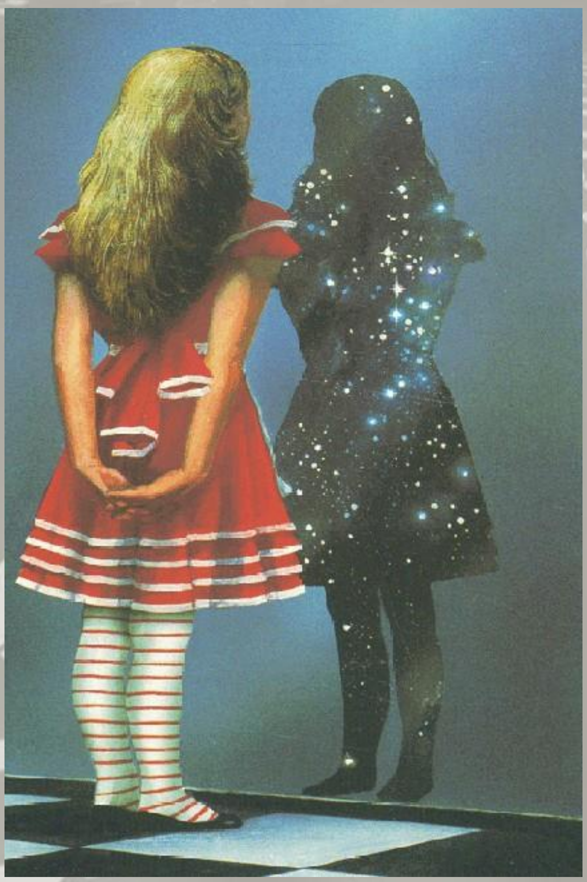
Industrial Artificial Intelligence The Driving Force of manufacturing



Professor Diego Galar

Head of Maintenance & Reliability, Tecnalia

Lulea *University* of technology

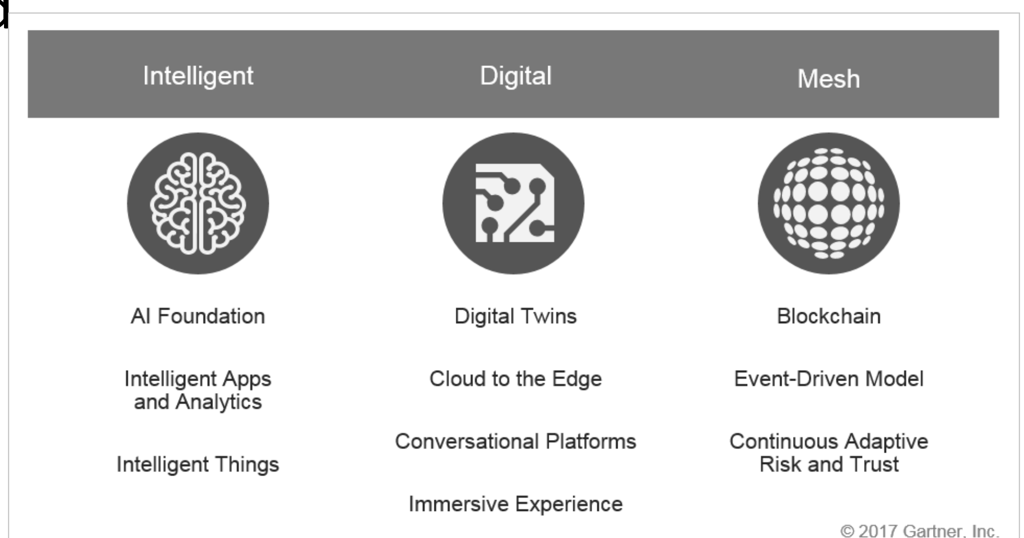
Ongoing industrial evolution

Digitalisation

- Integration of digital technologies into industrial context the **digitization** of everything that can be digitized

Industry 4.0

- Enabling industry to achieve Operational Excellence, through digitalised services



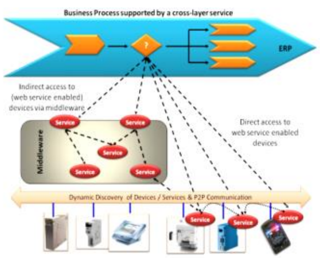
Manufacturing already generates more data than any other sector*

Measurement in Petabytes
1 Discrete manufacturing constitutes 1072 petabytes; process manufacturing 740 petabytes

* Source: IDC; McKinsey Global Institute analysis 2010

ICT-enabled Intelligent Manufacturing

- ICT is a key enabler for improving manufacturing systems at three levels:



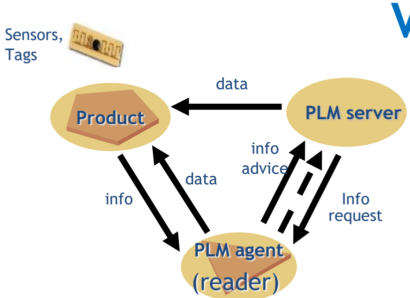
Smart Factories

– **Goal:**
More automation, better control & optimisation of factory processes

– **Means:**
Software, lasers & intelligent devices embedded in machines & factory infrastructure

Factory productivity

- Less waste
- Less energy use
- Faster time-to-market
- Better quality



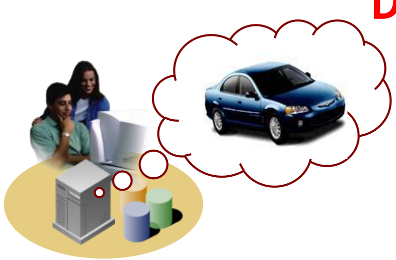
Virtual Factories

– **Goal:**
To manage supply chains; to create value by integrating products & services

– **Means:**
Software to holistically interconnect & manage distributed factory assets; new business models & value propositions

Supply-chain productivity

- High-value products
- Keep jobs in Europe
- Process transparency
- IPR security
- Lower CO2 footprint



Digital Factories

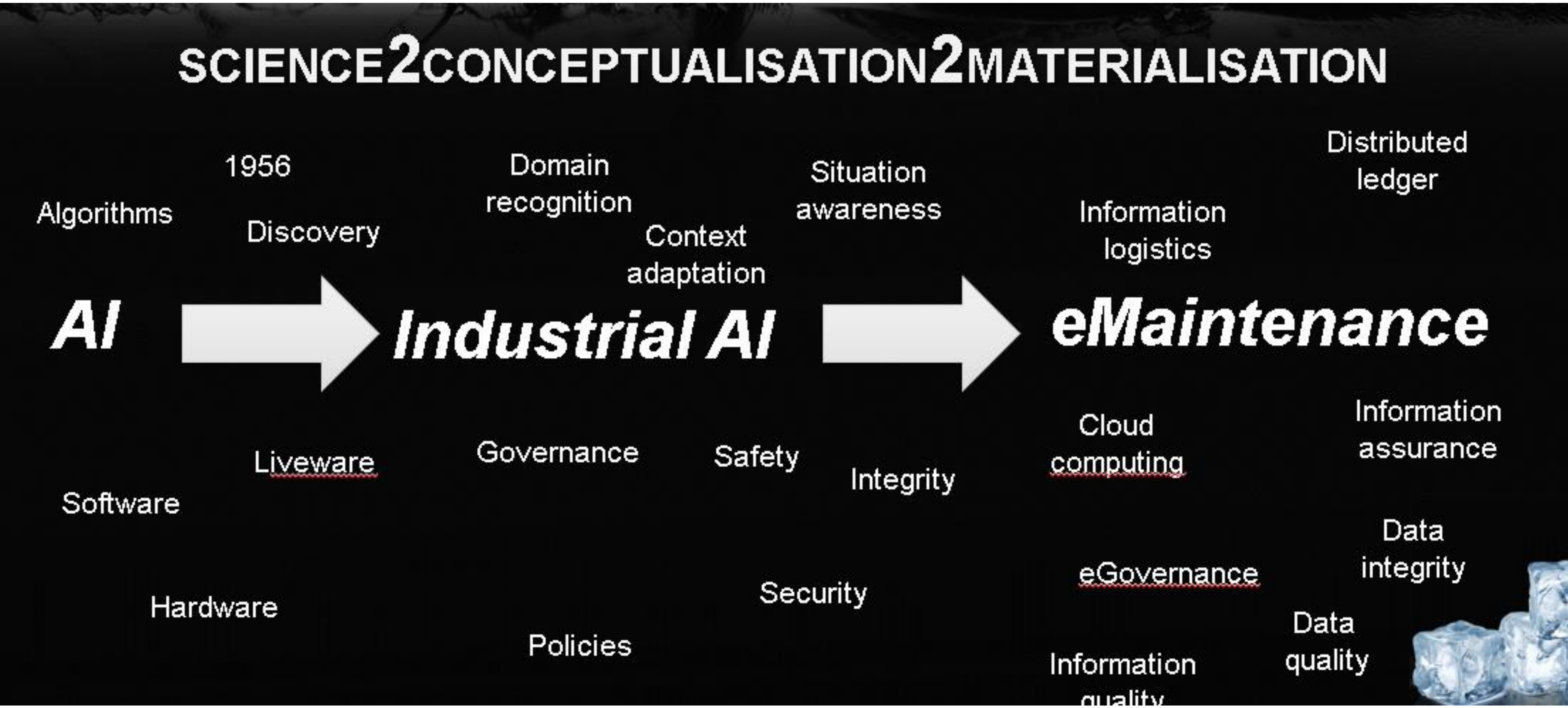
– **Goal:**
To "see" the product before it is produced

– **Means:**
Software for the digital representation & test of products & processes prior to their manufacture & use

Design productivity

- Reduce design errors
- Better & efficient products
- Less waste + rework
- Faster time-to-market

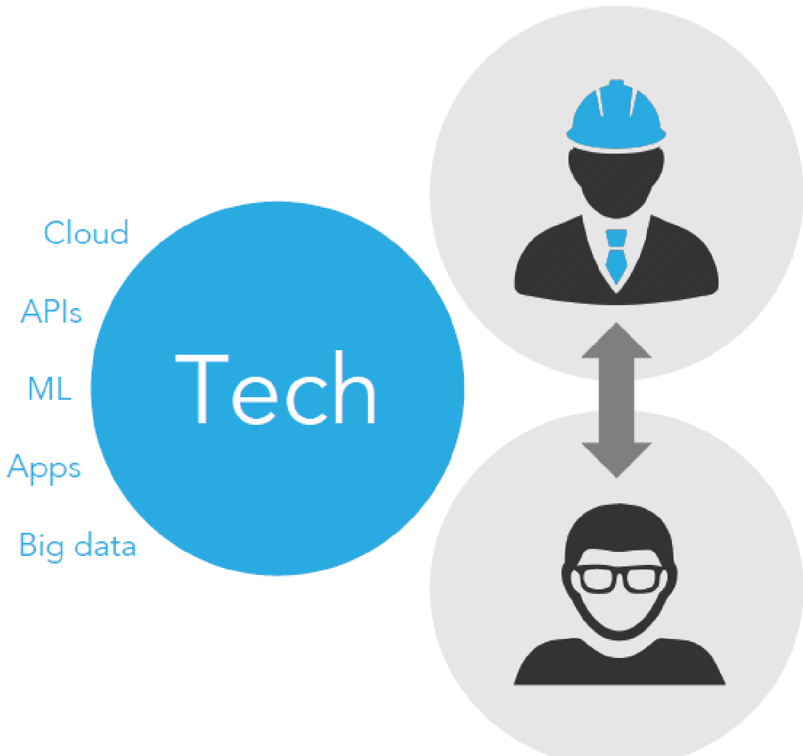
Industry is going digital


SCIENCE2CONCEPTUALISATION2MATERIALISATION
Algorithms
1956
Discovery
Domain recognition
Context adaptation
Situation awareness
Information logistics
Distributed ledger
AI
Industrial AI
eMaintenance
Liveware
Software
Hardware
Governance
Policies
Safety
Integrity
Security
Cloud computing
eGovernance
Information quality
Information assurance
Data integrity
Data quality

Data science and AI in industry and transport
..the transformation

Digital transformation enables design thinking in data science

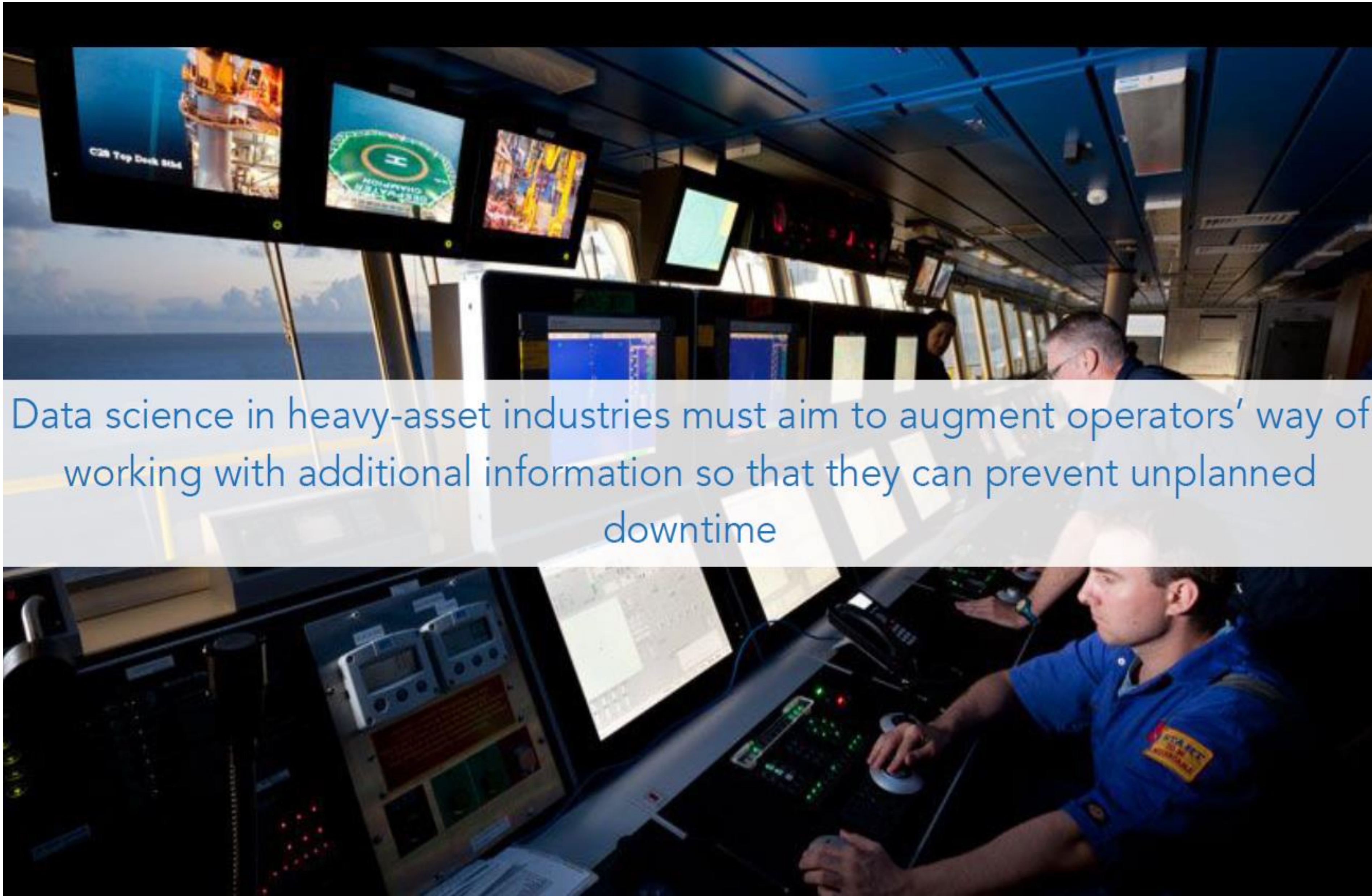
and design thinking enables digital transformation



Digitalisation should equip data scientists and engineers to cocreate a solution

tecnalia Inspiring Business

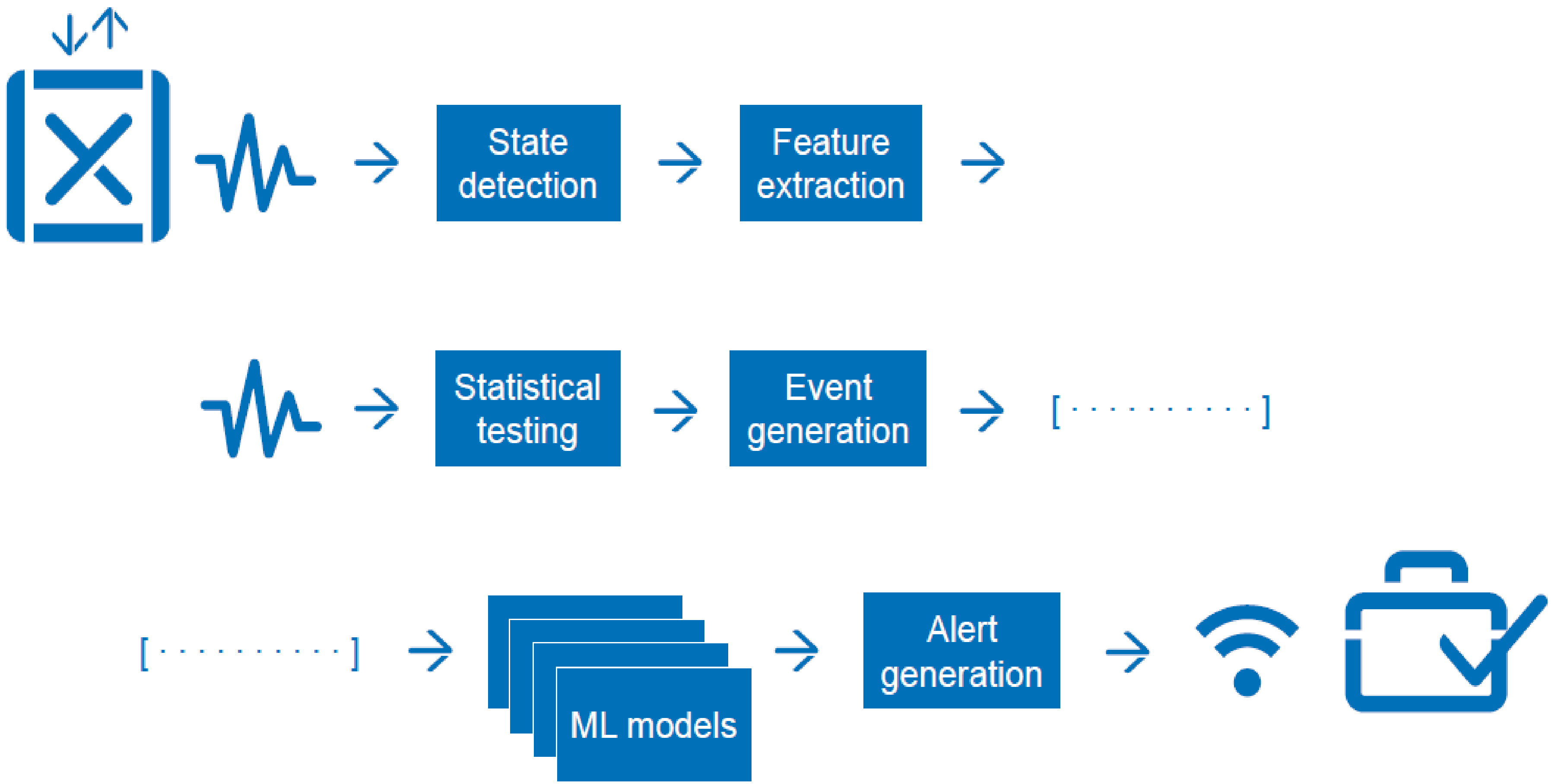
LULEÅ UNIVERSITY OF TECHNOLOGY



Data science in heavy-asset industries must aim to augment operators' way of working with additional information so that they can prevent unplanned downtime

The traditional way…..

