Digital twins in the water sector

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RAND WATER

Outline

DIGITAL TWINS IN THE WATER SECTOR

- **Introduction**
- What is a **digital twin?**
- A **generic patterns** in digital twin services / intended use.
- **Examples** of digital twins in the water sector.

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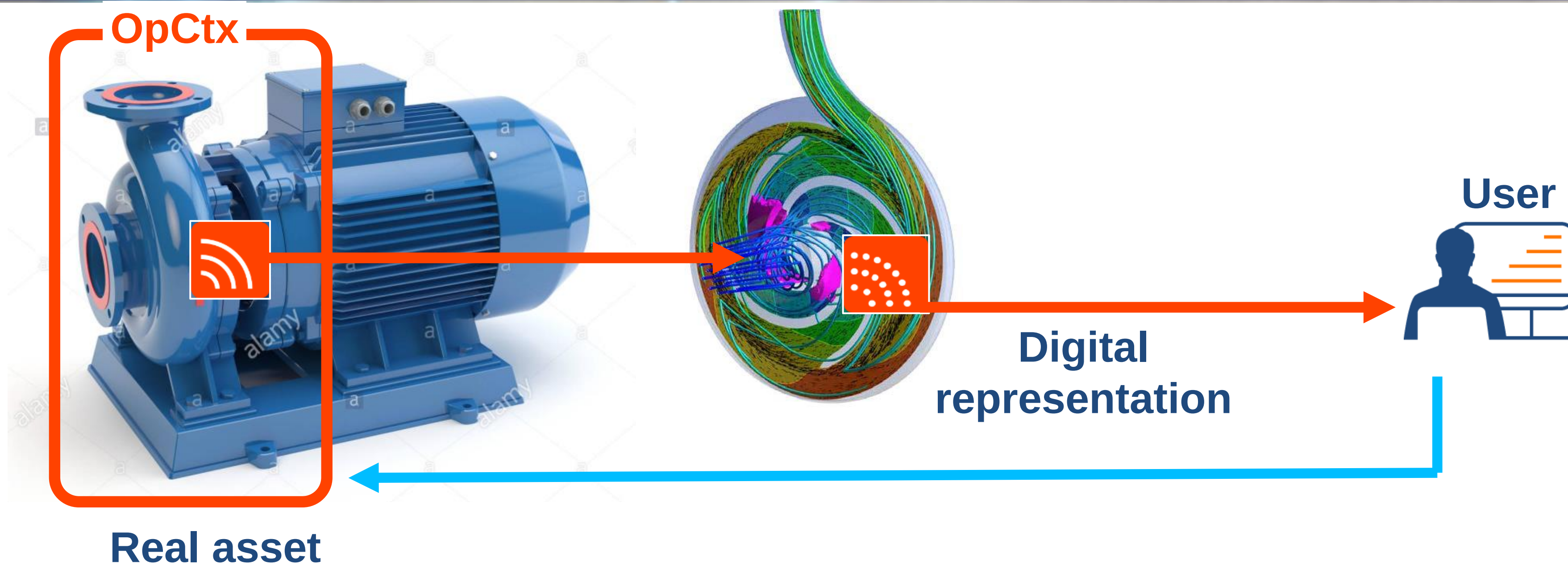
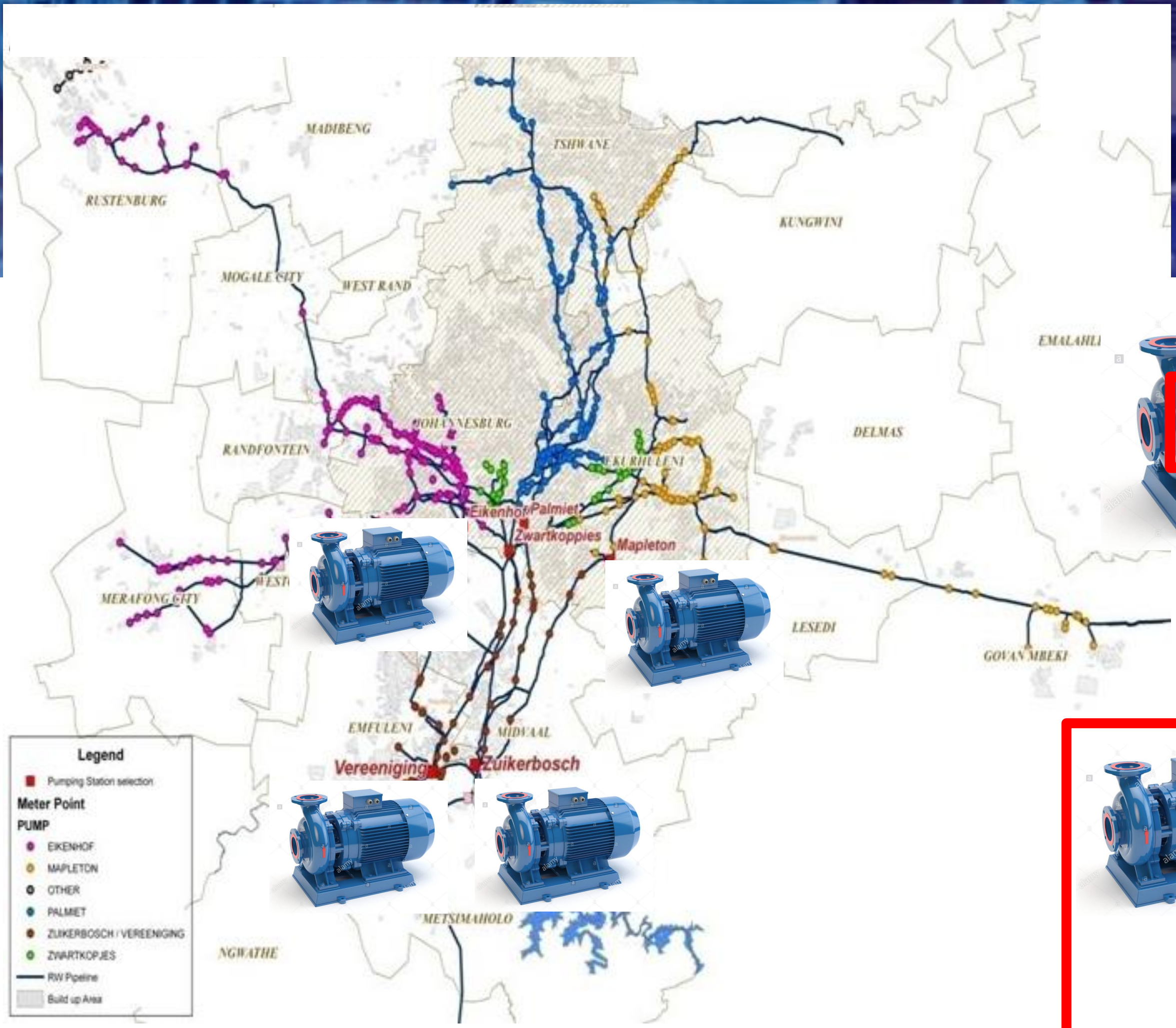
What is a digital twin

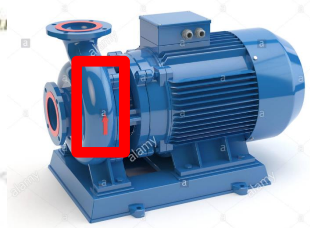
A DIGITAL REPRESENTATION OF THE STATE AND BEHAVIOR OF A REAL ASSET WITHIN ITS OPERATIONAL CONTEXT TOWARDS DECISION SUPPORT



