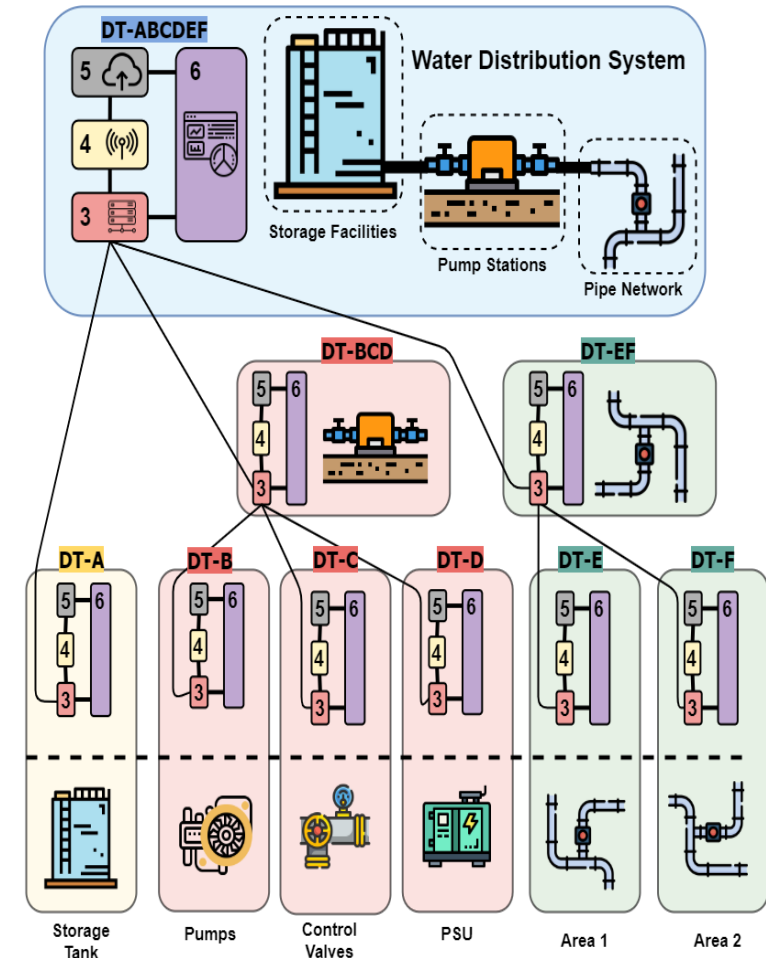
- **IoT sensors** – Continuous real-time data collection from the physical network.
- **Simulation tools** – Model network behaviour and test “what-if” conditions.
- **Cloud & edge computing** – Scalable analytics with local responsiveness.
- **AI/ML** – Predict failures, optimize operations, and simulate scenarios.
- **3D Visualization & VR/AR** – Intuitive interaction with infrastructure models.
- **Secure Connectivity** – High-speed, protected data exchange.

Digital Twin Infrastructure



Application to Water Distribution Systems

- Collect live data and do data processing - handling missing values or outliers, do data storage.
- Continuously compare measured and simulated parameters generated via models: physics-, statistics-, and machine-learning-based.
- Detect leaks, pressure drops, and quality issues in real time.
- Predict asset failure and optimize maintenance cycles.
- Provide remote maintenance support via Augmented Reality with immediate access to historical and real-time data.
- Improve energy efficiency via dynamic pump scheduling.