Data refining pipeline



Type of Anomaly

- Point Anomalies
- Contextual Anomalies
- Collective Anomalies

FALSE NEGATIVE

FALSE POSITIVE

Black swans and the swan song
Achilles heel of diagnosis and prognosis
Enemies of digitization....

tecnalia Inspiring Business

LULEÅ UNIVERSITY OF TECHNOLOGY

Black Swan Events

- **Rarity**—It is an *outlier*, as it lies outside the realm of regular expectations, because nothing in the past can convincingly point to its possibility.
- **Extreme impact**—It carries an extreme impact.
- **Retrospective (though not prospective) predictability**—In spite of its outlier status, human nature makes us concoct explanations for its occurrence *after* the fact, making it explainable and predictable.

The term "Swan Song" comes from a belief dating back to 3rd century B.C. that the Mute Swan is silent its entire life until it sings one beautiful song right before it dies.

Risk perspective

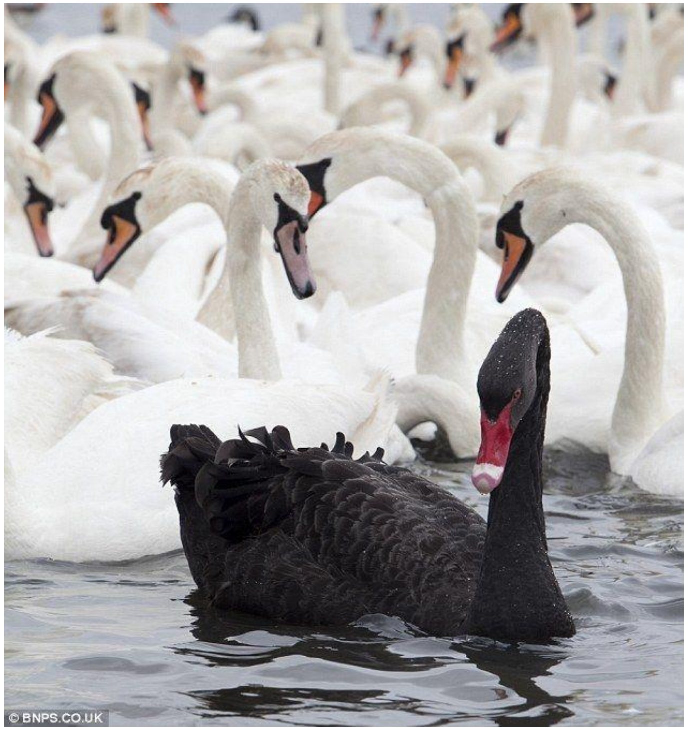
Probability-based
Historical data

+

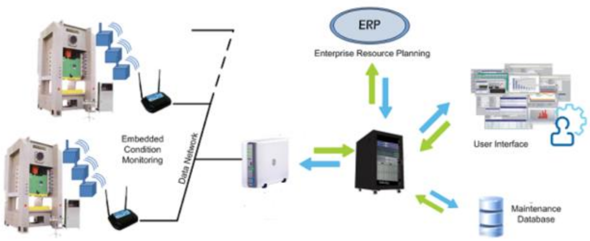
Knowledge
dimension

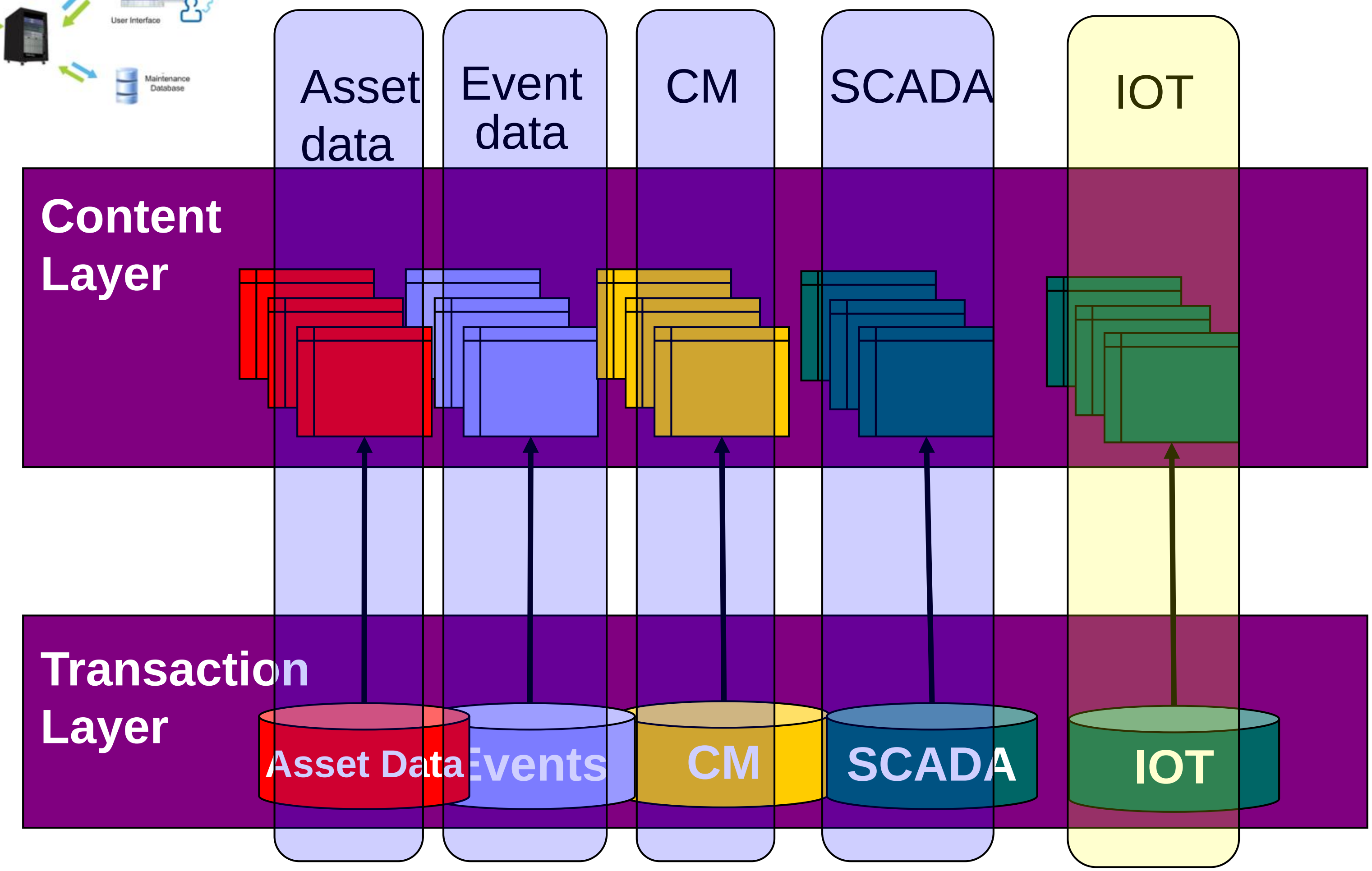
+

Surprises



Unified data format:
What connections are needed?





Silos of data by functional area

MATERIALISATION OF CYBER-PHYSICAL ENVIRONMENT (DIGITAL TWIN)

Business connectivity
- Analytics
- Visualisation
- Cognitive

→ ***DT Services***

Data & model connectivity
- Management
- Processing
- Computing

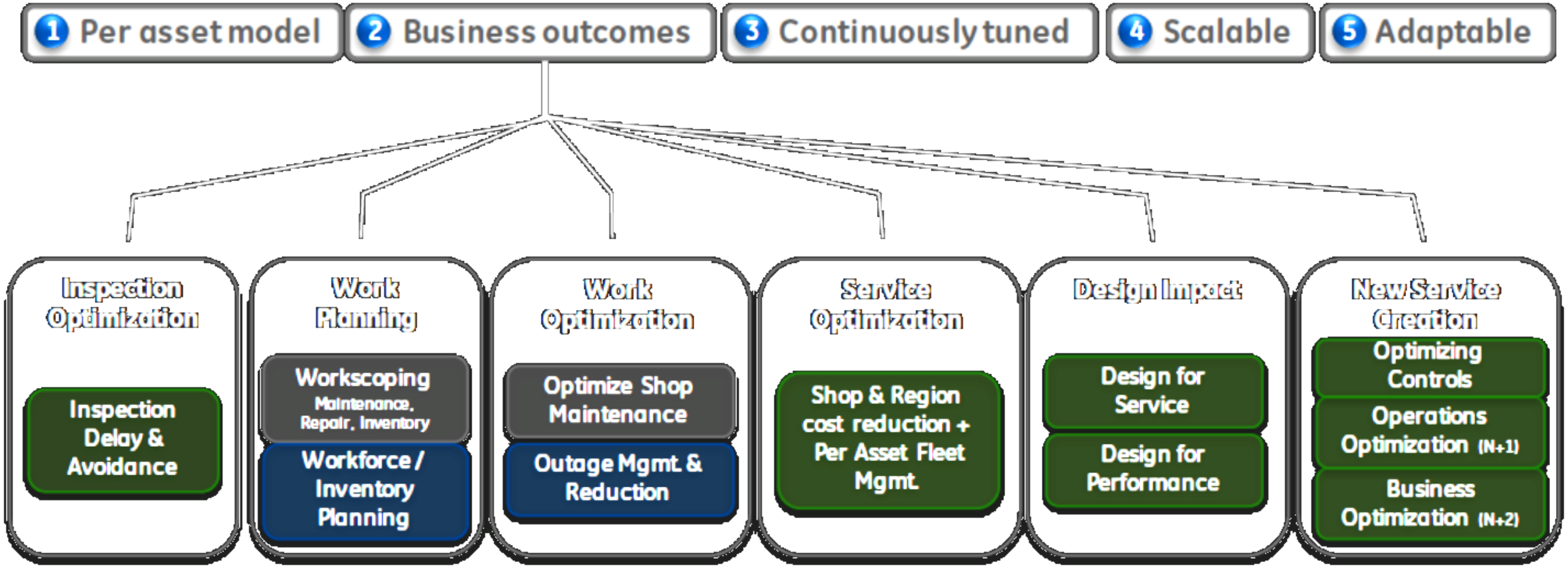
→ ***DT Architecture***

Device connectivity
- IoT
- Industrial internet

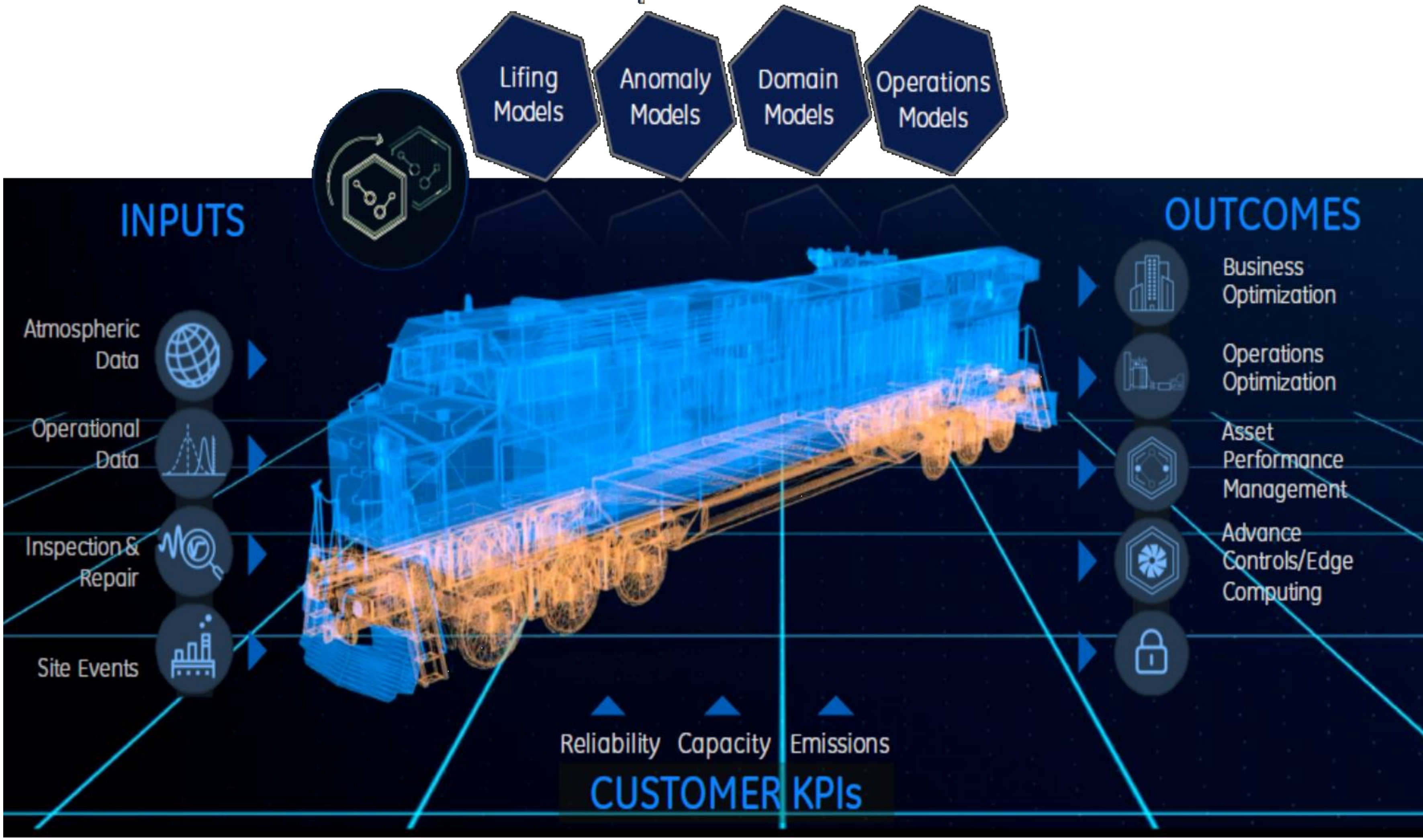
→ ***DT Infrastructure***

Digital Twin – Definition

Engineering models that **continuously increase insights** into each asset to deliver specific **business outcomes**