Digital twin : real asset

A DIGITAL REPRESENTATION OF THE STATE AND BEHAVIOR OF A **REAL ASSET** WITHIN ITS OPERATIONAL CONTEXT TOWARDS DECISION SUPPORT





Component - impeller

System - pump

System of systems (Pump station with multiple pumps)

Digital twin : digital representation

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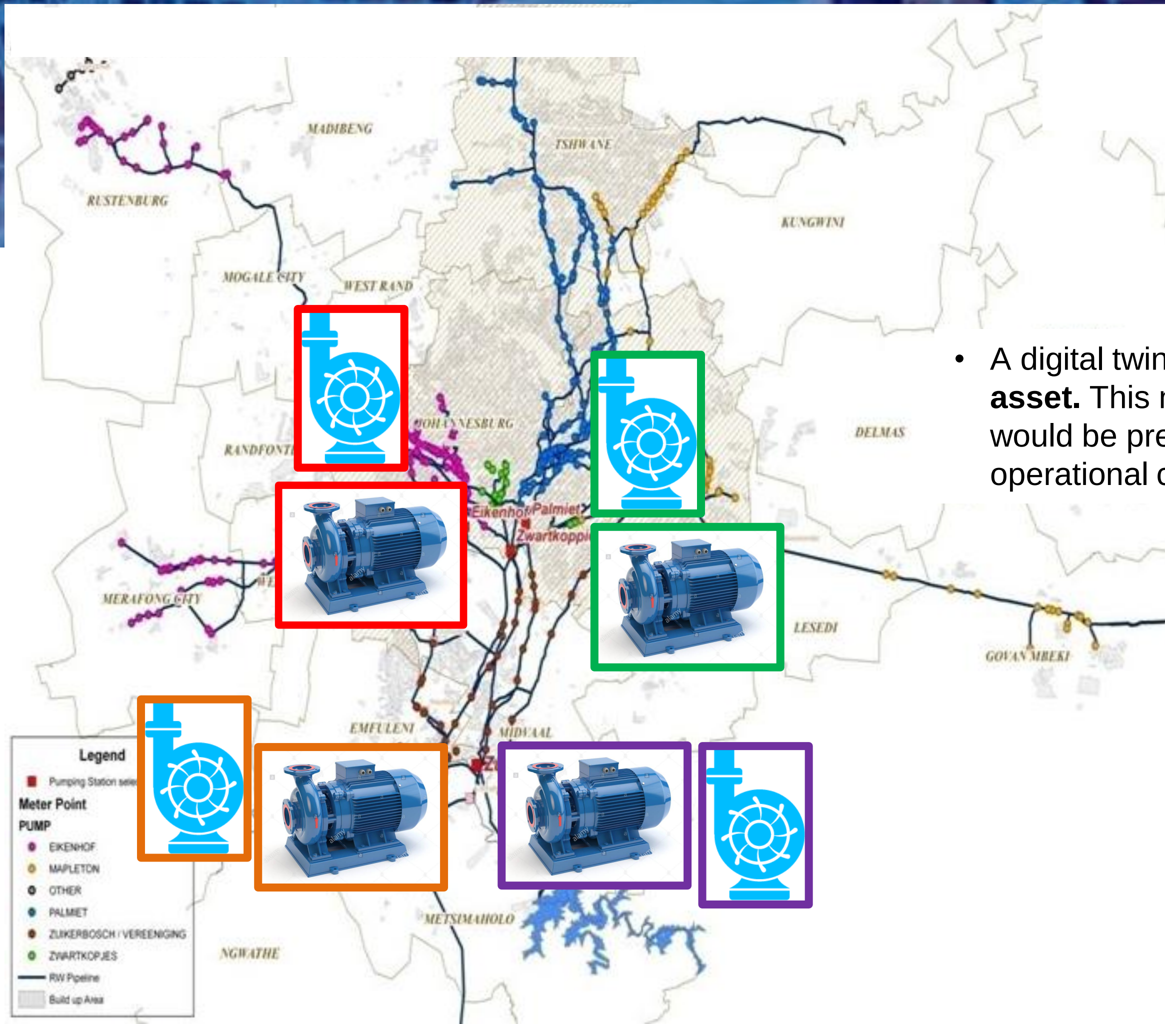
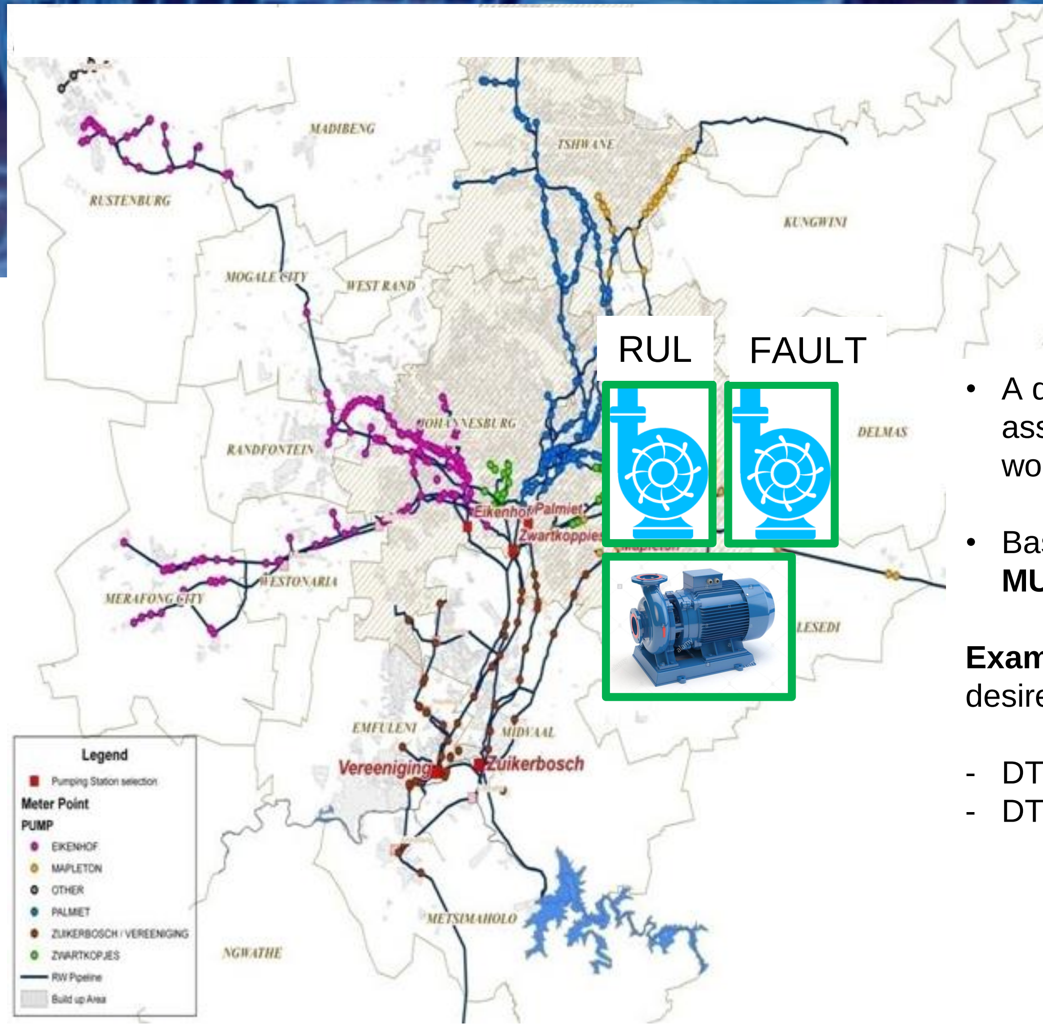


- A digital twin is **a one-to-one coupling with a real asset.** This means that every pump in a network would be presented by its own DT subject to its own operational conditions, state and behavior.