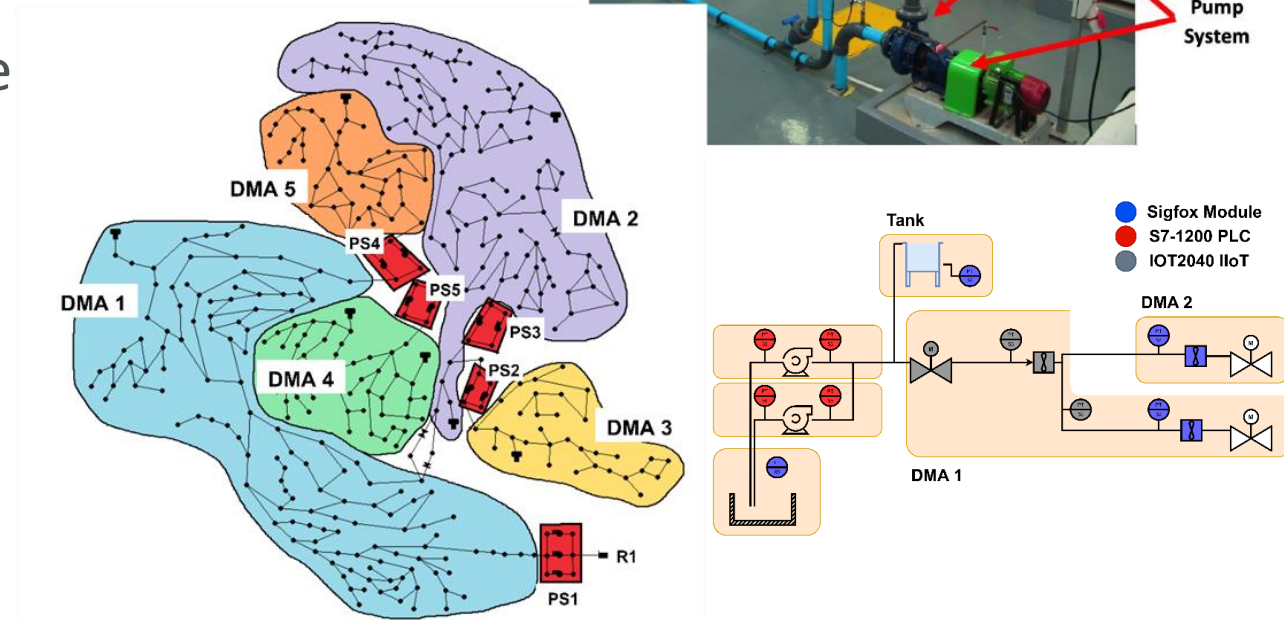
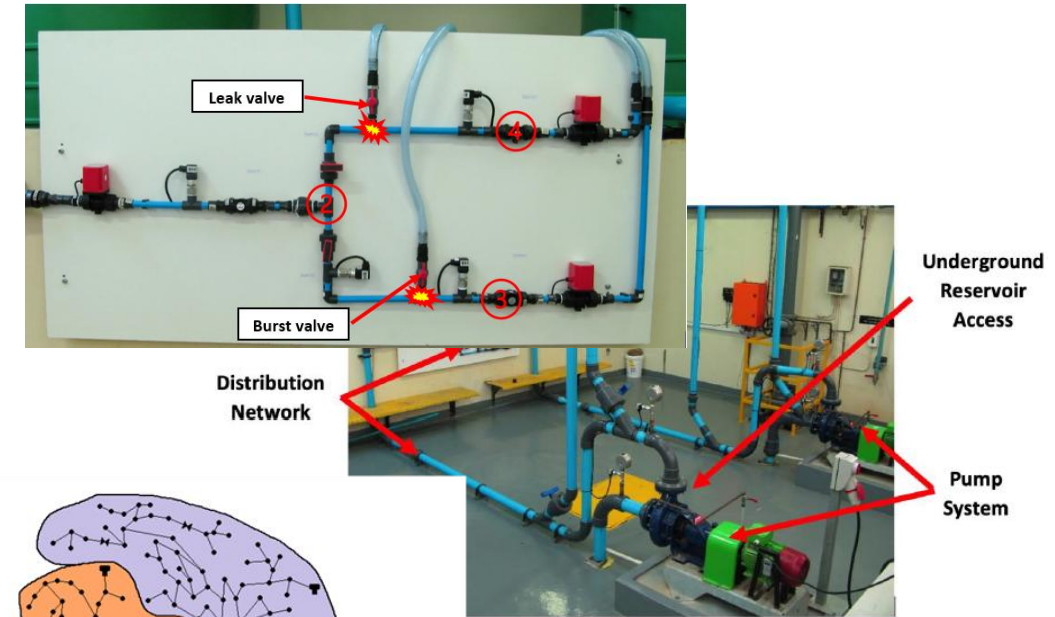
Faculty of Engineering team

- Prof Anton Basson and Dr Clint Steed
 - Mechatronics, Automation and Design Research Group.
 - Digital twins for complex systems.
- Prof Annie Bekker
 - Noise and Vibration Research Group.
- Prof Johan van der Spuy
 - Turbomachinery CFD and experimental research.
 - Pump and Water Distribution System lab.
- Prof Pieter Rousseau
 - Thermofluid Systems Modelling.
- Prof Jacomine Grobler
 - Machine Learning applications.
 - Anomaly detection, predictive maintenance, ...