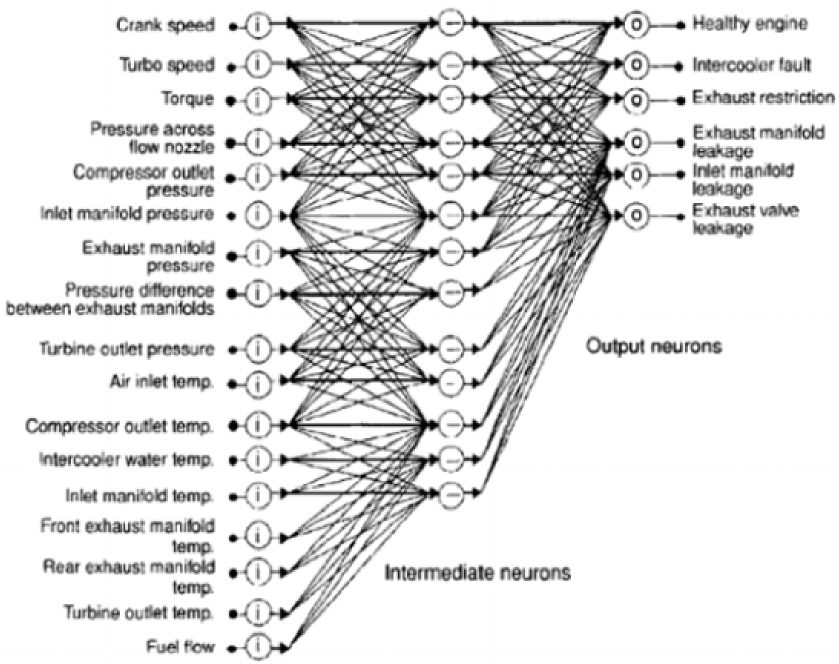
Some Representative Twins

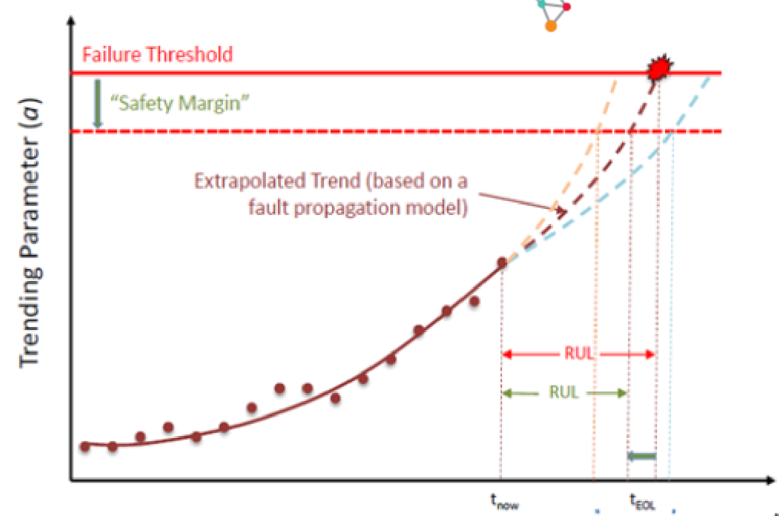


tecnalia Inspiring Business

LULEÅ UNIVERSITY OF TECHNOLOGY

Digital twin 1.0





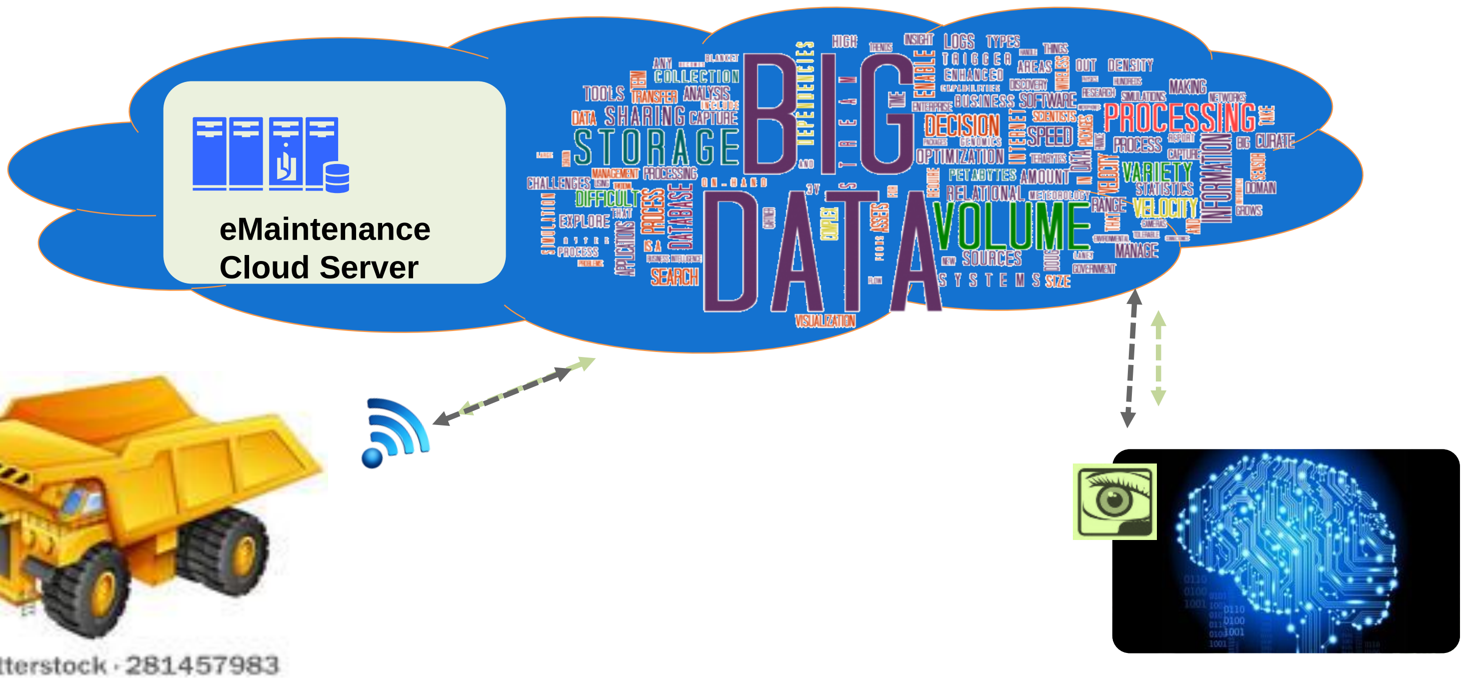
Diagnostics

Prognostics

tecnalia Inspiring Business

LULEÅ UNIVERSITY OF TECHNOLOGY

Digital twin 1.0



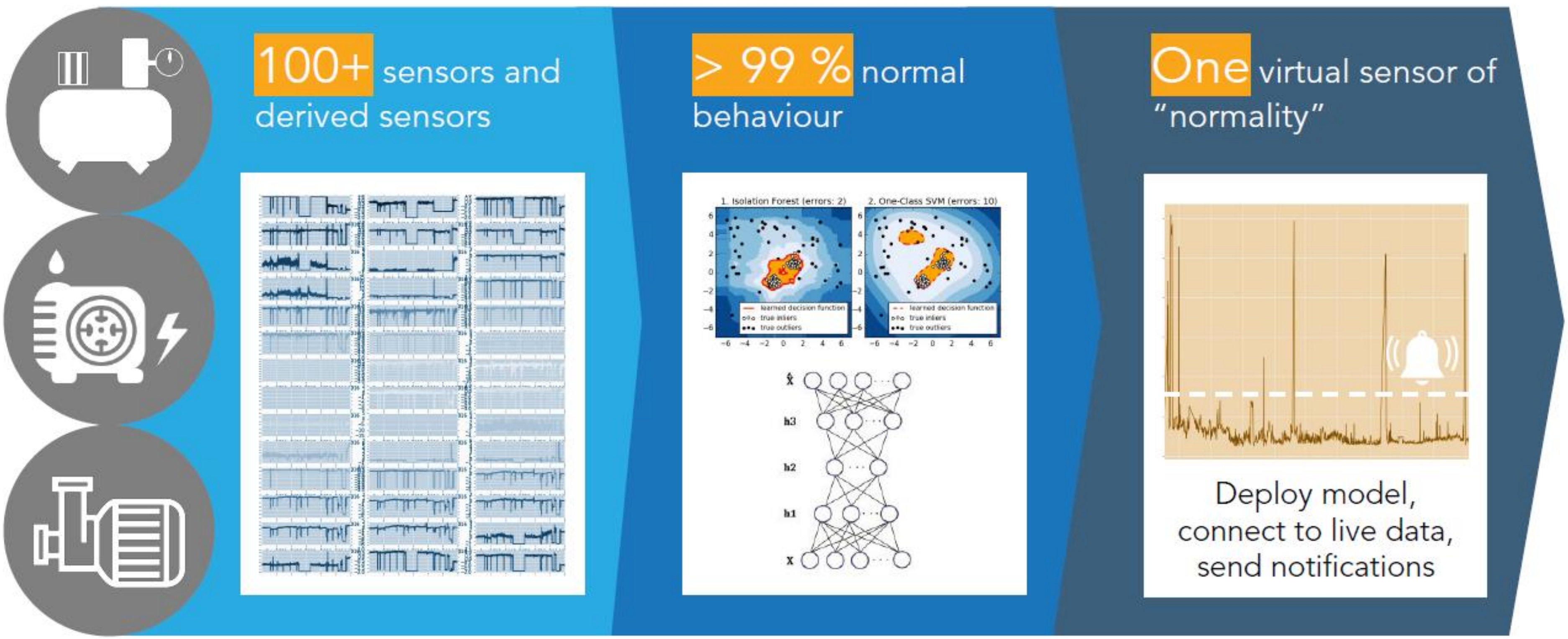
On board Wireless System

Machine Maintenance Analytics

Data → Information → Knowledge

Everything is normality……

Smarter: Anomaly detection



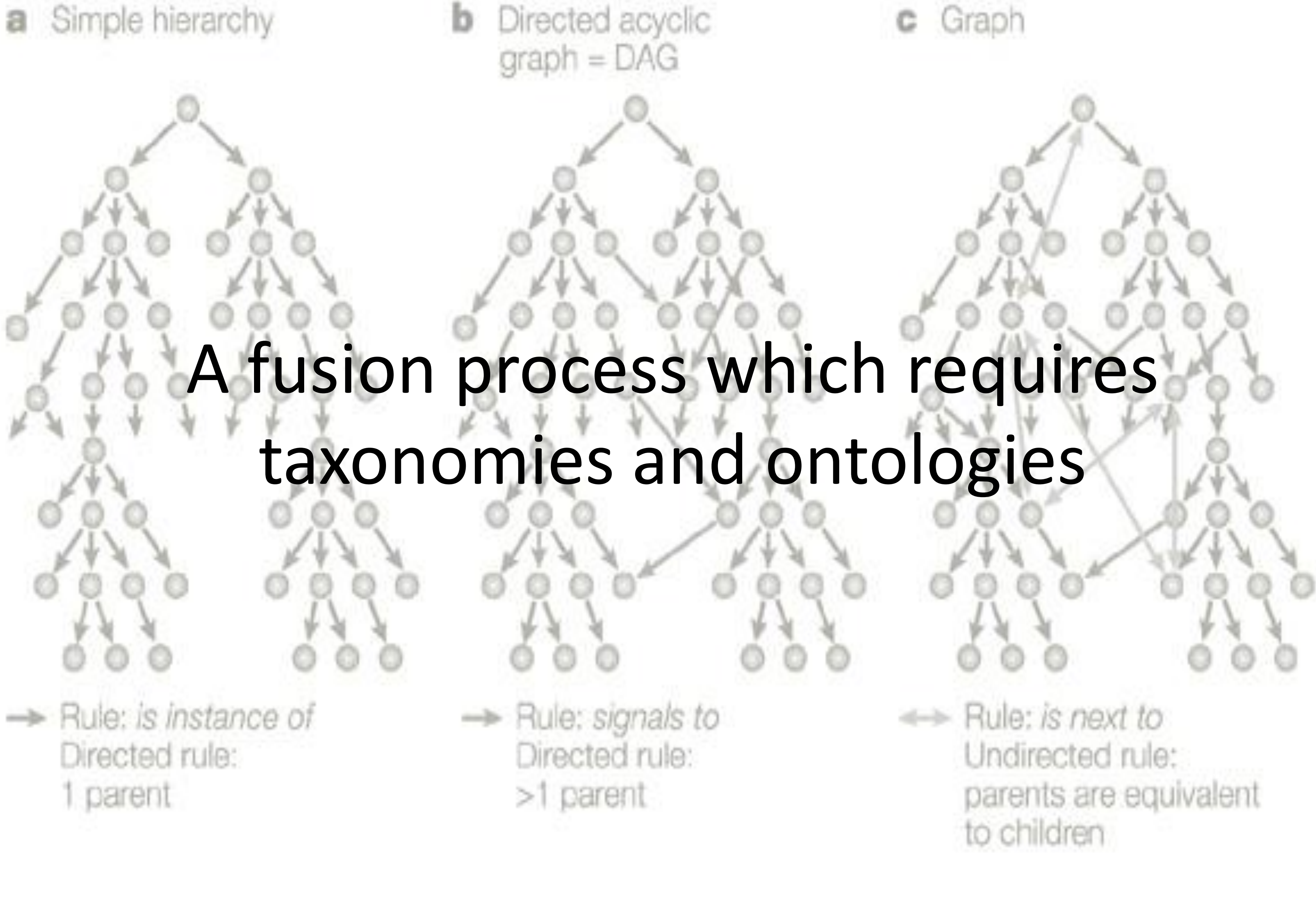
Digital twin made with OT

Do you have IoT in your plant?

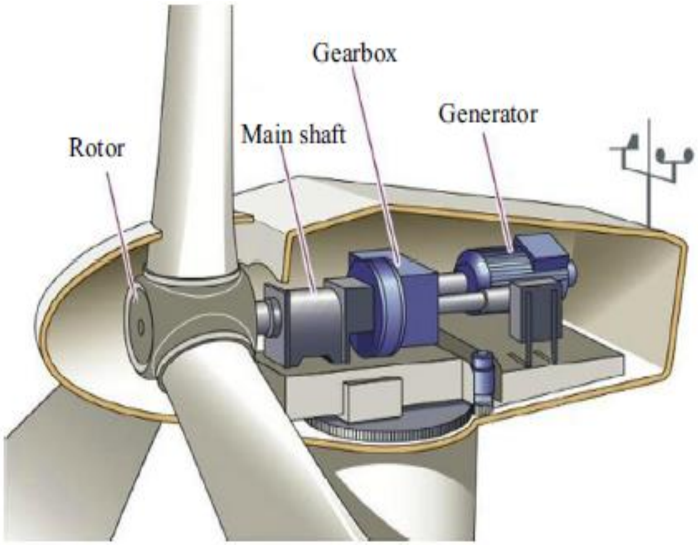
Devices	Connections	History	Analytics	Presentation
Control loops & processes	**Field Networks** Fieldbus HART	Plant-based historians	Offline analysis	Solution-dependent tools
Smart instruments, valves, etc.	**DCS/PLC** OPC xml Historian AMS ODBC/SQL	Laboratory information management systems	Home-grown tools	Back to DCS or HMI
Not-so-smart instruments, valves, etc.	**Business/Cloud** Gateways MQTT	Computerized maintenance management	Platforms with limited tools	Display anywhere
Augmented by context		Vendor data	Vendor solutions	

What about IT systems?