Digital twin – digital representation



A **DIGITAL REPRESENTATION** OF THE STATE AND BEHAVIOR OF A REAL ASSET WITHIN ITS OPERATIONAL CONTEXT TOWARDS DECISION SUPPORT

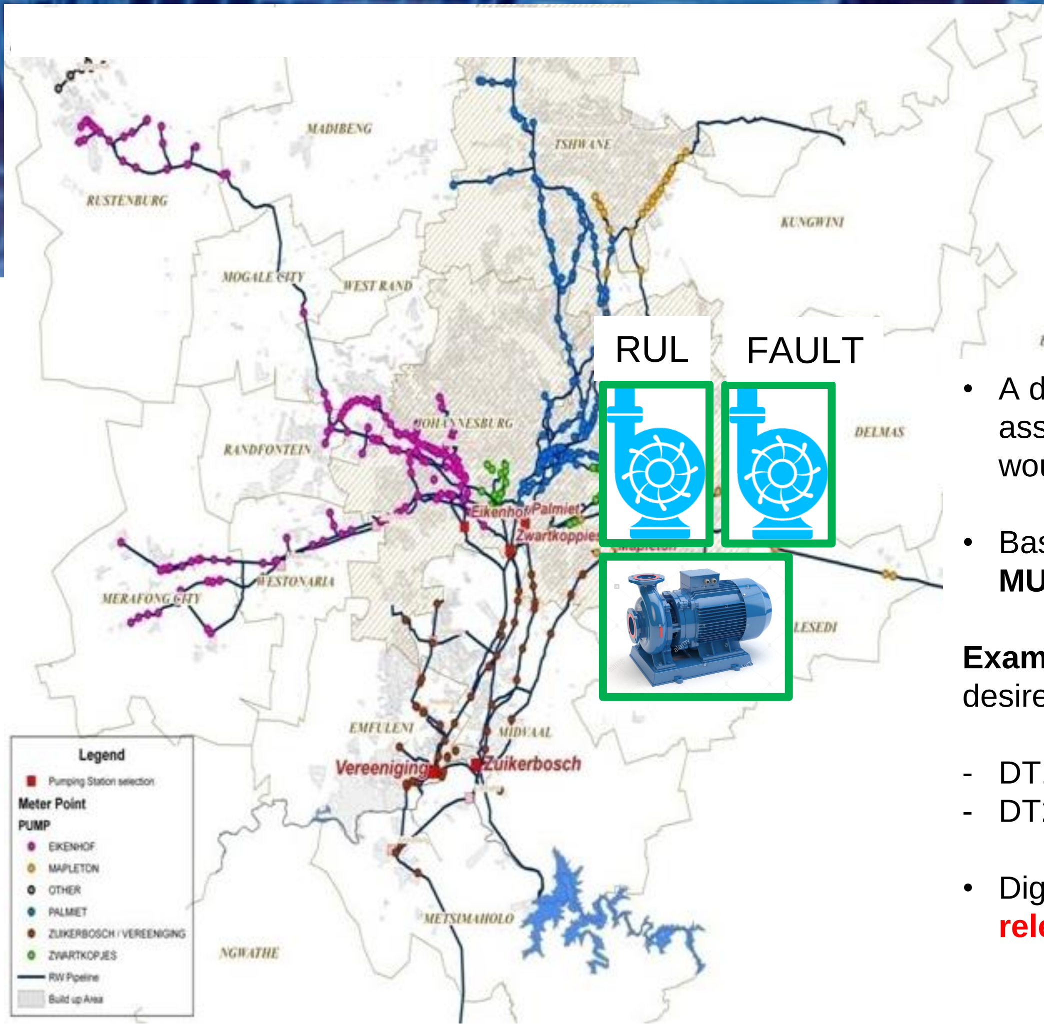
- A digital twin is a one-to-one coupling with a real asset. This means that every pump in a network would be presented by its own DT.

- Based on the intended use a pump may have **MULTIPLE DIGITAL TWINS**.

Example: If failure prediction and fault classification are desired then two different DT models must be created.

- DT1: Remaining useful life
- DT2: Fault classification

Digital twin – digital representation



A **DIGITAL REPRESENTATION** OF THE STATE AND BEHAVIOR OF A DIGITAL ASSET WITHIN ITS OPERATIONAL CONTEXT TOWARDS DECISION SUPPORT

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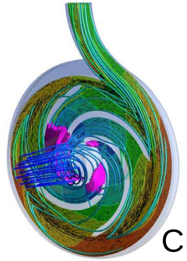
- Digital representation includes **the states which are relevant** to the intended use of the DT.

Digital twin – digital representation

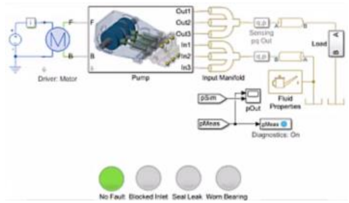
A **DIGITAL REPRESENTATION** OF THE STATE AND BEHAVIOR OF A DIGITAL ASSET WITHIN ITS OPERATIONAL CONTEXT TOWARDS DECISION SUPPORT

Physics-based



CFD

FEM



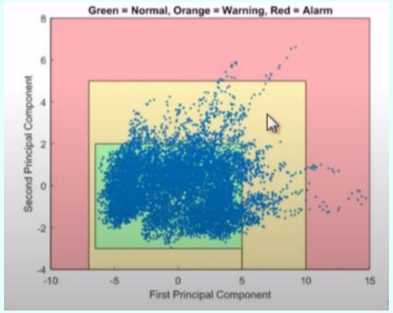
SYSTEM & COMPONENTS

$$P = \frac{Q\rho g h}{\eta_t}$$

EQUATION

Kalman filter (Best linear combination of data and physics)

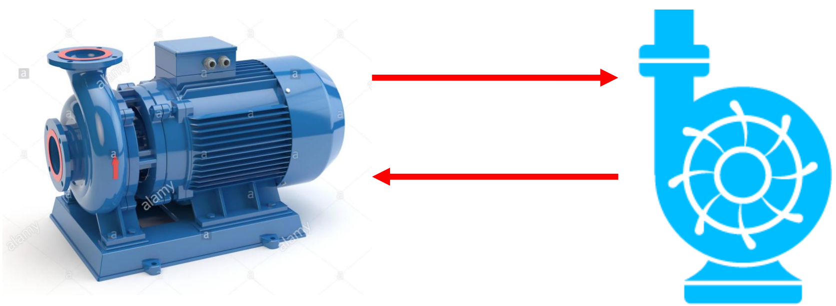
Data-driven



- Curve-fit
- Multi-variable regression
- Machine learning

Digital twin – entanglement

A DIGITAL TWIN requires **entanglement / connection** between the real asset and



Entanglement – There must be a link (direct or indirect) between the Real asset and digital representation to enable an update to the digital reflection of the state / behavior of the real asset. (Governed by connectivity, promptness and association)