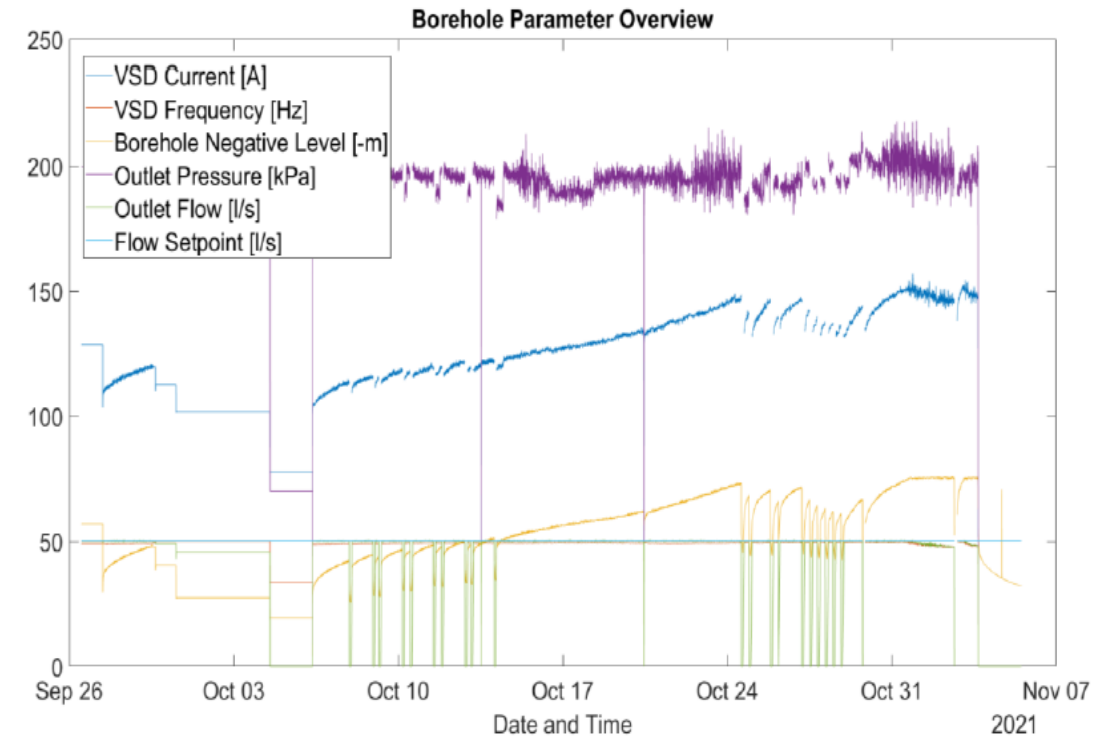
DT for WDS monitoring and fault detection

- Evaluation of DT architectures for application in Water Distribution Systems.
- Case study 1: Lab-scale water distribution system with variety of monitoring devices.
- Conducted laboratory tests to demonstrate methodology.
- Case study 2: Large scale WDS.
- Simulated results used to demonstrate methodology.