A fusion process which requires taxonomies and ontologies

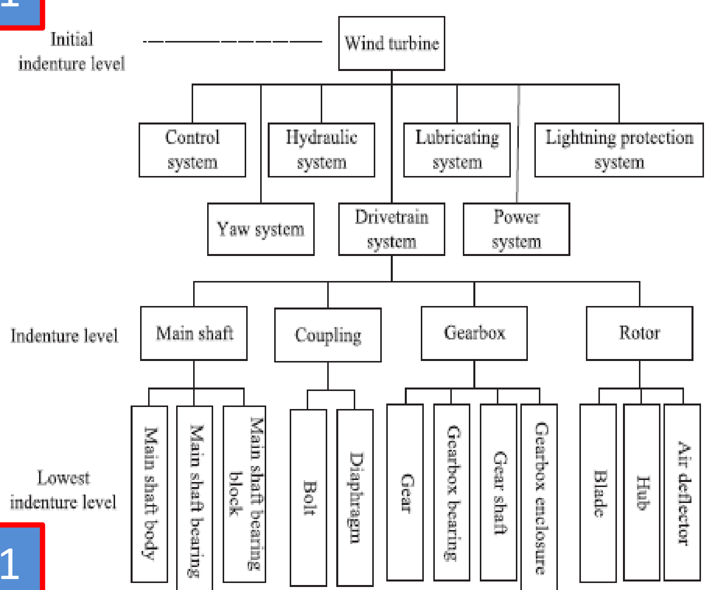


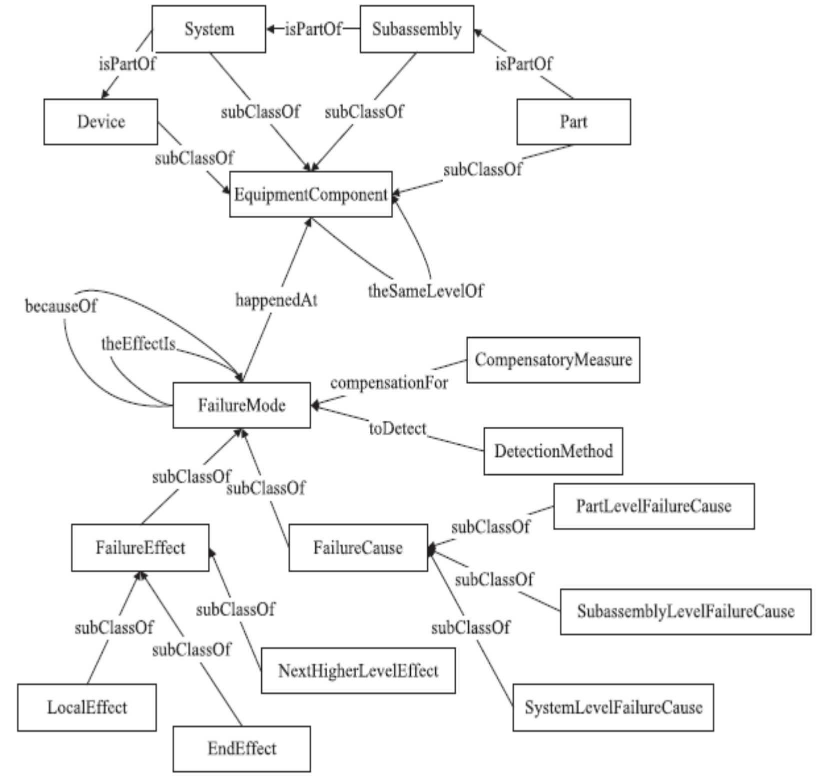
Taxonomies and ontologies



1

2





Rule-1

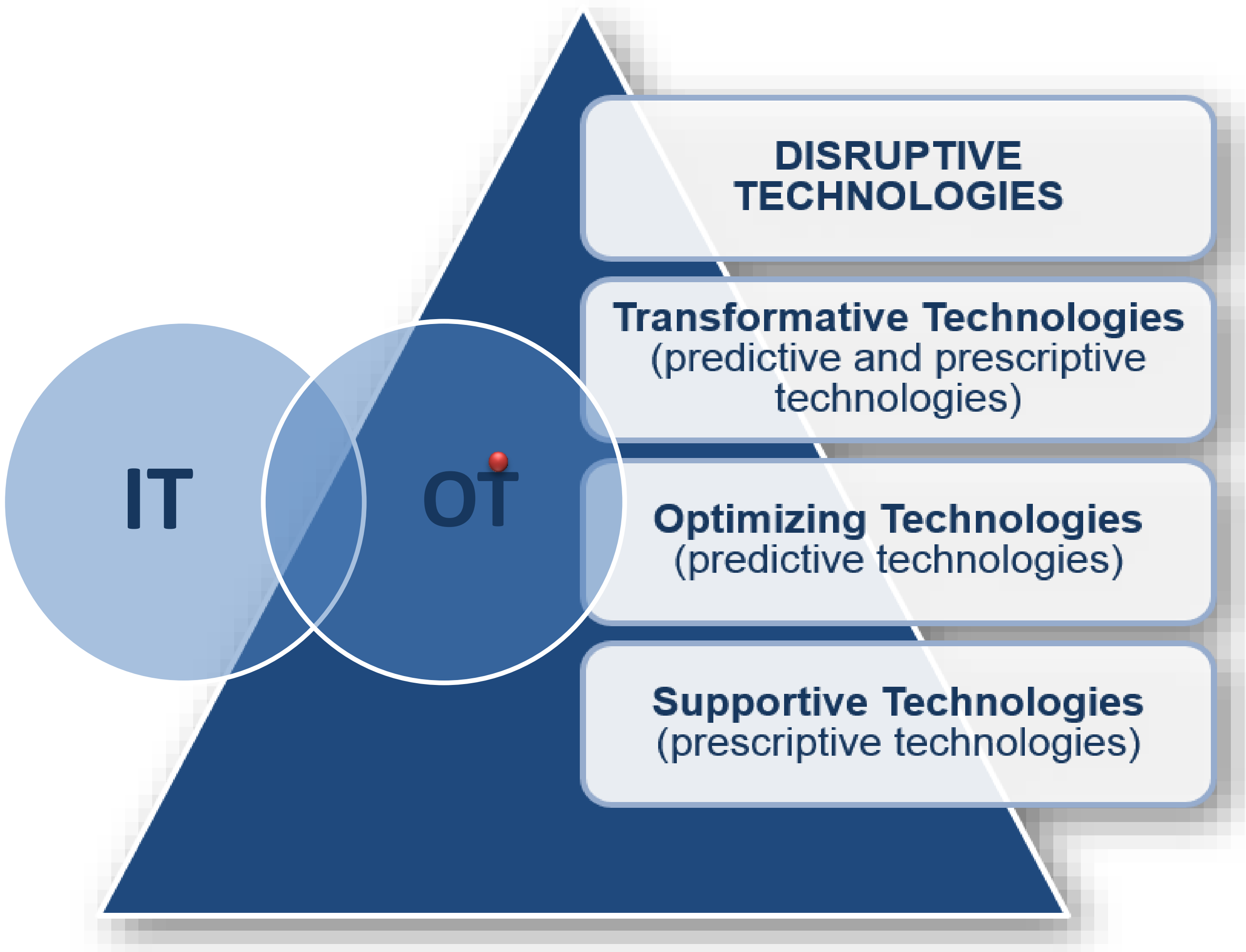
FailureMode(?x) ^ hasHappened(?x, true) ^ Device(?y) ^ happenedAt(?x, ?y) ^ FailureMode(?z) ^ theEndFffectIs(?z, ?x) ^ FailureMode(?a) ^ theHighEffectIs(?z, ?a)?theDirectFailureCauseIs(?x, ?a) ^ hasHappened(?a, true)

1

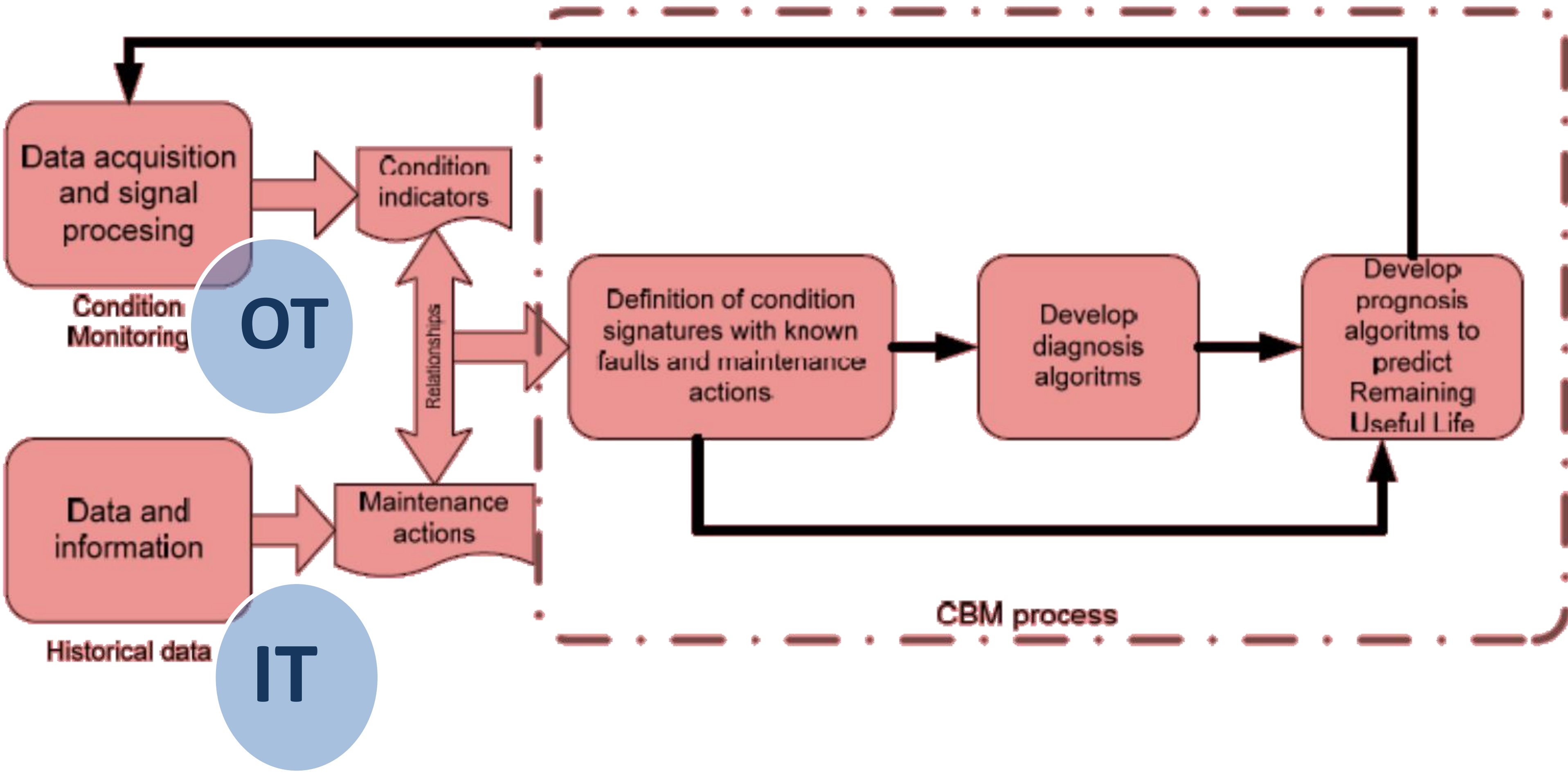
2

TRANSFORMATIVE MAINTENANCE SOLUTIONS

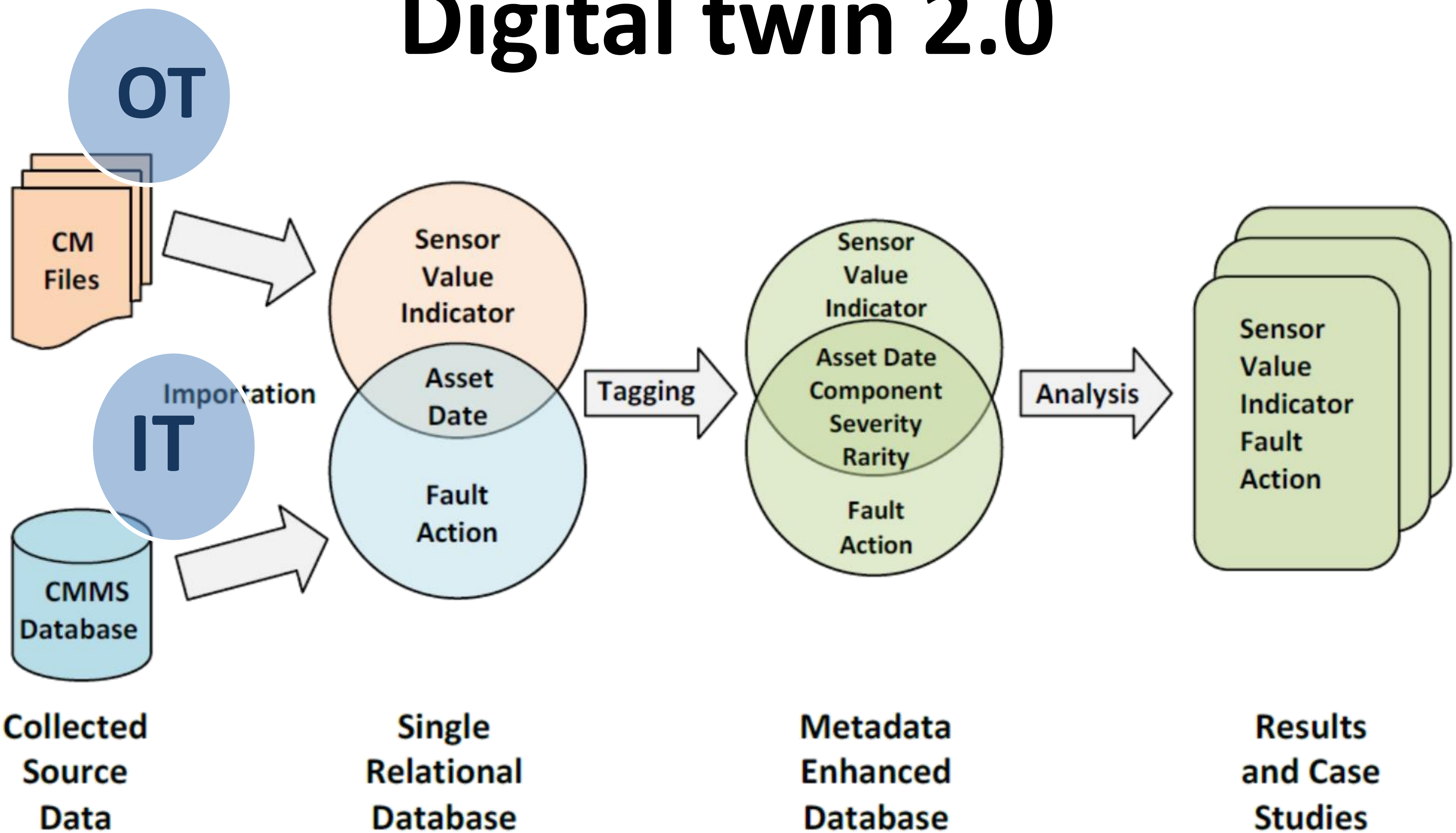
Integration & Application of Technologies