Weak entanglement

- Information inferred by indirect observations

Simple entanglement

- Link can be interrupted
- Unidirectional communication
- Not necessarily real-time

Strong entanglement

- Constant link
- Direct, bidirectional communication
- Digital twin can be controlling instance

INCREASED SOPHISTICATION & COST

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Digital twin – service scoping map

A DIGITAL TWIN requires **entanglement / connection** between the real asset and

DECISION LEVEL

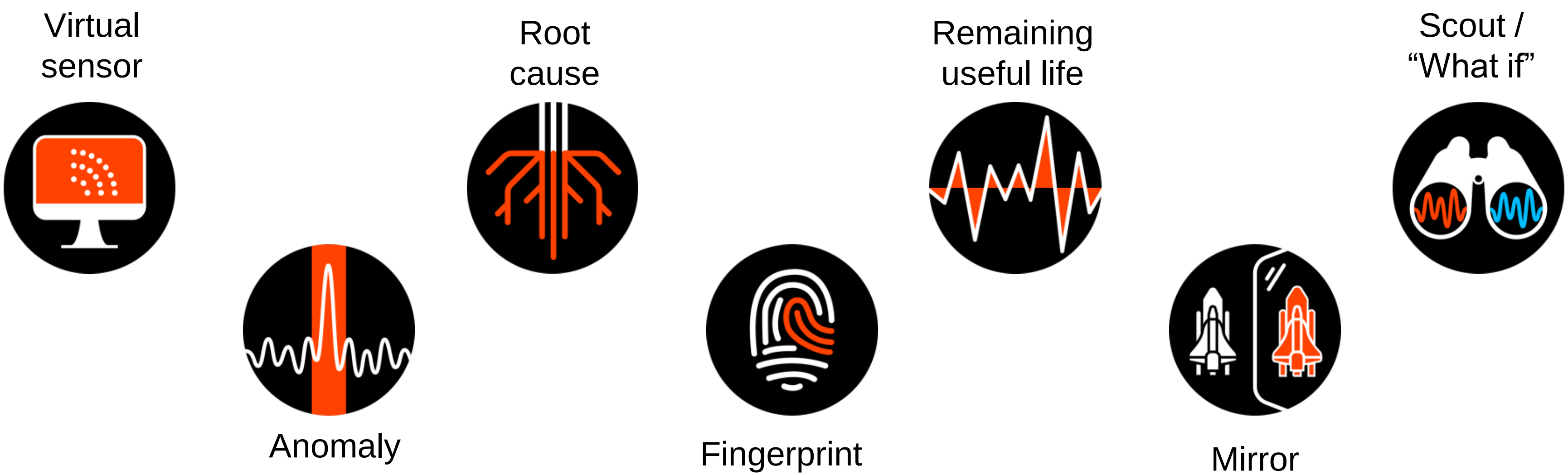
- What is the time horizon which the DT service should impact?
  - Long term (Strategic)
  - Medium term (Tactical)
  - Short term (Operational)

TEMPORAL SCALE

- Should the DT model provide insight, hindsight or foresight
- The temporal aspect drives the direction of investment
  - Hindsight: Invest in Analysis
  - Insight: Invest in sensing
  - Foresight: Invest in predictive modelling

Digital twin – service patterns

A DIGITAL TWIN requires **entanglement / connection** between the real asset and



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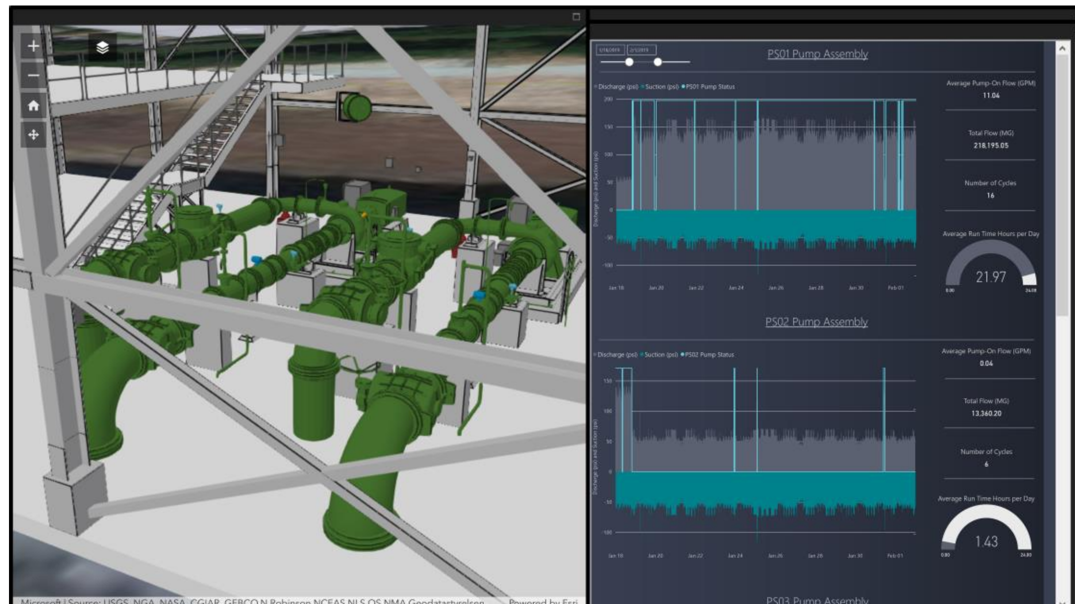
Mirror

Dynamic (real-time) display of the performance of KCI Wastewater Pumping Station assets