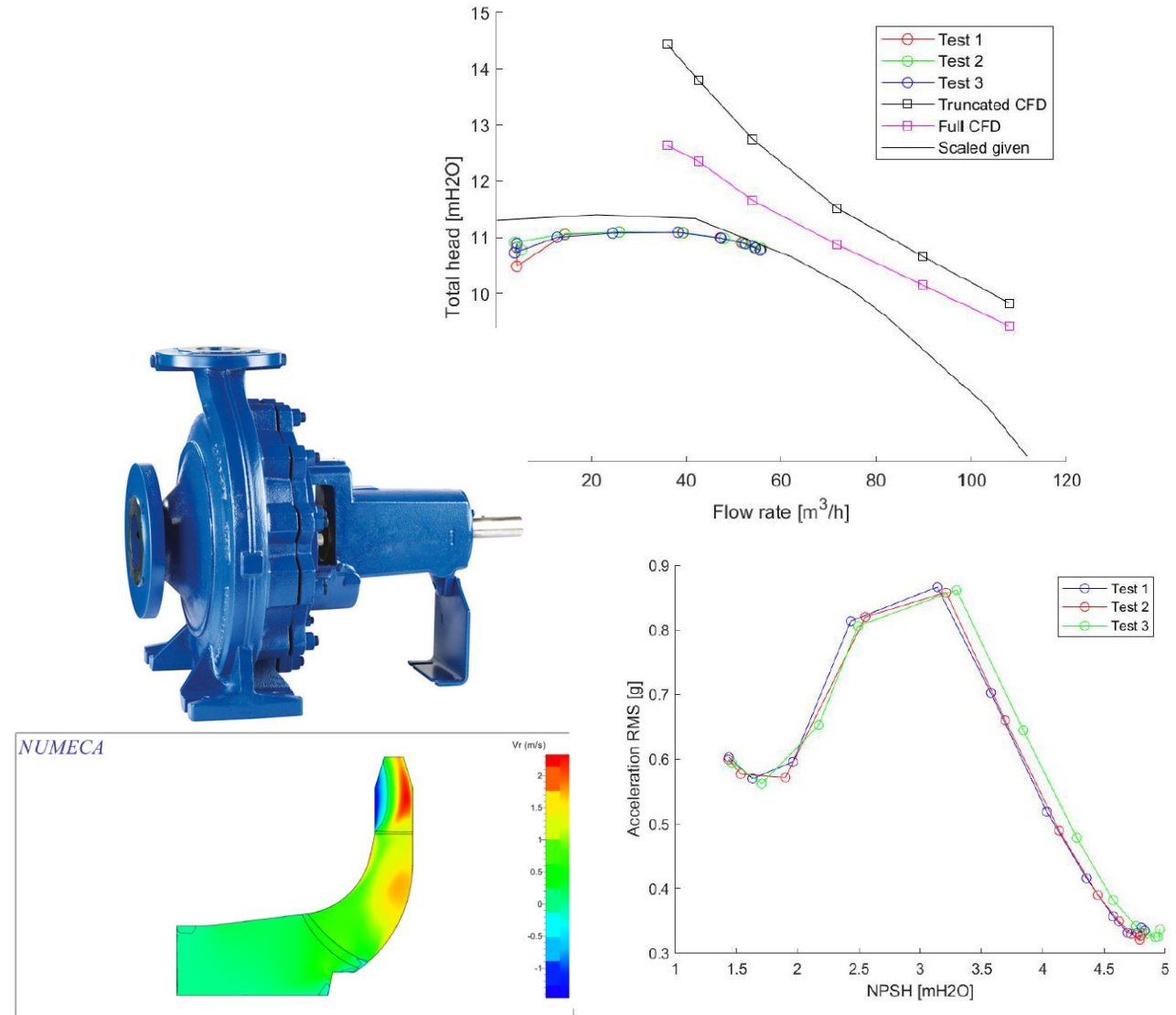
DT for deep aquifer pump monitoring

- Developed dashboard that reads the SCADA data in real time.
- Presents current performance in context of expected performance.
- Expected performance based on design point duty, performance curves, physics-based performance models, and expected movement of measured parameters.
- Provides additional “digital visibility” of operations.
- Operators still make assessments based on additional information.