A necessary merging process



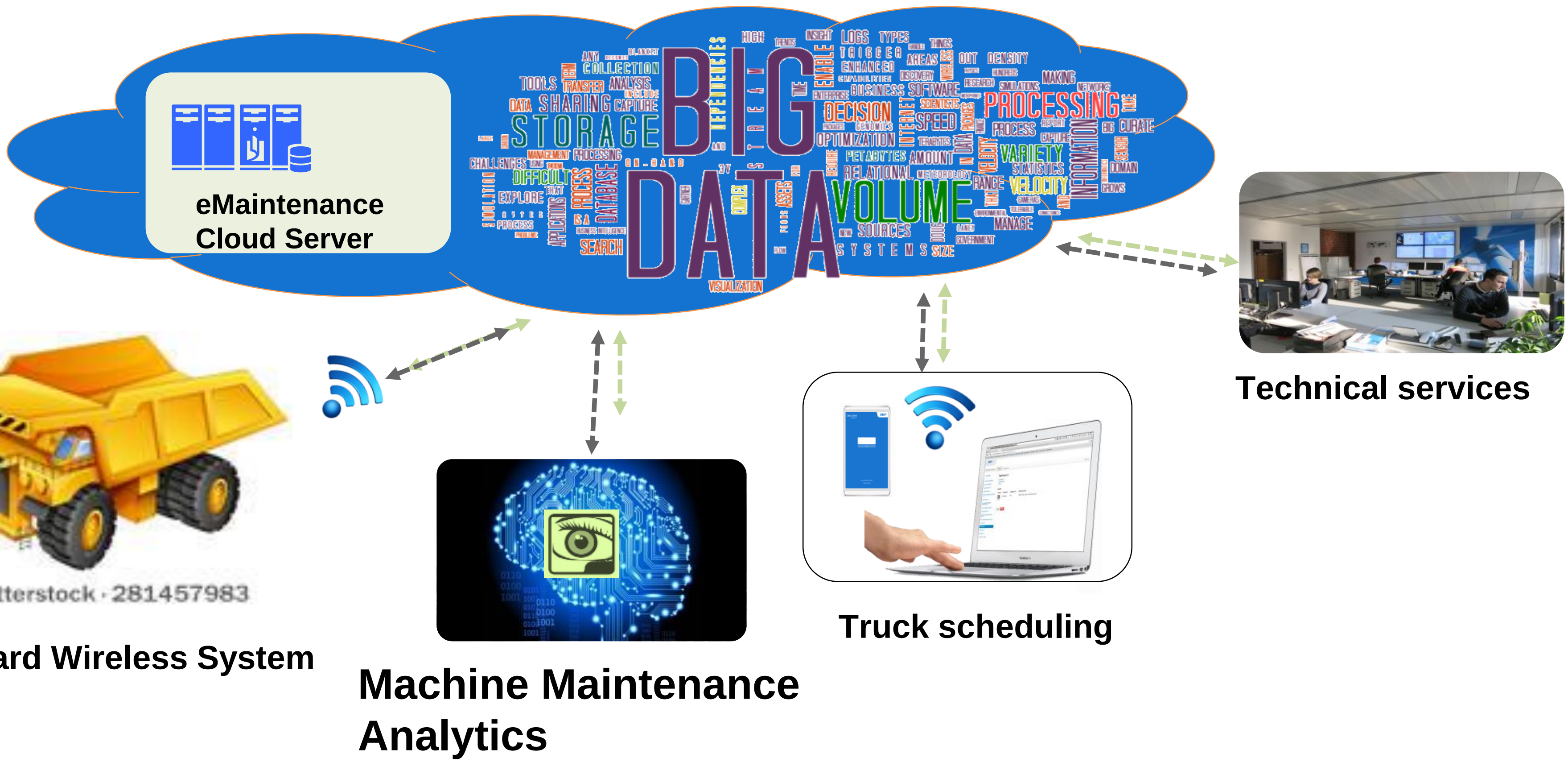
Digital twin 2.0



tecnalia Inspiring Business

LULEÅ UNIVERSITY OF TECHNOLOGY

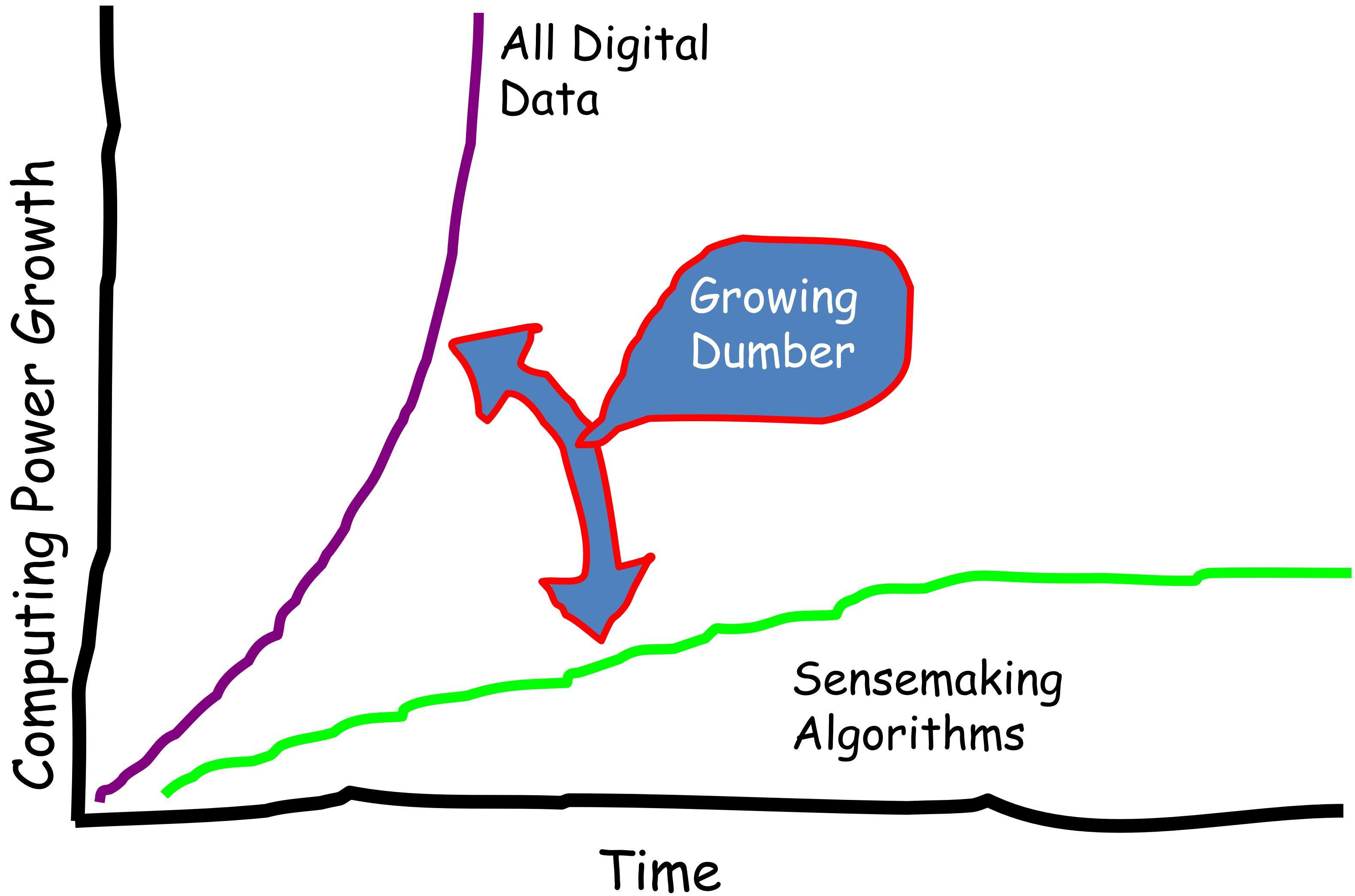
Digital twin 2.0



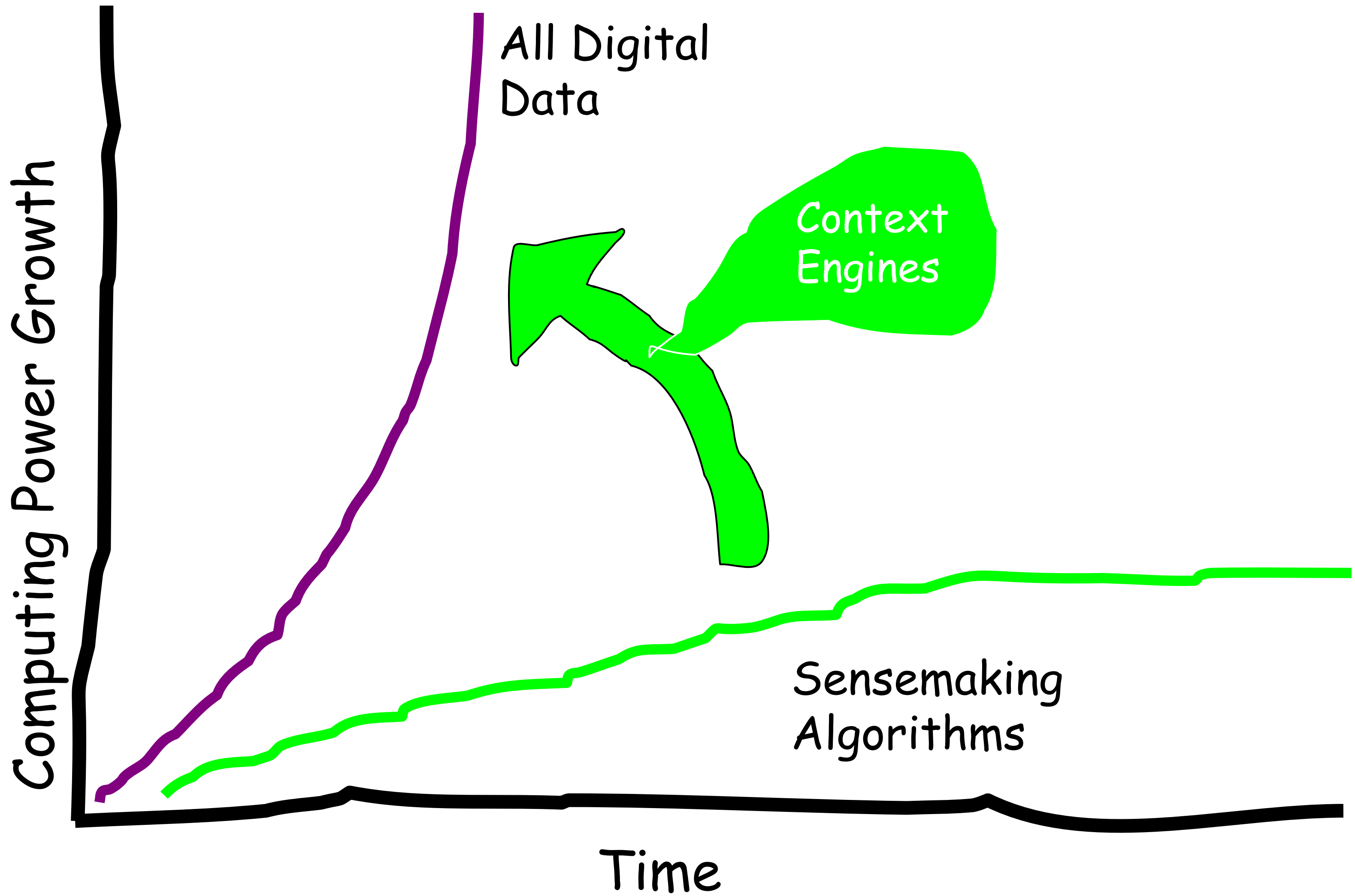
Data | Information | Knowledge


The need for
sensemaking analytics

Trend: Organizations are Getting Dumber



The Way Forward



What is context awareness?

- "An application's ability to adapt to changing circumstances and respond according to the context of use"

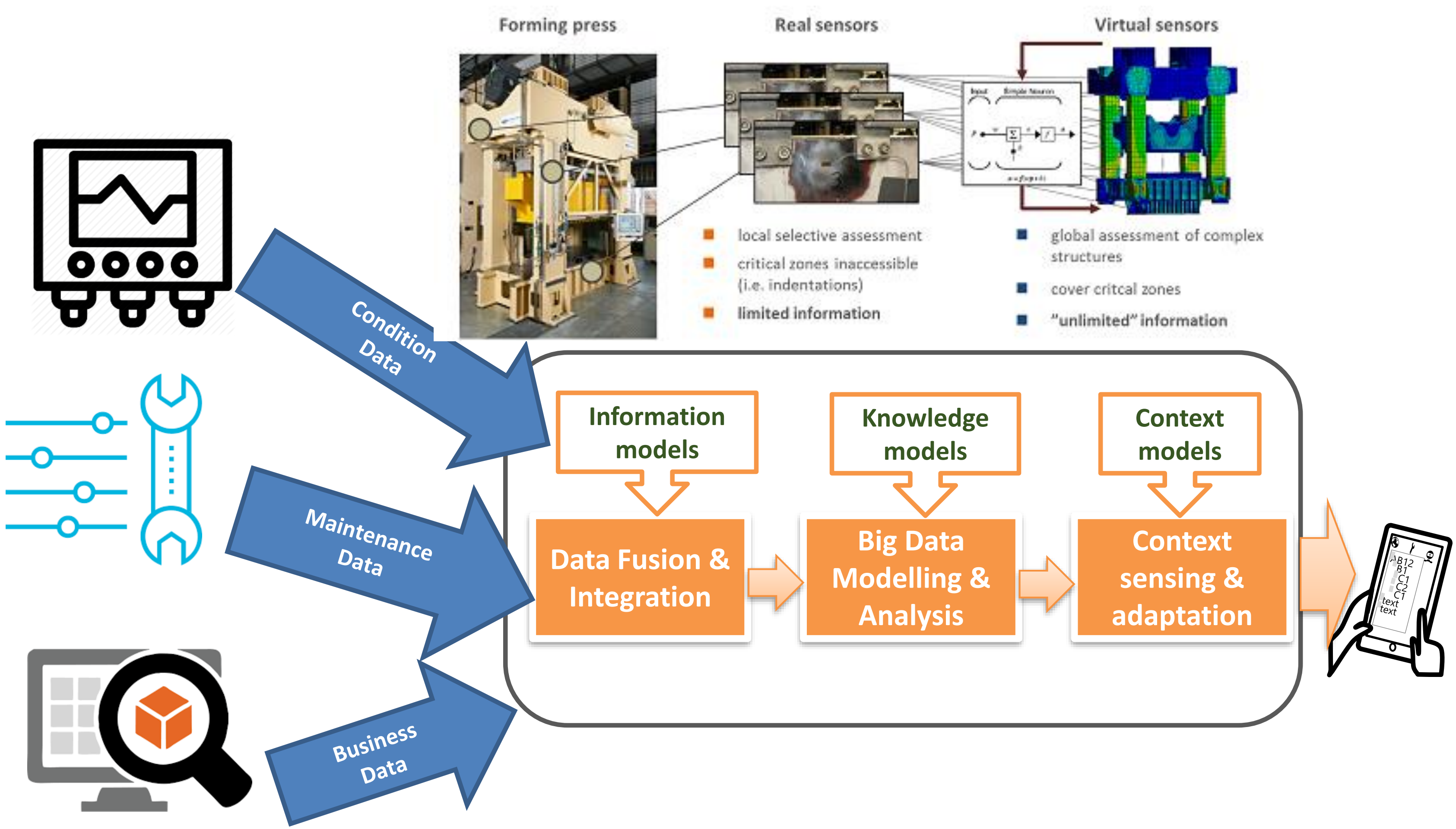
- Issues in context awareness system implementing
  - How is context represented?
  - How frequently does context information have to be consulted?
  - What are the minimal services an environment needs to provide to make context awareness feasible?
  - ...

tecnalia Inspiring Business

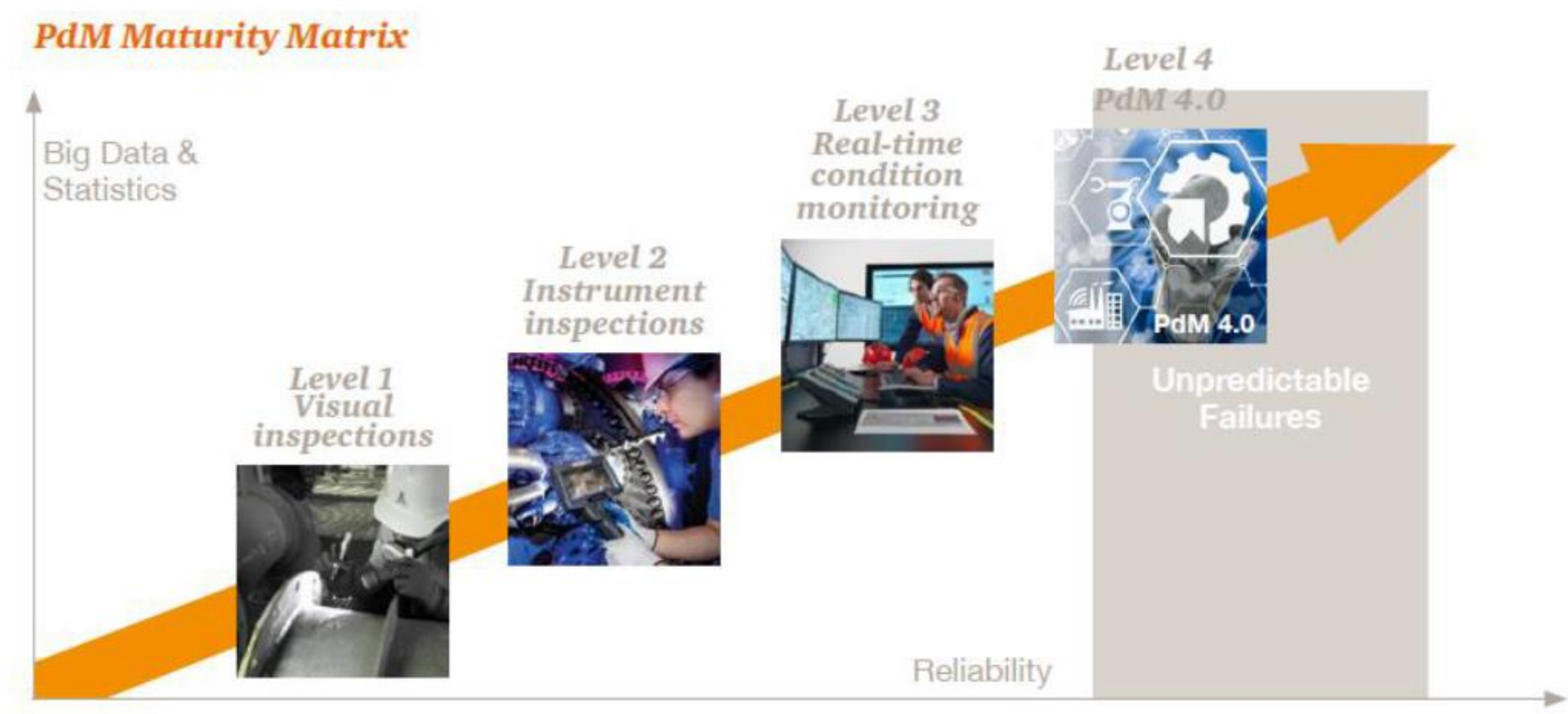
LULEÅ UNIVERSITY OF TECHNOLOGY

Context-aware Maintenance Decision Support Solution

Digital twin 2.1



PdM Maturity



DETECTION, ISOLATION & PROGNOSIS

Detection

Through sensors, Models etc

Isolation

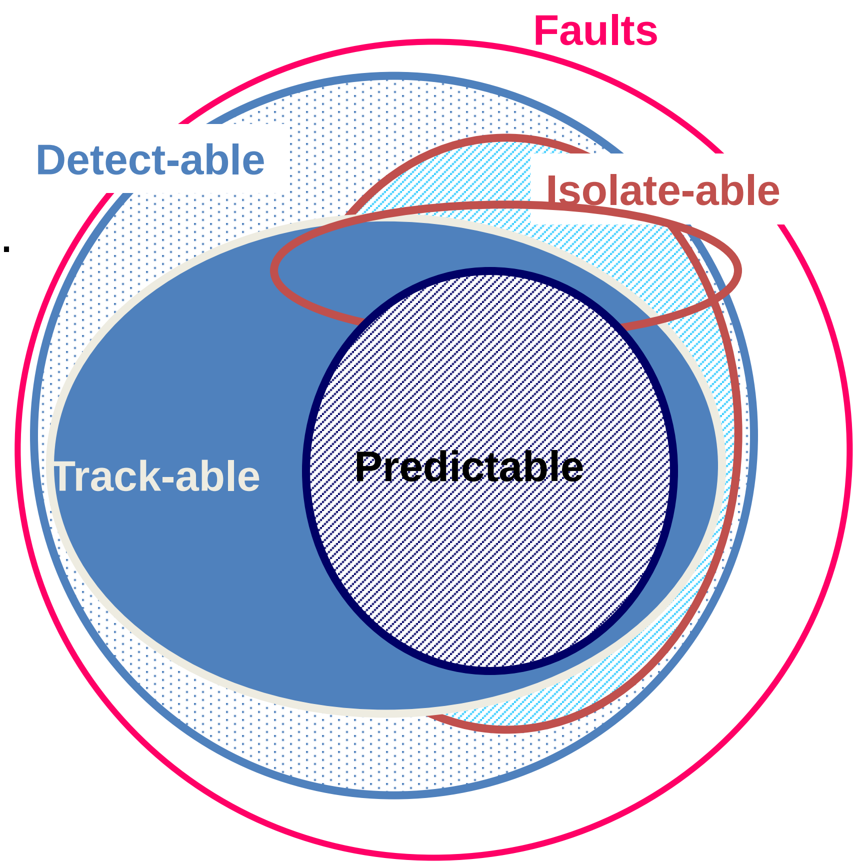
Information fusion from sensors, Models etc.