3D model of “as is” state of Pump Station

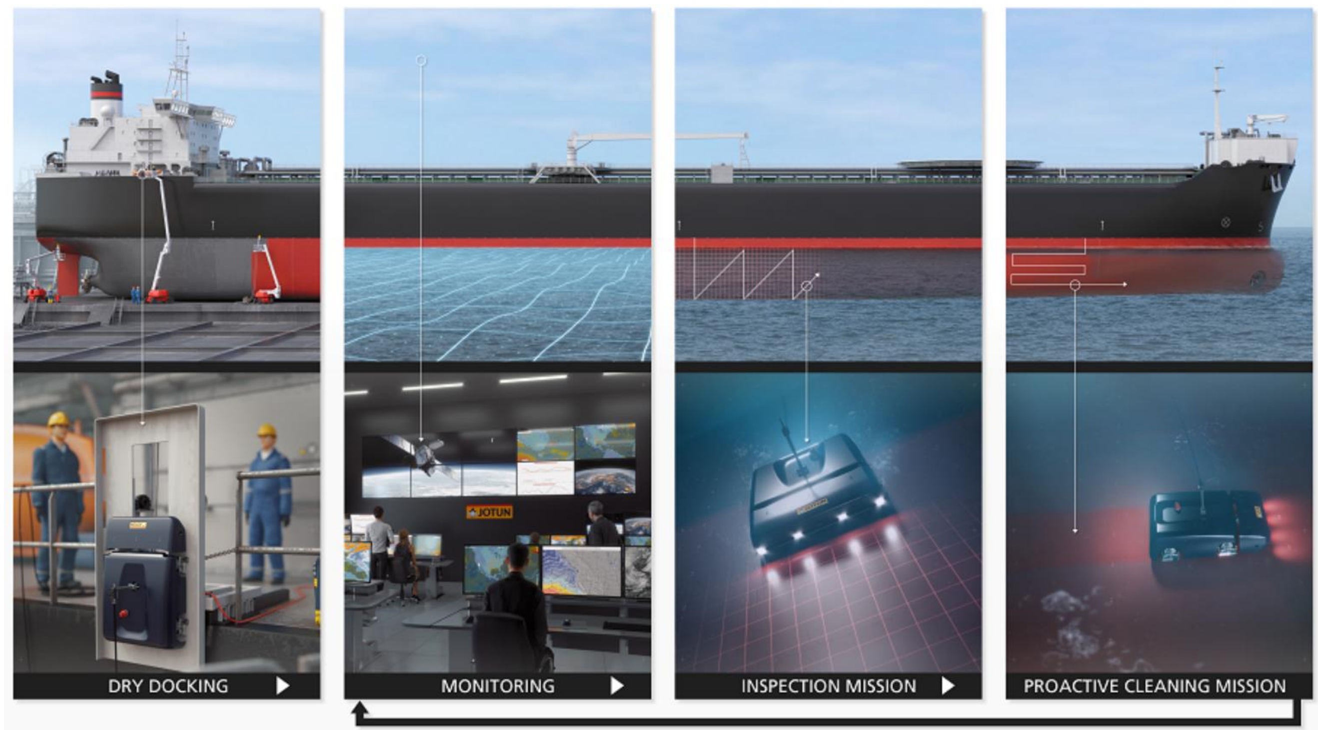
- System information from LiDAR scans, drone imagery and traditional surveys.
- Asset information from mechanical, electrical and wastewater assets information through surveying Gwinnett’s station.
- Assets IDs and data such as make, model and serial number.
- Pressure, flow, temperature, vibration, and volume sensor outputs from their equipment



Underwater robotics for active anti-fouling operations

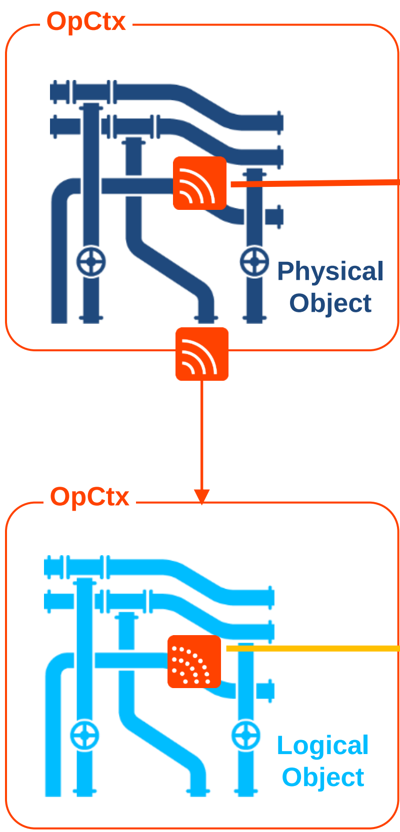
Mirror

Digital model is used to reflect the current state of an asset to visualize a remote operation / hazardous operation.



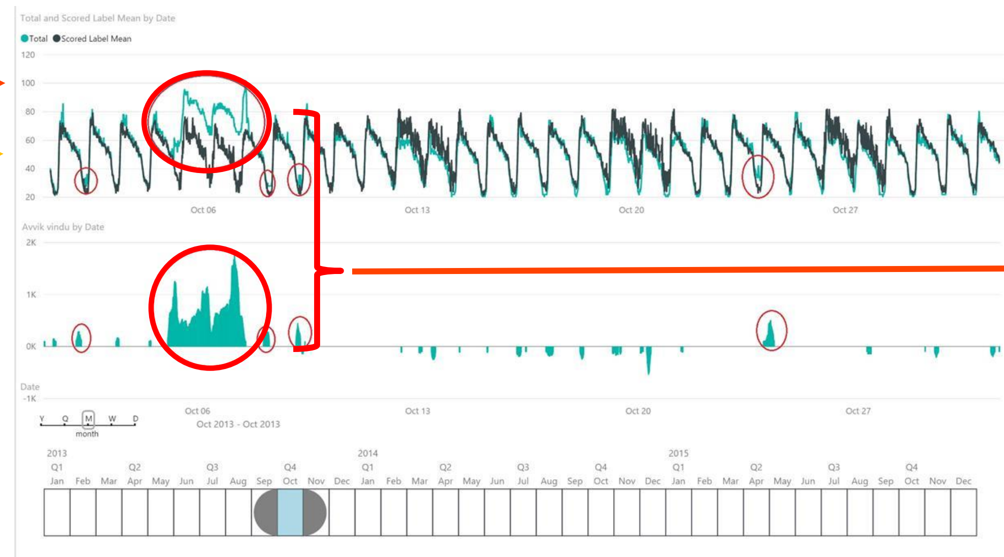
Leak detection

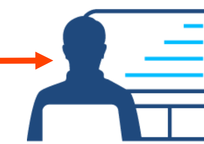
Anomaly



DT is used to benchmark expected state

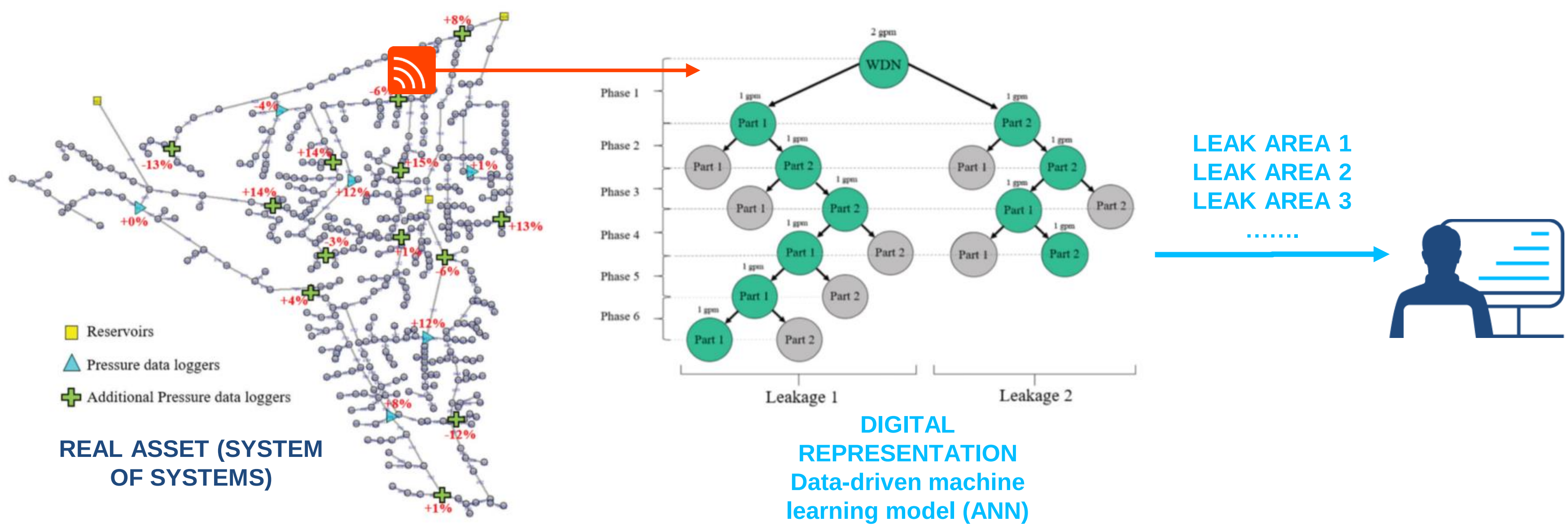
- Compared to measured state
  - Deviations indicate an anomaly which is communicated to the user