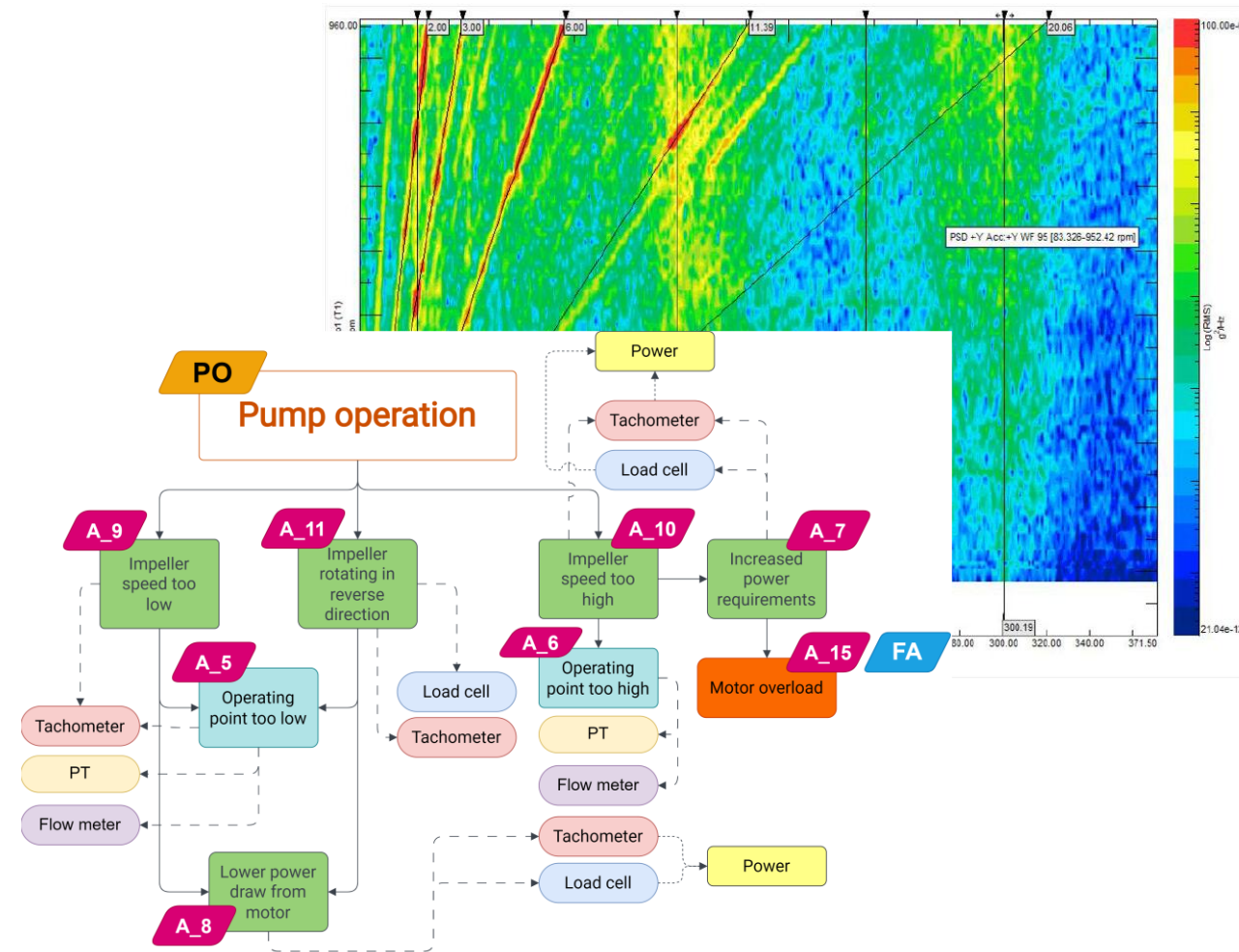
Simulation of cavitation in pumps

- Detail CFD analysis of cavitation phenomena using NUMECA.
- Laboratory-scale measurements of onset of cavitation.
- Comparing experimental and CFD simulation results.
- Evaluated vibration sensors to detect inception of cavitation.
- Showed potential of having a surrogate model embedded in DT.