Tracking/Trending

Processed PHM data

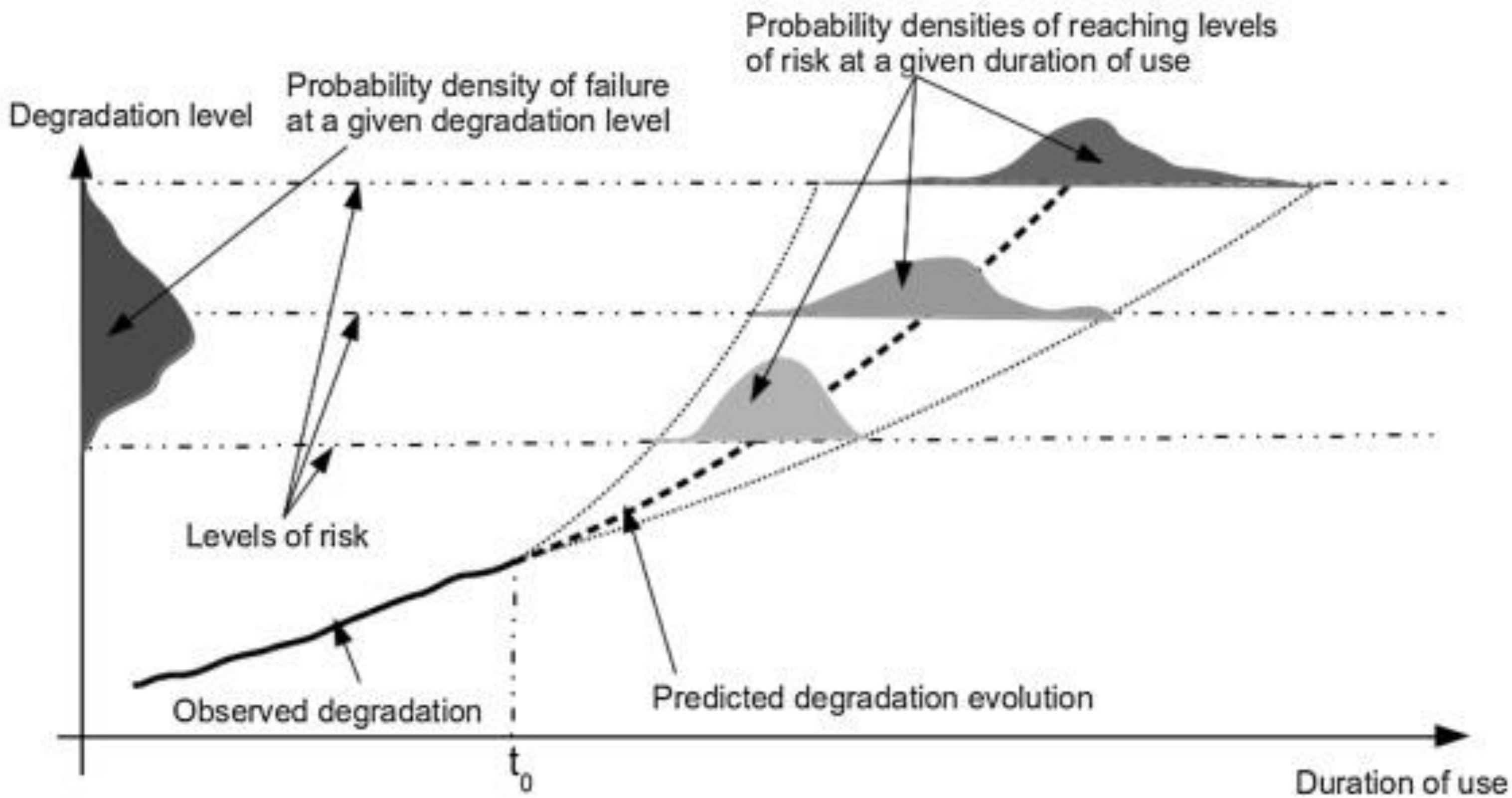
Prediction/Prognosis

Based on tracking/trending, & lifing models



tecnalia Inspiring Business

LULEÅ ERSITY TECHNOLOGY

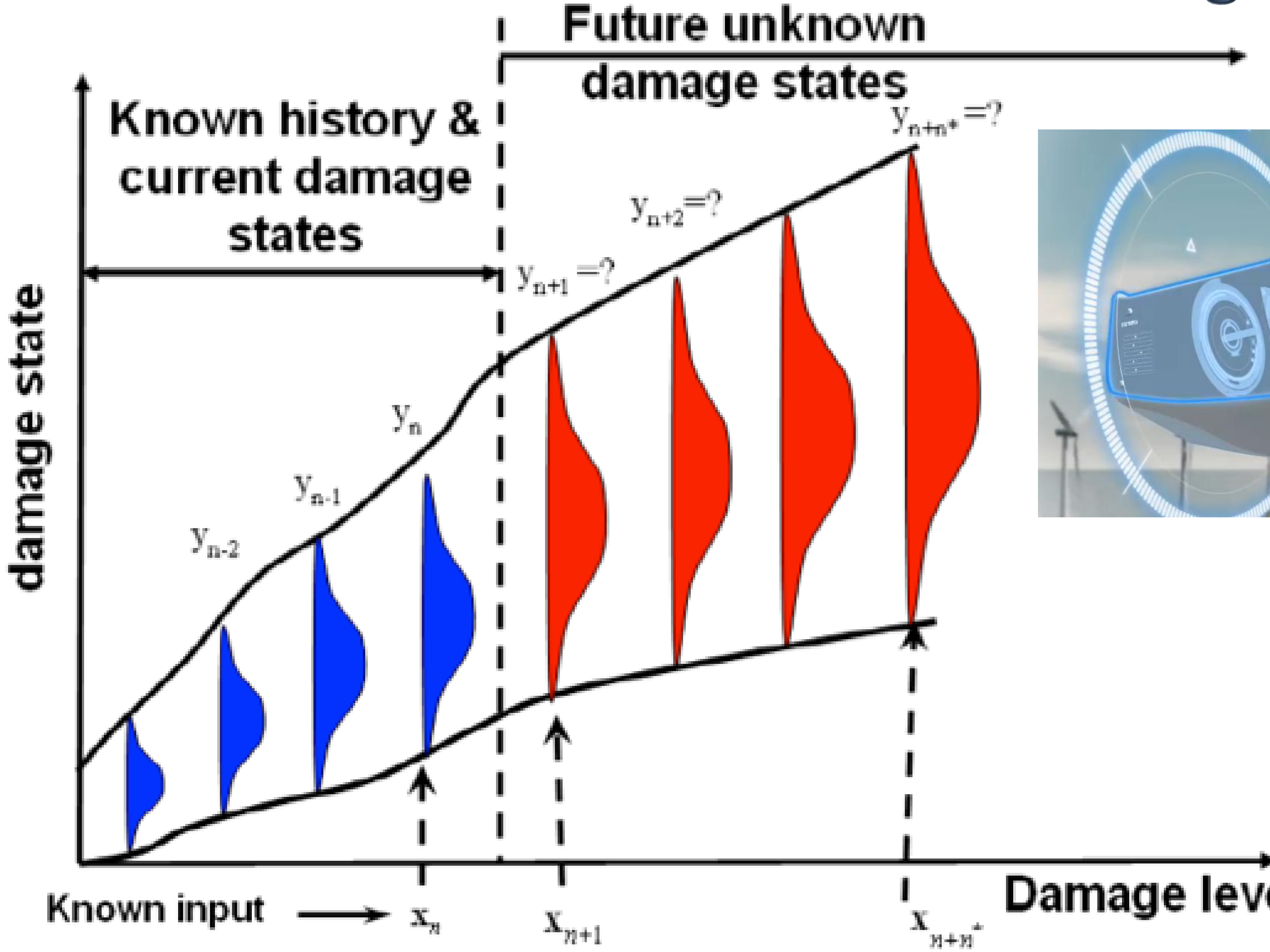


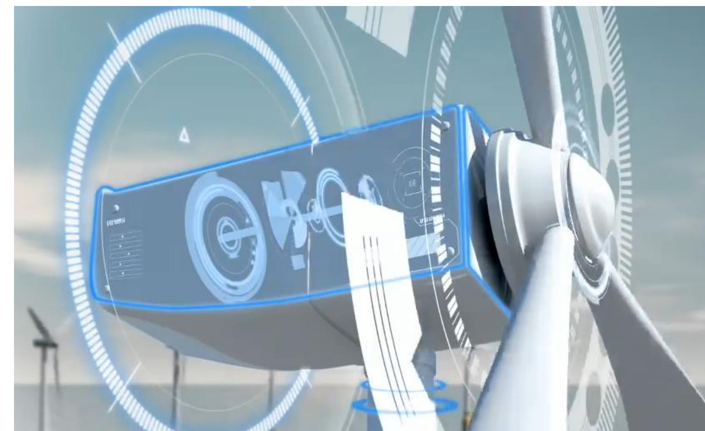
1. In the absence of direct “stressors, loading meters” how can we infer the best (descriptors/features) to capture future damage dimensions?
2. How can we accurately predict the progression of a specific failure mode? Considering that multiple failure modes may occur at any time in a complex equipment, system?
3. Given the numerous sources of uncertainty, how do we assign confidence associated with the predictions?

Data science…
Narrow vision
and mistakes

Prognosis when ignorant.....?

Remember the unknown stages





Black Swan Losses

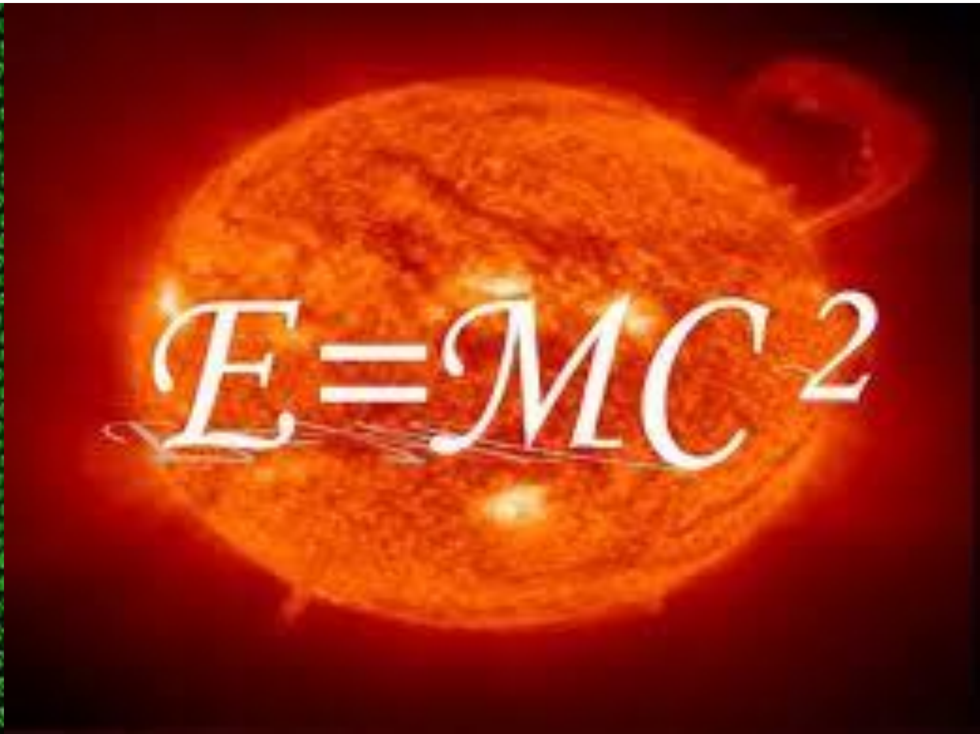
- Loss Distribution
  - Tail events are rare – very little data
  - Typically strong model assumptions

tecnalia Inspiring Business

LULEÅ UNIVERSITY OF TECHNOLOGY

Data driven or model based?

Data-Based or Physics-Based Models? – That is the question!



Hybrid models

- Combine knowledge about the physical process and information from sensor readings to enhance prognostics capabilities.

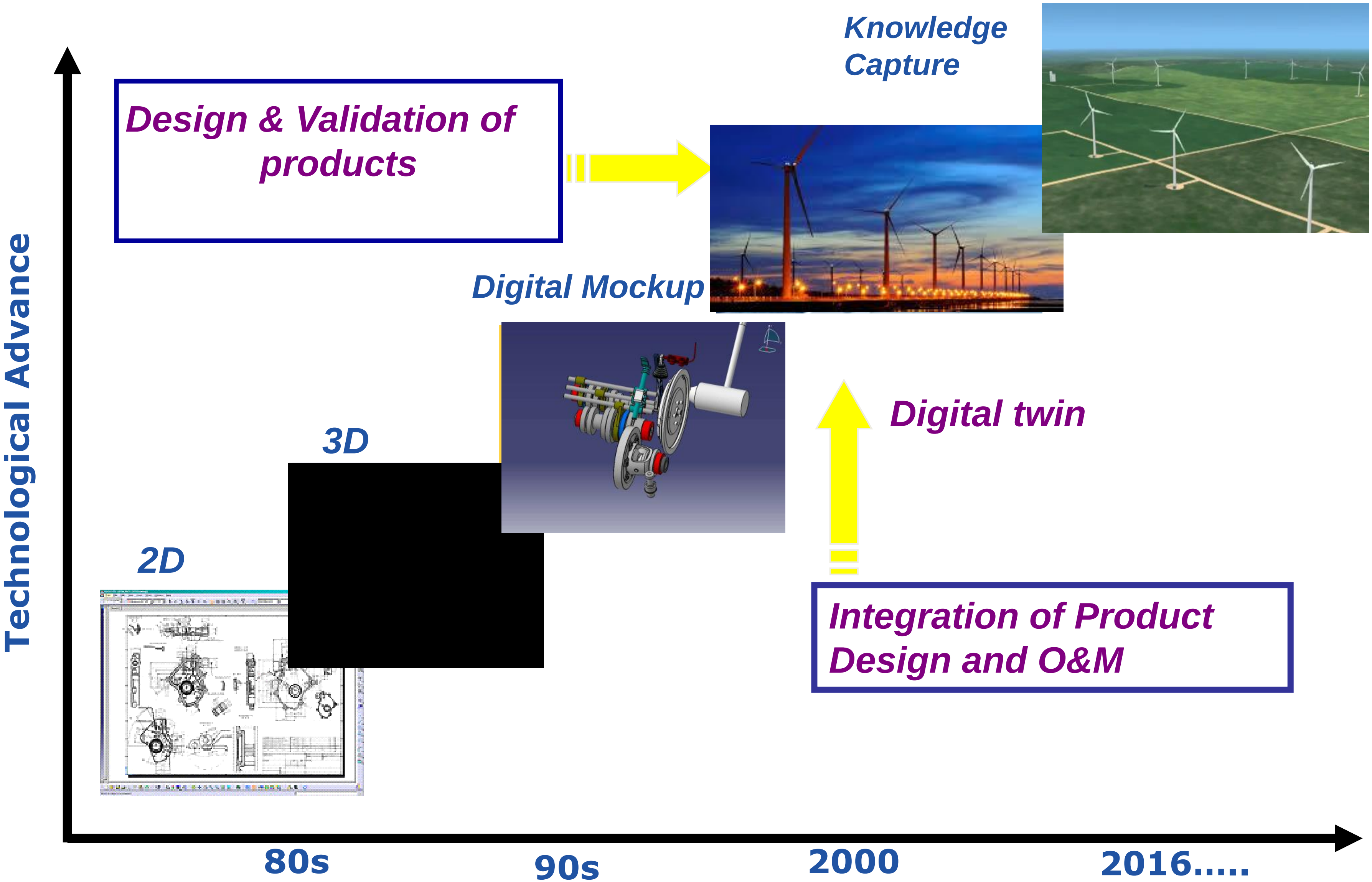
- Integration of measured data and physics can lead to a reduction of uncertainty (e.g. adjust predictions from model using observed data).

- Integration can be implemented at different levels of the PHM process:
  - Online model parameters updating.
  - Model predictions correction based on observed data.
  - Measure current damage level and propagate.
  - Build empirical degradation models from data.

tecnalia Inspiring Business

LULEÅ UNIVERSITY OF TECHNOLOGY

Evolution of the Process



PLM and digital twins

Product Lifecycle Processes

Design → Build → Operate → Maintain

O&M Processes

Digital Twin Solutions

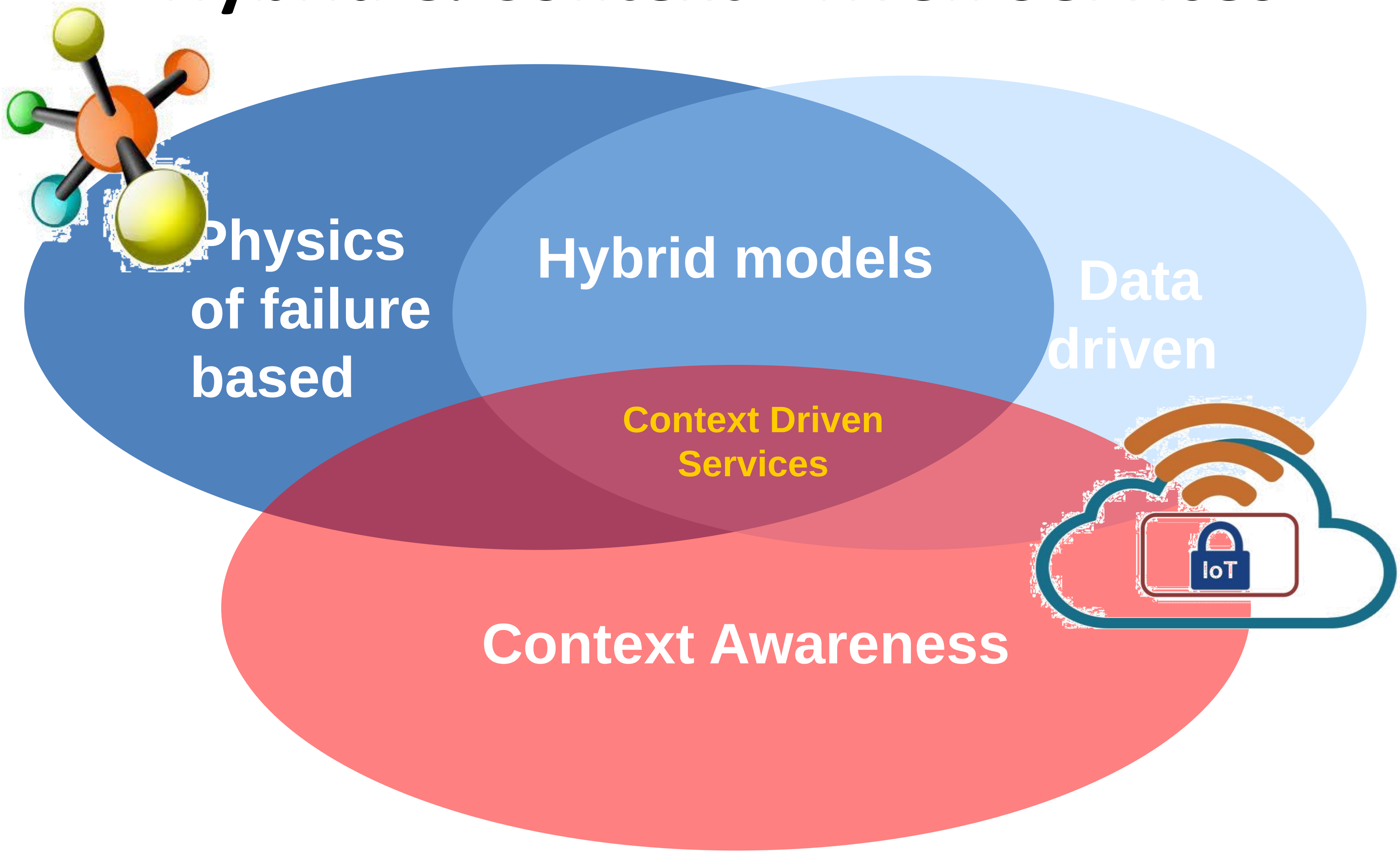
Create Processes → Plan Processes → Simulate & Validate Processes → Execute Processes