Root cause

Leak detection & Localisation: Balerma water distribution network

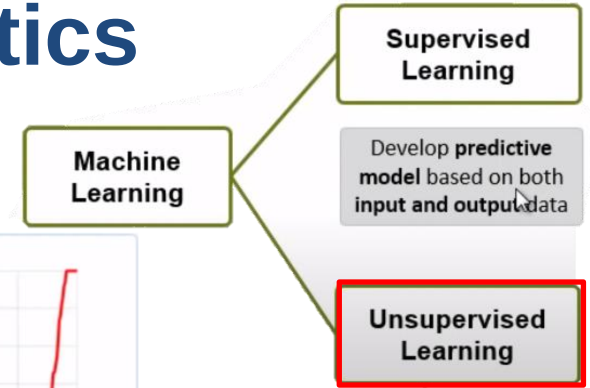


A methodology for leak detection in water distribution networks using graph theory and artificial neural network

https://doi-org.ez.sun.ac.za/10.1080/1573062X.2020.1797832

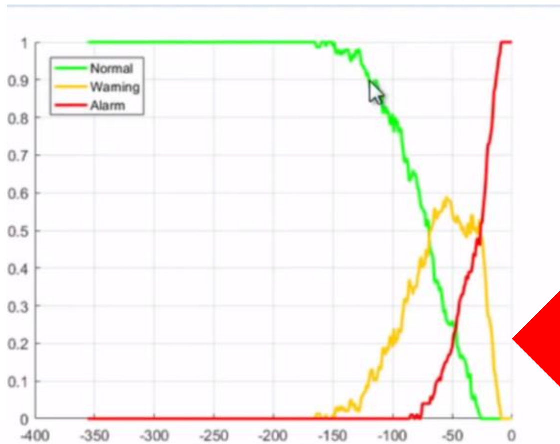
Remaining useful life

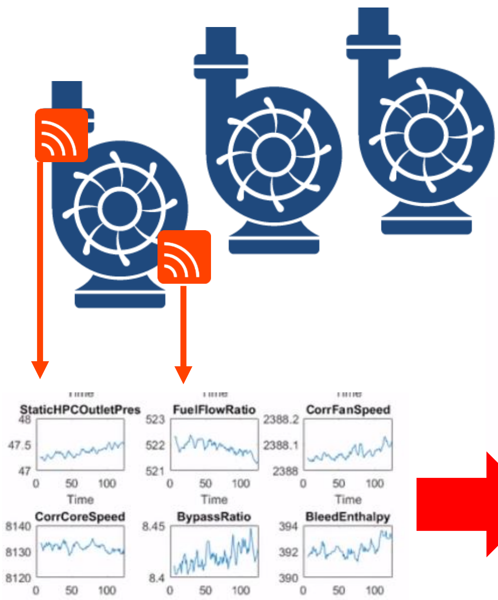
Digital twins for prognostics

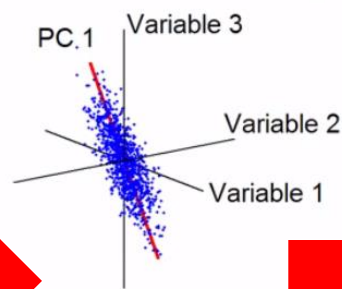


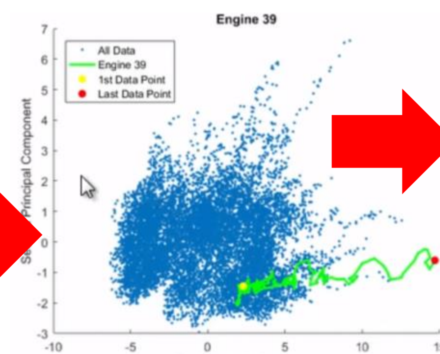
Scenario 1: NO data from failures

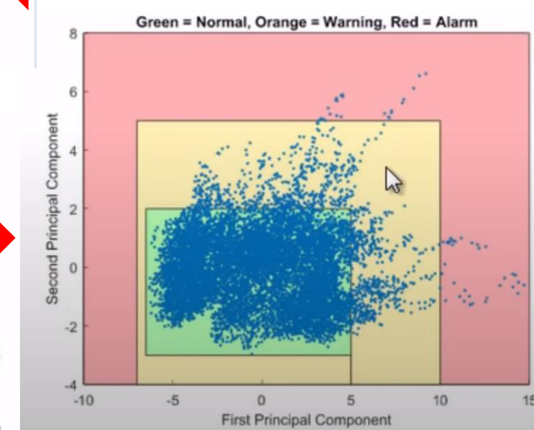
Can we be smarter about scheduling maintenance intervals without knowing what failure looks like?











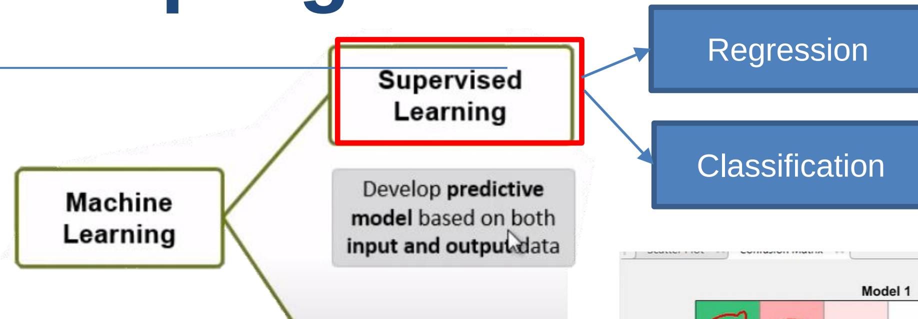
Data from multiple sensors → PC analysis → Identify trends of degraded performance → Create clustering