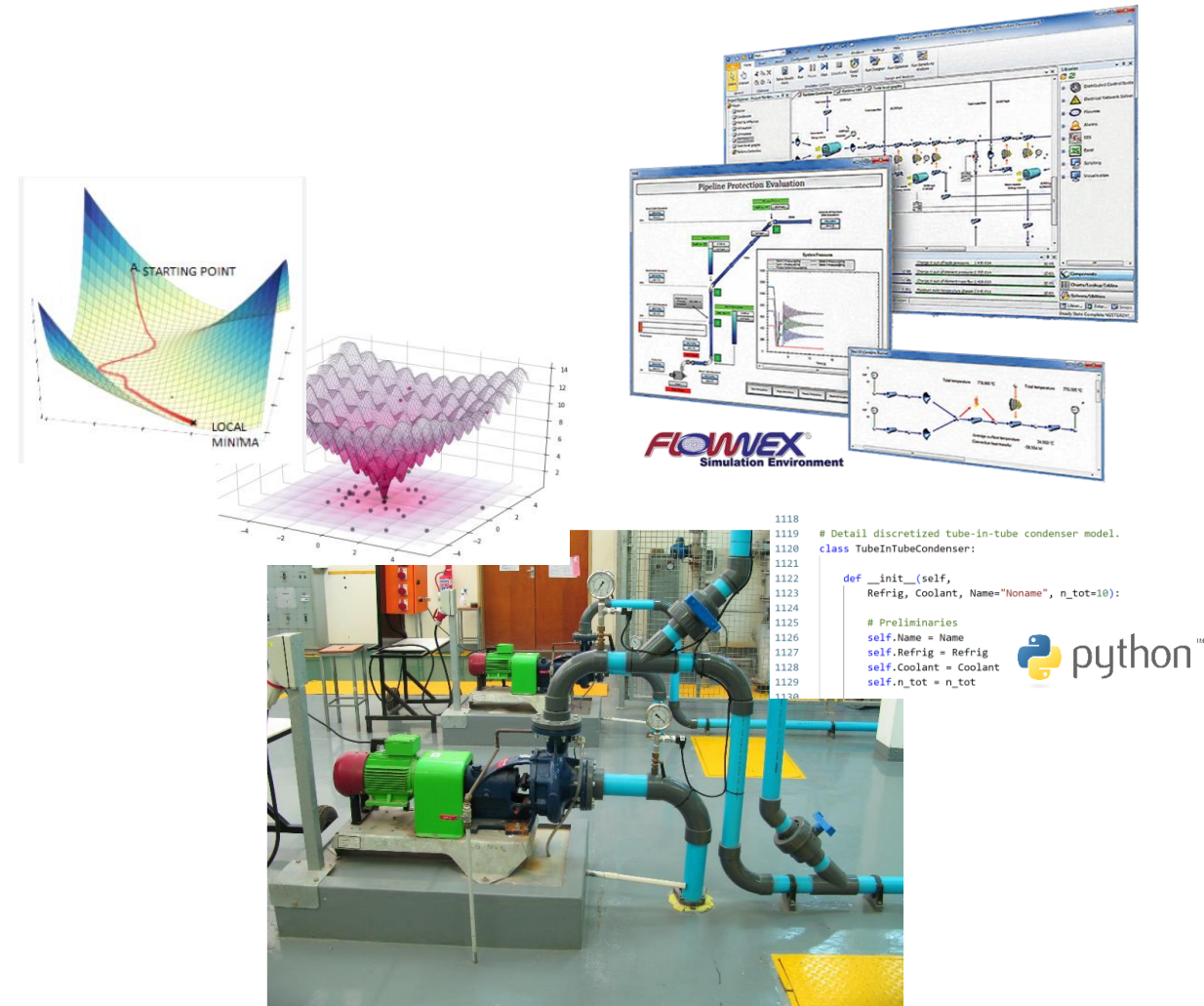
Fault detection and diagnosis in pumps

- Range of experiments conducted in pump laboratory with expanded vibration measurements.
- Identified unique fingerprints of key faults based on vibration monitoring combined with pump performance data.
- Statistics-based models to identify and characterise unique collective fault states.
- Provides basis for DT implementation.



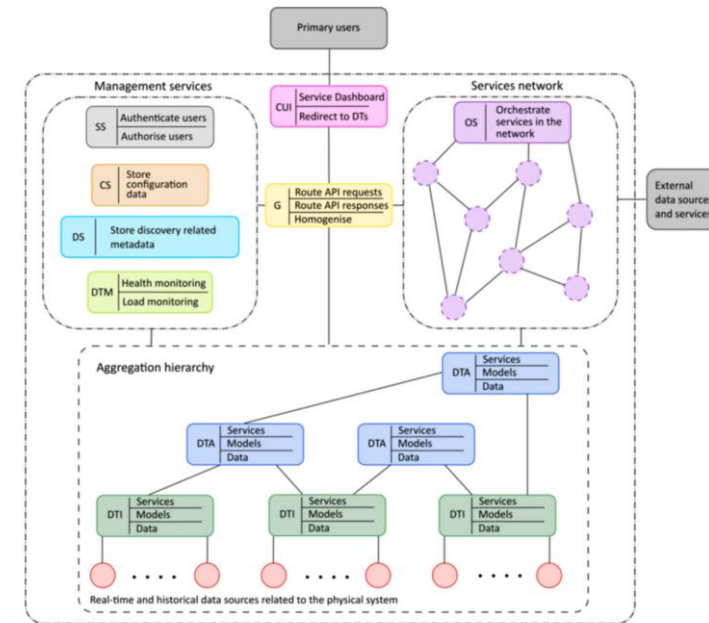
Modelling and calibration of WDS networks

- High-fidelity models required for model-based condition monitoring.
- Calibration required to align model results with physical system.
- Develop lab-scale physical water distribution network and conduct test of different operational scenarios.
- Set up physics-based integrated system model in Flownex.
- Apply parameter identification to calibrate physics-based model.



DT and AR for remote maintenance support

- Augmented Reality application for handheld tablet devices to support maintenance teams.
- Improve technicians' access to relevant documentation, data, and information.
- Improve communication between technicians.
- Active link with specialists situated at the offices/centres.
- DT acts as broker for information and communication as well as capturing of maintenance records.





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Thank you
Enkosi
Dankie