Engineering Design

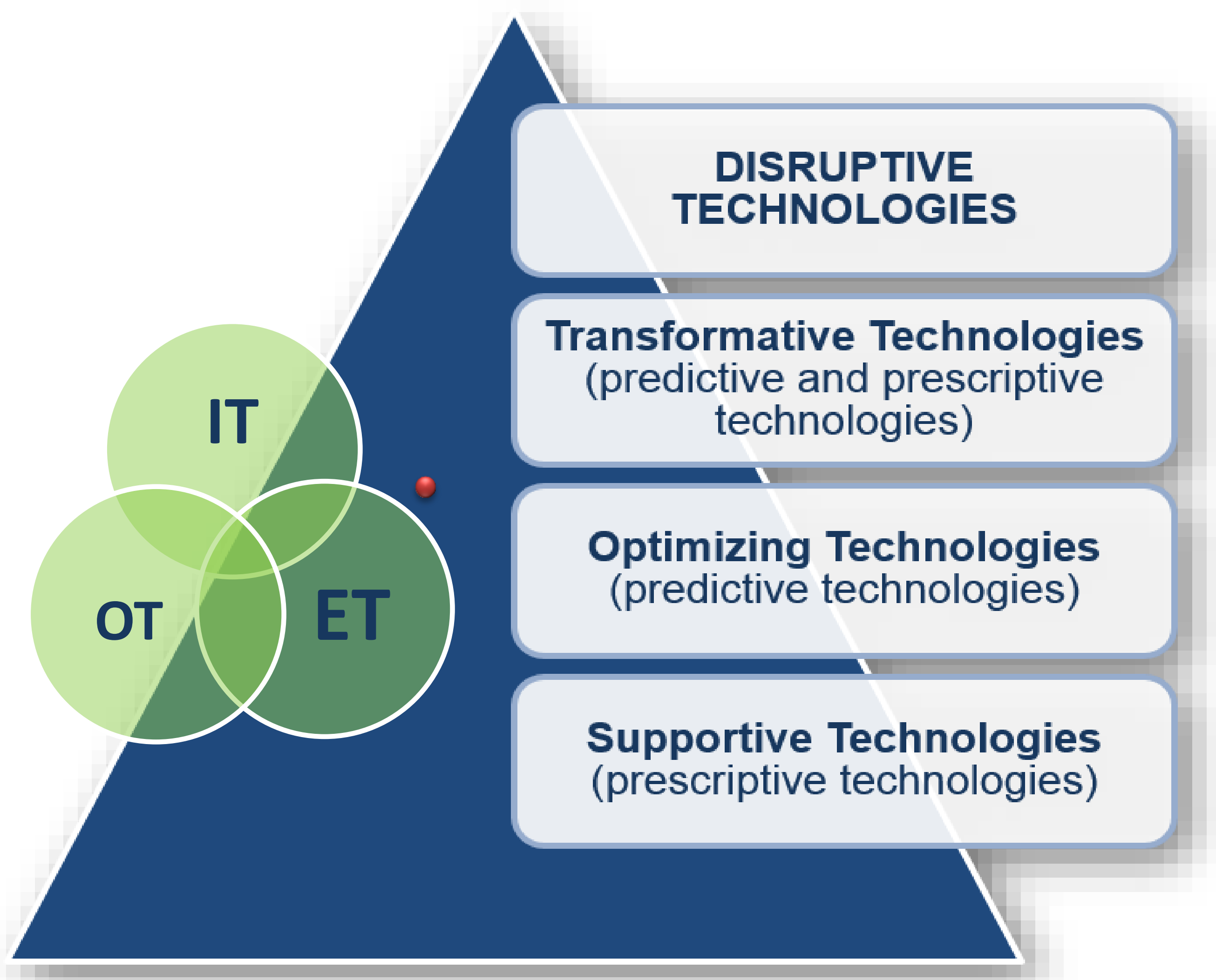
Validate

As – Built Records

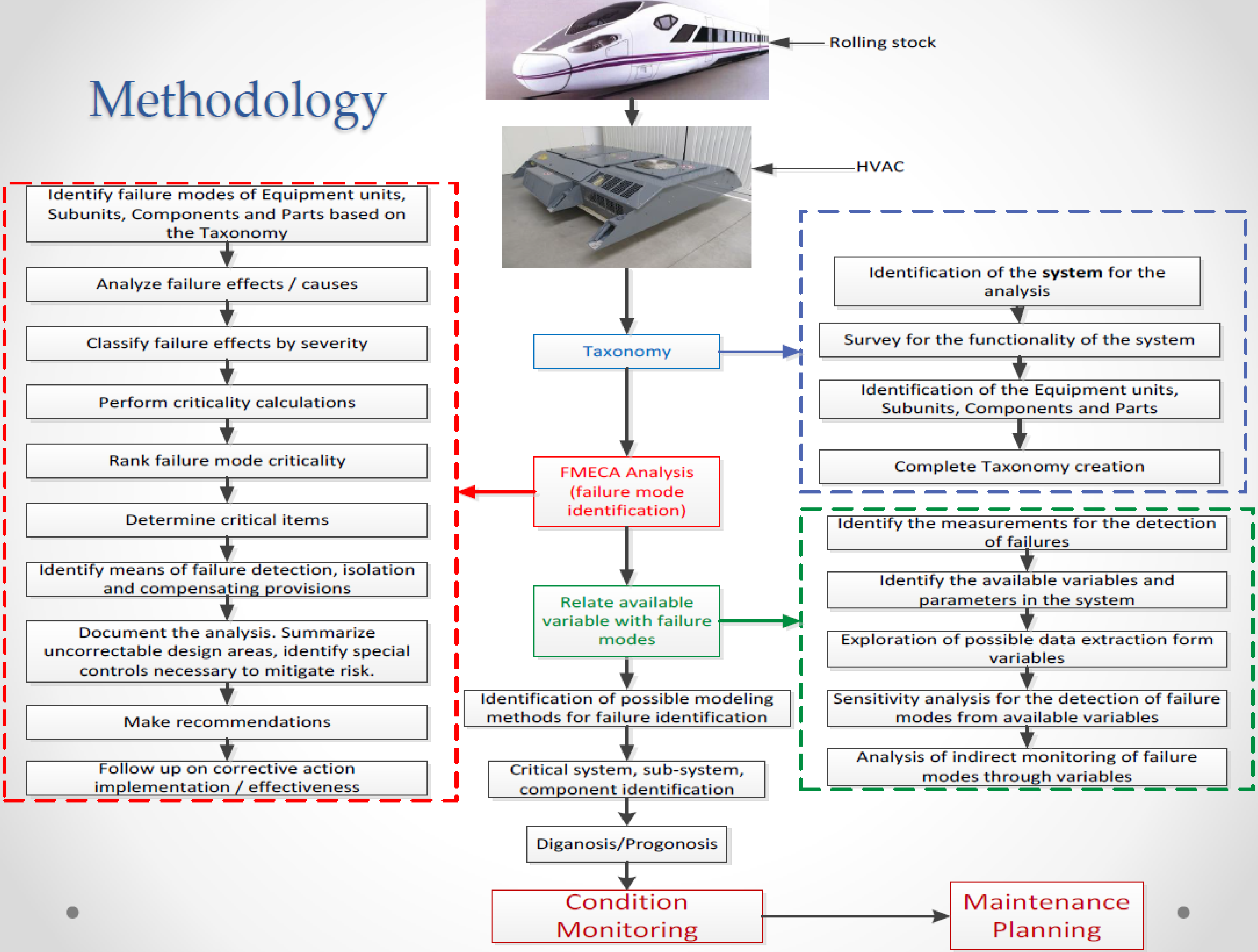
Hybrid & Context Driven Services



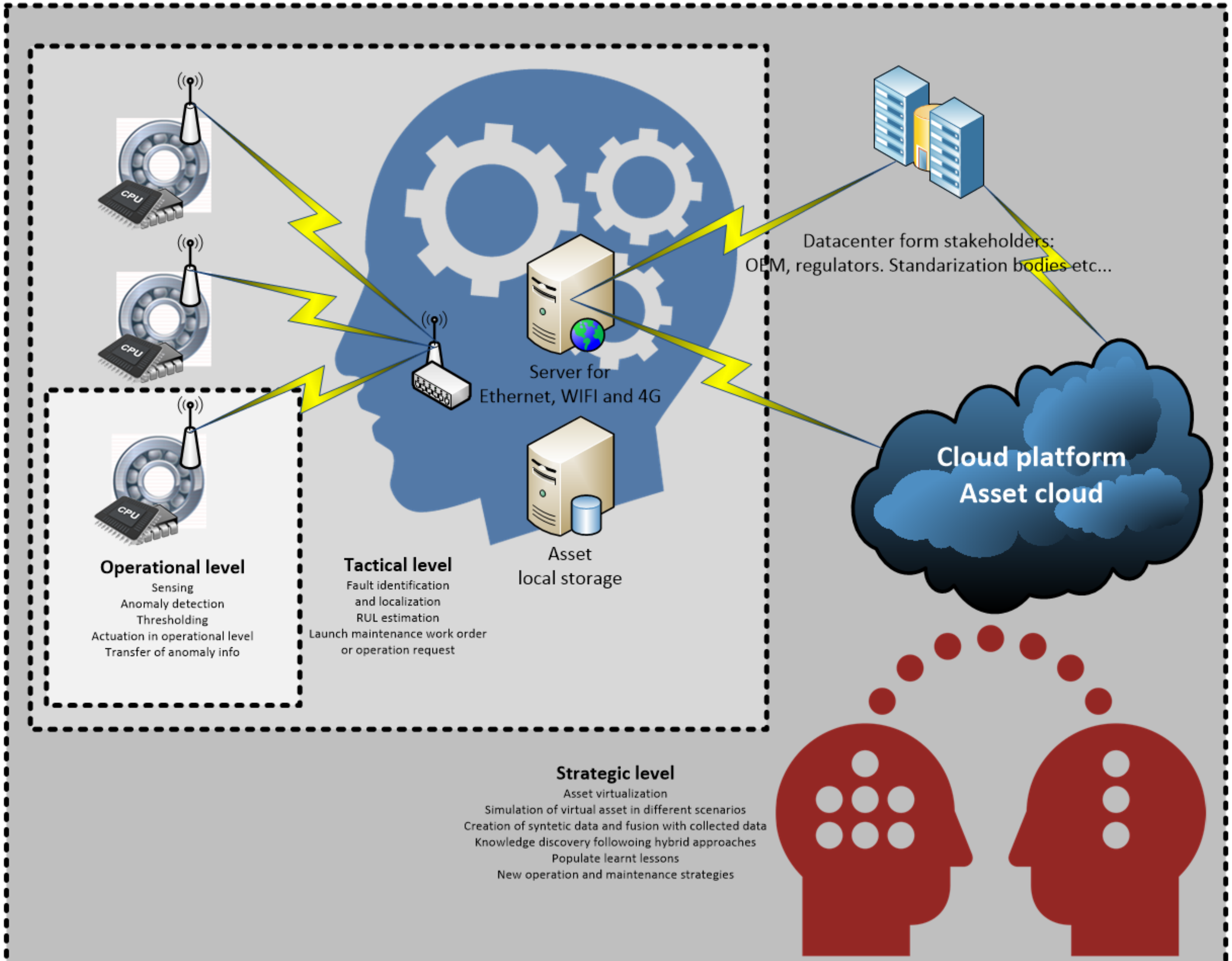
Digital twin 3.0



Methodology

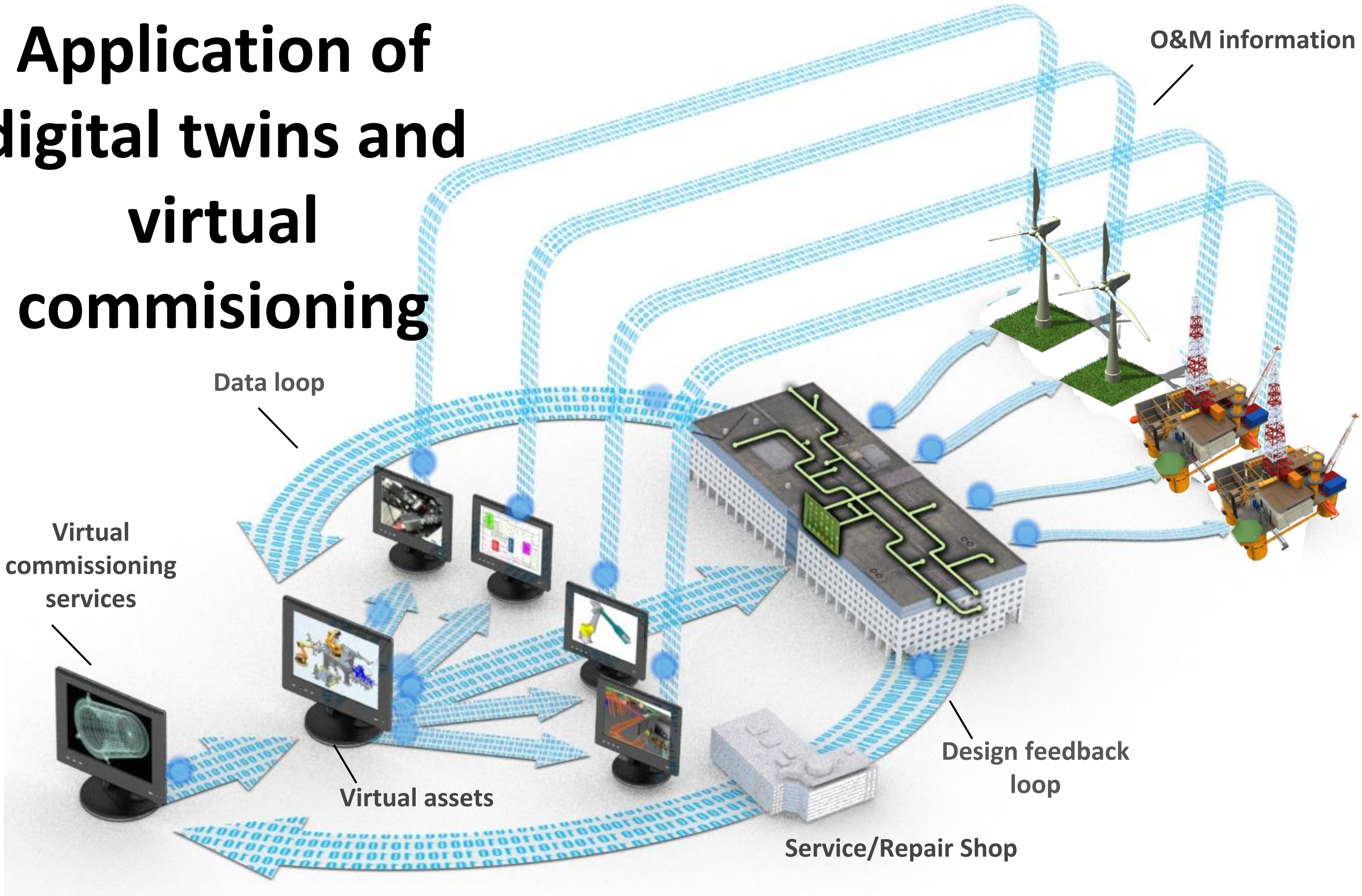


Are digital twins 1.0 and 2.0 useless????



What do we expect from hybrid digital twins?

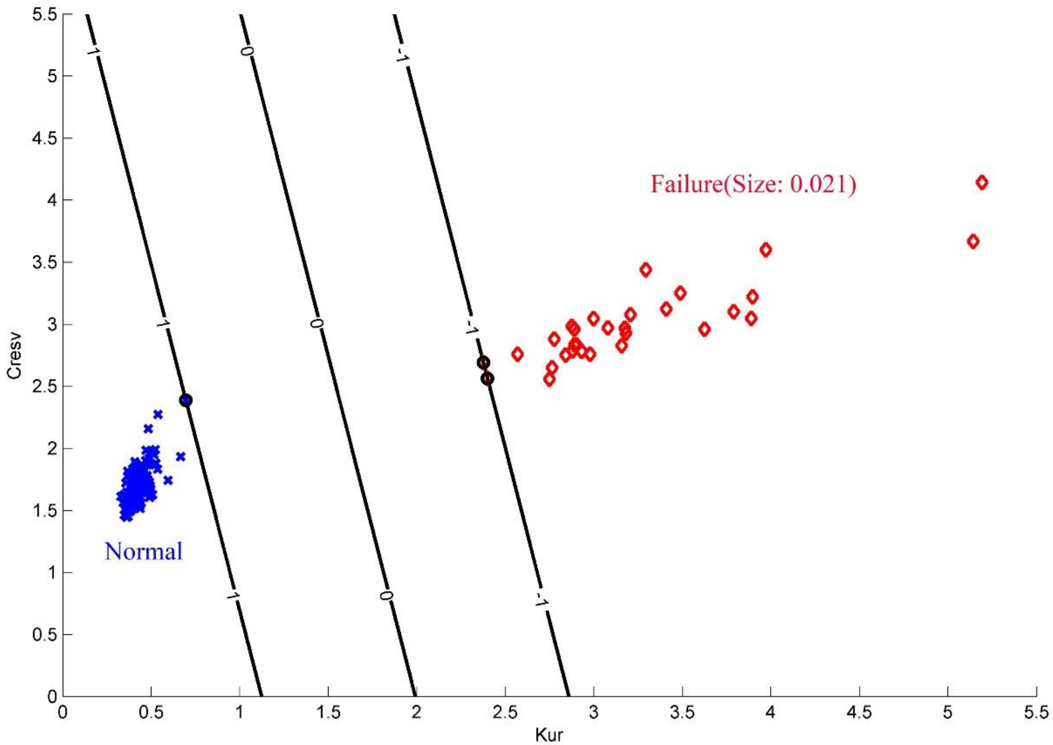
Application of digital twins and virtual commisioning