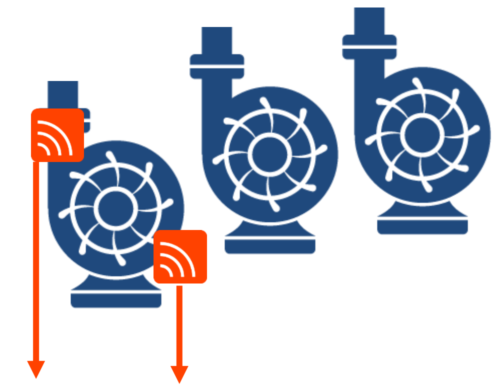
Remaining useful life

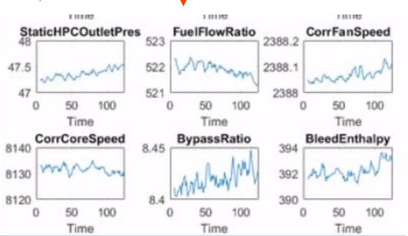
Digital twins for prognostics

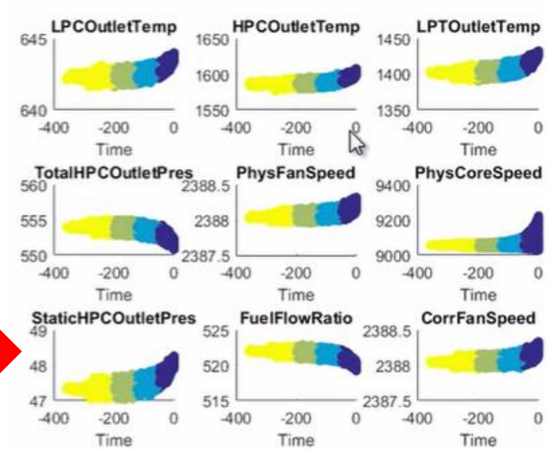
Scenario 2: HAVE data from failures

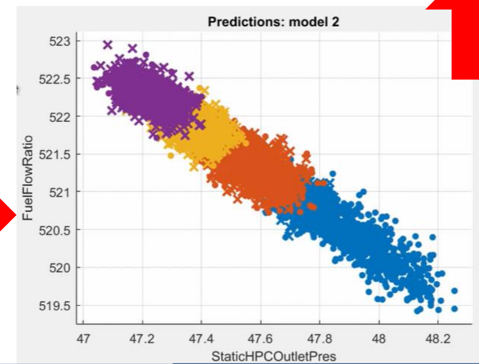
Can we predict how long until failures occur?







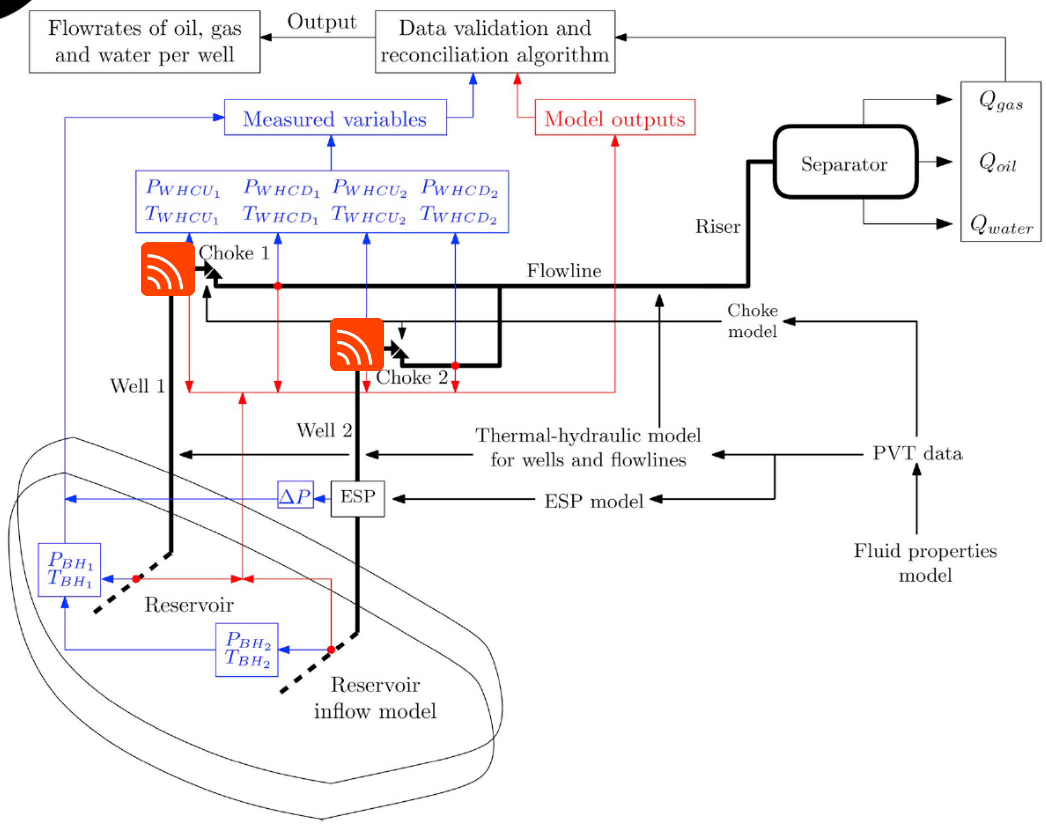




Data from multiple sensors → Identify failure data → Create classifications → Train model & evaluate

Virtual sensor

Virtual flow metering



FLOW METERS

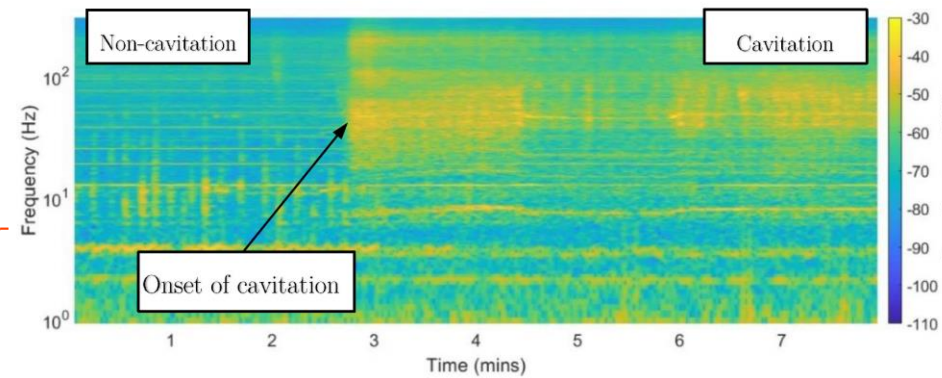
- Expensive ~R30k to R600k per meter for large diameter pipes.

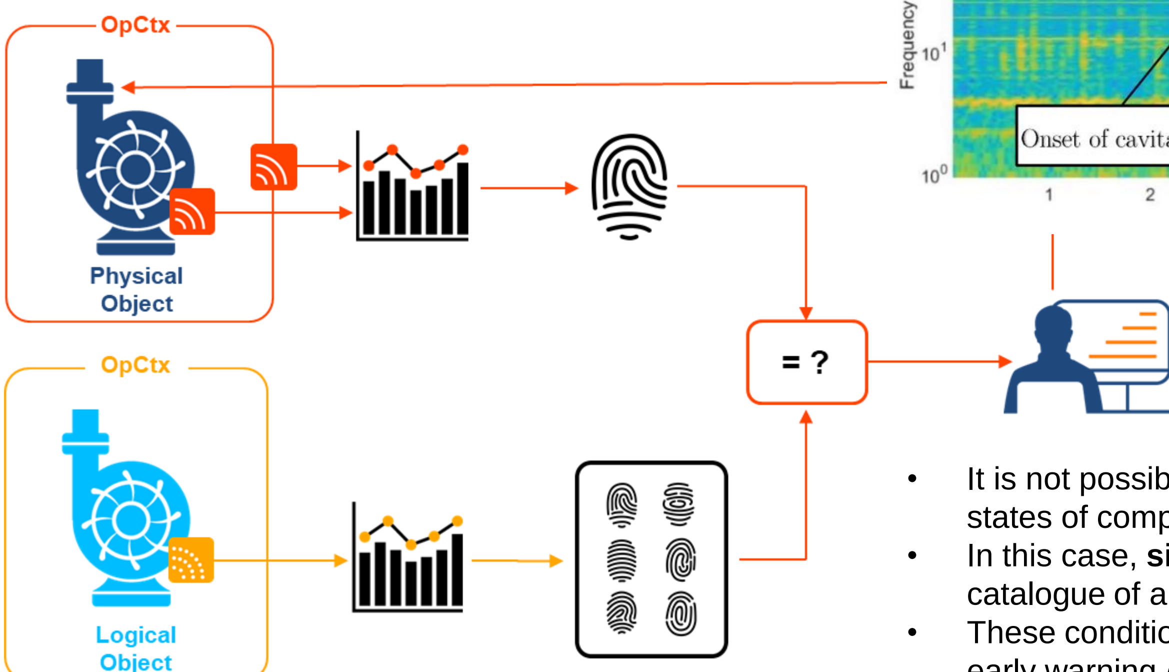
DT can act as a virtual sensor

- Example from oil industry
- Real subsea oil and gas production systems are equipped with more cost effective sensors and use digital models to infer flowrate of production from wells.
- Can offset cost, obtain information in hazardous or inaccessible environments, can use model to determine critical measurement.