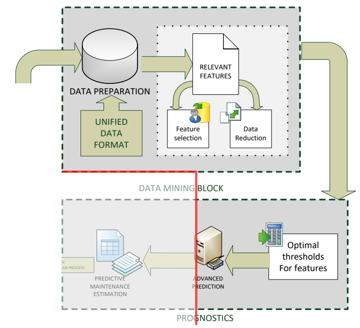


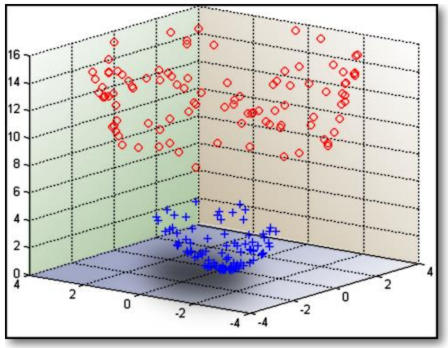
Types of data analytics

Descriptive Analytics Group historical data according to their similarity Reports Mapping	**Diagnostic Analytics** Determine cause of successes and failures Statistical analysis Queries Data Mining

Descriptive/ Diagnostic analytics







Types of data analytics

To Educate and Inform

Descriptive Analytics

Group historical data according to their similarity

Reports
Mapping

Diagnostic Analytics

Determine cause of successes and failures

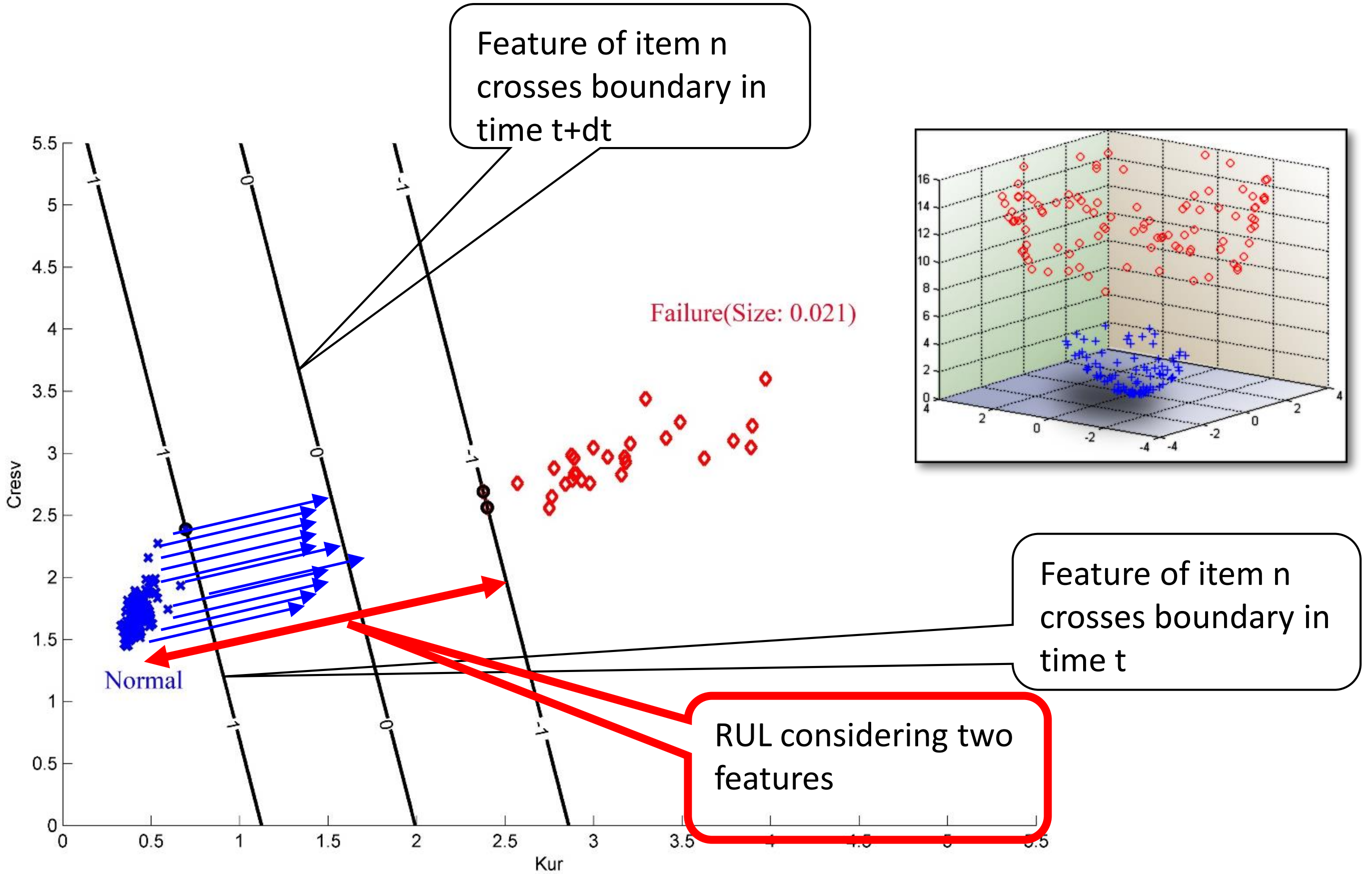
Statistical analysis
Queries
Data Mining

Predictive Analytics

Learning from the past to find out trends, standards, correlations. Anticipate the future.

Machine learning,
Simulation,
Forecasts

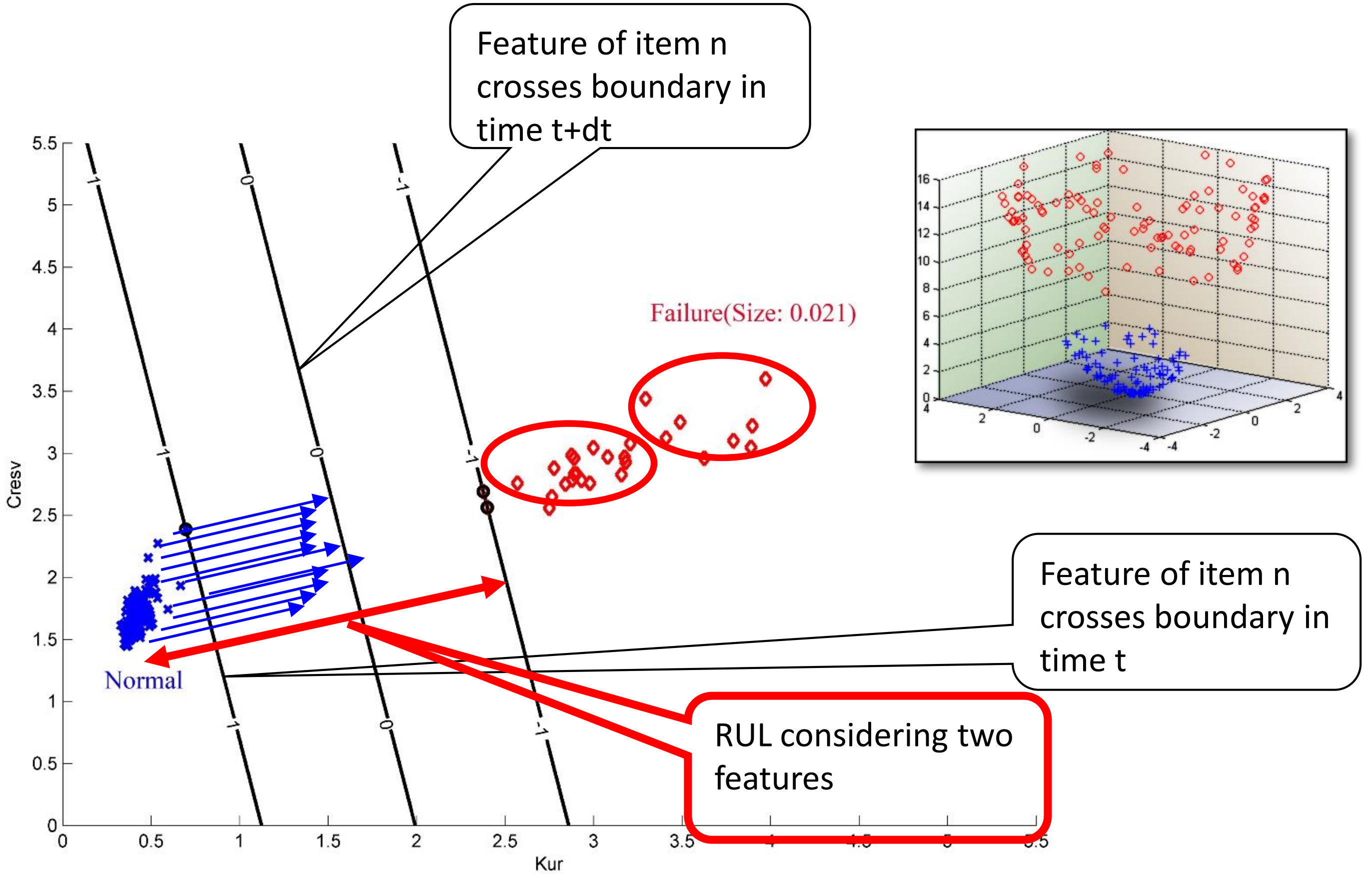
Predictive analytics:RUL prediction and simulation of scenarios



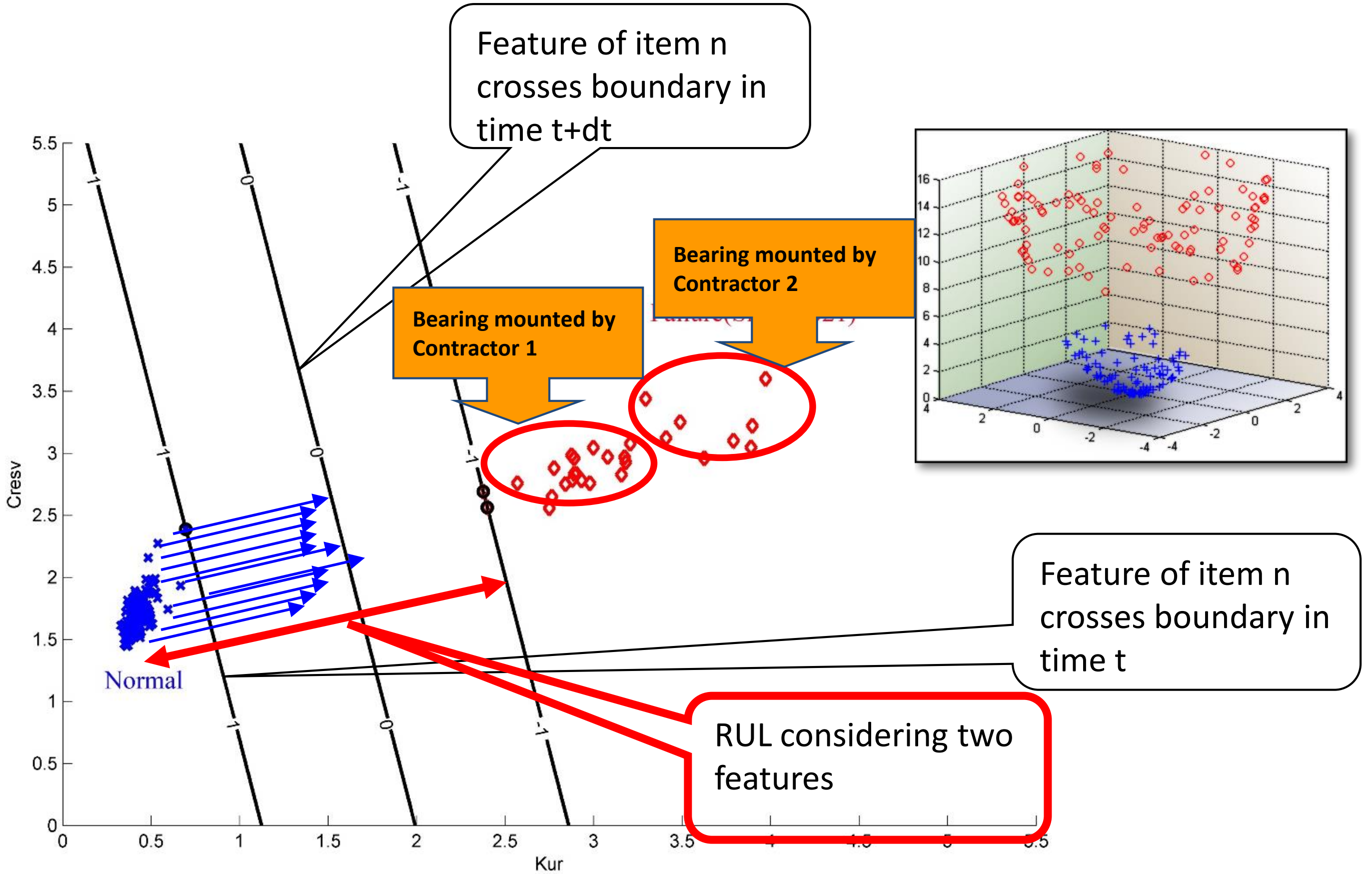
tecnalia Inspiring Business

LULEÅ UNIVERSITY OF TECHNOLOGY

Predictive analytics:RUL prediction and simulation of scenarios



Predictive analytics:RUL prediction and simulation of scenarios



tecnalia Inspiring Business

LULEÅ UNIVERSITY OF TECHNOLOGY

Types of data analytics

To Educate and Inform

Descriptive Analytics

Group historical data according to their similarity

Reports
Mapping

Diagnostic Analytics

Determine cause of successes and failures

Statistical analysis
Queries
Data Mining

Predictive Analytics

Learning from the past to find out trends, standards, correlations. Anticipate the future.

Machine learning, Simulation, Forecasts

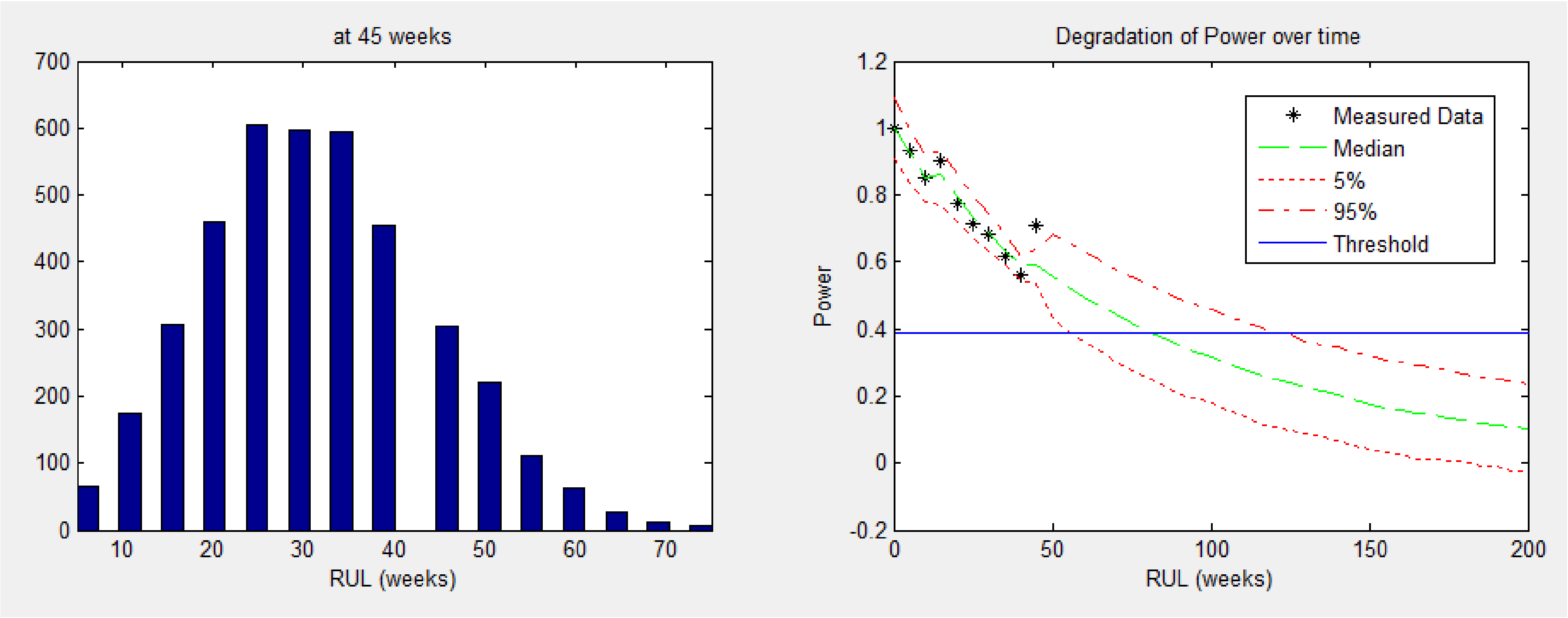
To optimize

Prescriptive Analytics / Decision Support

Provide better options based on forecasts. Show implications of each option.

Optimization, Decision models, Planning

Prognosis information: Particle filter considering context



Types of data analytics

To Educate and Inform

Descriptive Analytics

Group historical data according to their similarity

Reports
Mapping

Diagnostic Analytics

Determine cause of successes and failures

Statistical analysis
Queries
Data Mining

Predictive Analytics

Learning from the past to find out trends, standards, correlations. Anticipate the future.

Machine learning,
Simulation,
Forecasts

To optimize

Prescriptive Analytics / Decision Support

Provide better options based on forecasts. Show implications of each option.

Optimization,
Decision models,
Planning

To decide

Cognitive Analytics / Intelligent Autonomous Actions

AI systems that learns from actions, finding correlations, and learn from outcomes. Autonomous operations.

Artificial Intelligence

Reduced human intervention

Take direct action

Concluding remarks

- Digital twins and Hybrid models are needed for virtual commisioning to deliver O&M services and kill black swans and listen the swan song
- O&M based on Data driven solutions can lead to catastrophic failures
- Cognitive analytics is the logical sequence of prescription
- Digital twin 4.0 will consider evoltionary models and normality dynamics

tecnalia Inspiring Business

LULEÅ UNIVERSITY OF TECHNOLOGY

Thanks!!

diego.galar@tecnalia.com
diego.galar@ltu.se