Fingerprint

A fingerprint DT to create a catalogue of states



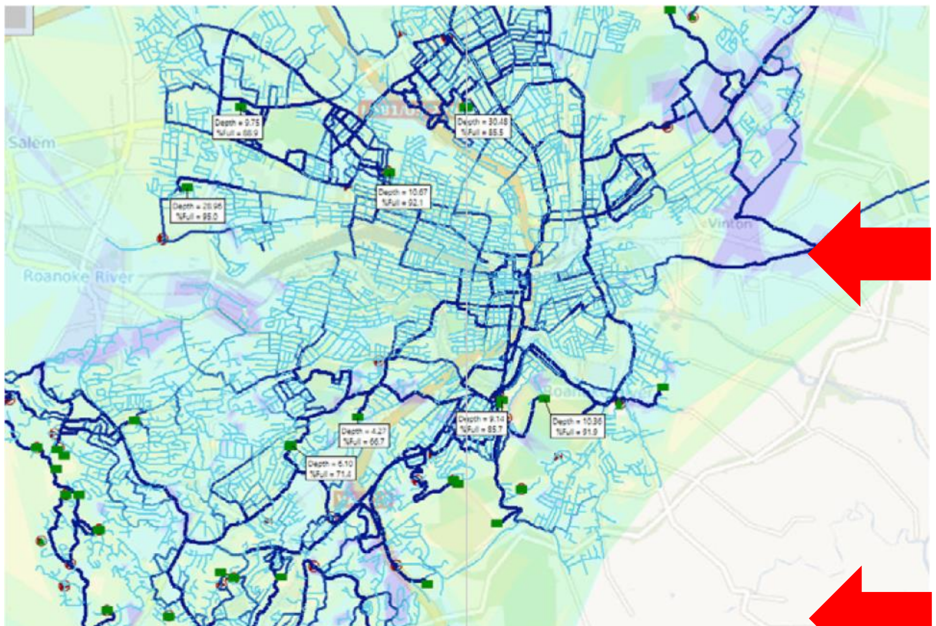


- It is not possible to have data available for the pre-failure states of complex one-off assets when they are commissioned.
- In this case, **simulated data** can be generated to create a catalogue of alert conditions.
- These conditions can be compared to measurements as an early warning / diagnostic tool.

Scout /
"What if"

System of system distribution network models

Hydraulic models, some extremely detailed and sophisticated, support planning decisions, problem solving, what-if analysis, forecasting and even regulatory reporting



Scenario 1: Population growth

Scenario 2: Flash flood

Newcastle University & Northumbrian Water Group DT of Newcastle - a digital city.

Scout /
"What if"

System of system distribution network models

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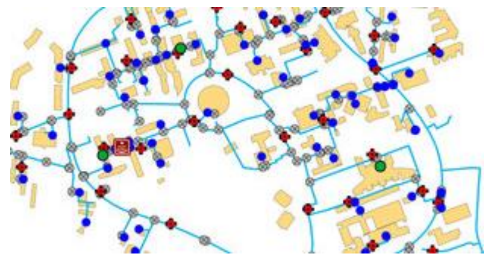
Scenario 1: Water supply + cost



Scenario 2: Water supply + cost

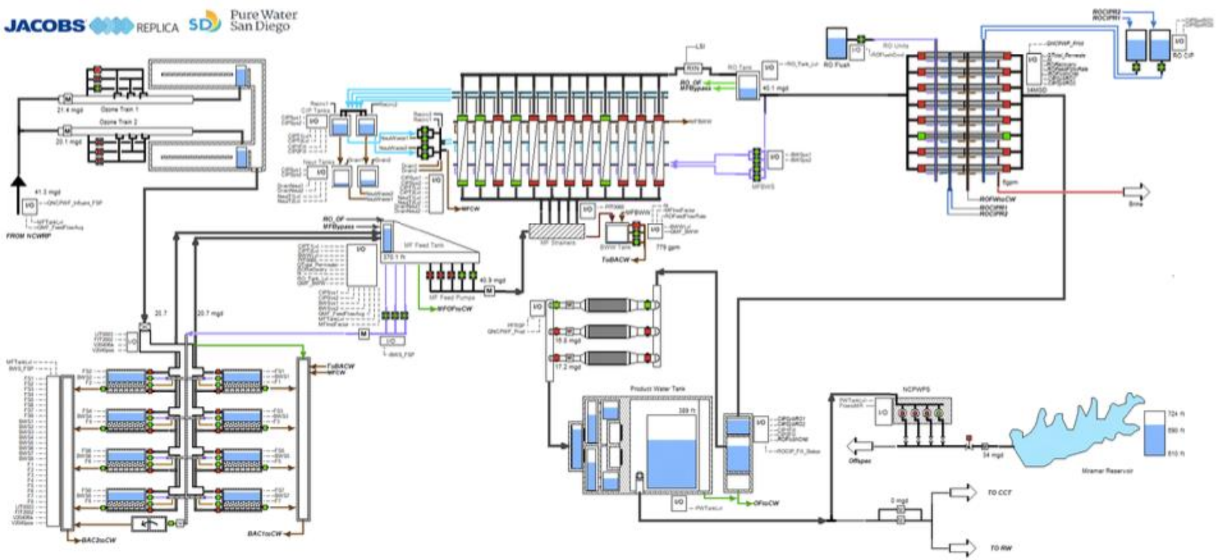
Companhia Águas de Joinville

- DTR for hydraulic simulations of WDN
- Scenarios using the master water plan as a future reference.
- OpenFlows WaterGEMS for the hydraulic simulations and attribute data from ArcGIS
- The project resulted in a consistent water supply at a low implementation cost of BRL 250,000.

Scout /
“What if”

San Diego Pure Water Facility

DT used during design – even before commissioning



Used to:

- Improve commissioning and long-term operations as an operator training platform
- Reduce potential future operational challenges
- Verify control points to sync process units
- Mimic control schemes
- Predictive process modelling

- **Scheme to supply 1/3 of San Diego’s water locally by 2035**
- **Includes multiple facilities**
- **Digital twin of advanced water purification facility**

Conclusion

- Digital twins are transpiring everywhere in the water sector. Opportunities seem boundless.
- **DTs offer** strategic, tactical and operational **benefits.**
- Massive trend towards **system of system DT integration of water assets into smart cities.**
- **DT technology using artificial intelligence is revolutionizing asset management**. Inferring patterns from data clusters.

Questions?

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