Perspectives on Digital twins

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Digital Twins for Engineering Applications – The Emerging Science and Technology

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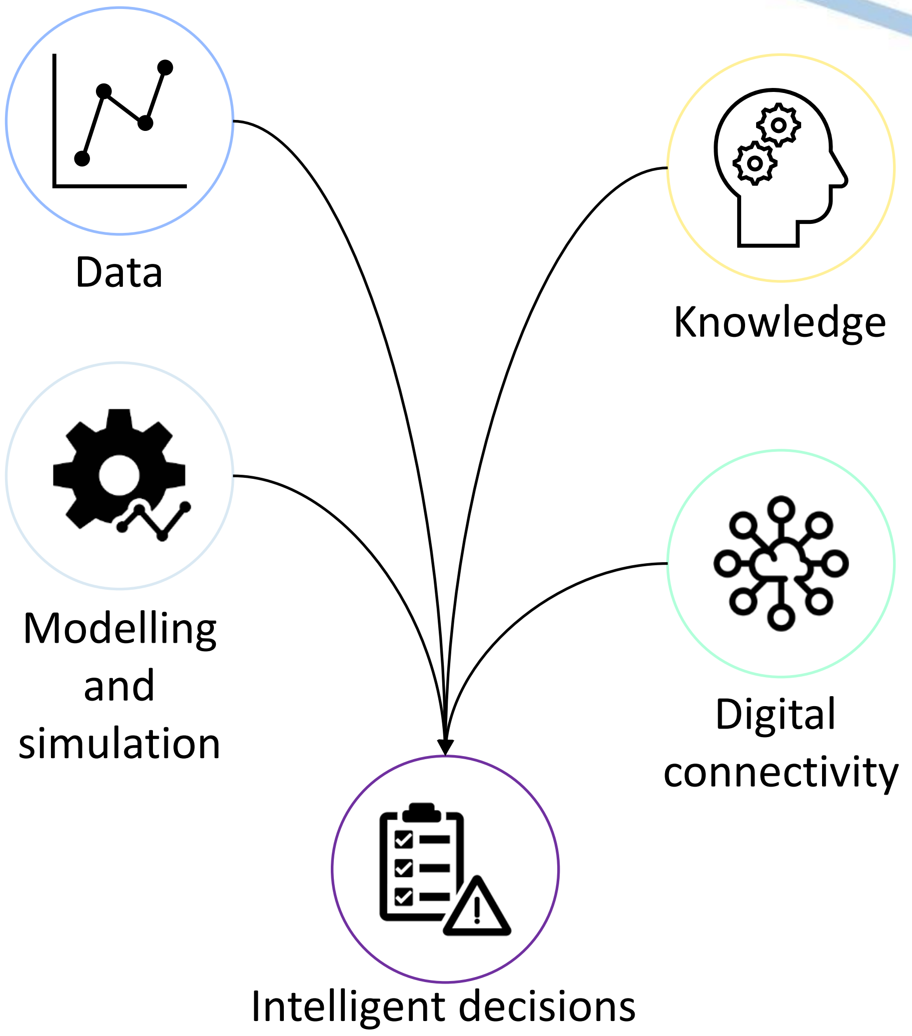
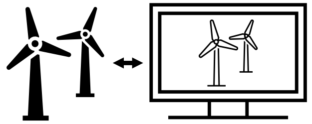
Introduction

- Perspectives
- Use cases
- Case studies
- Summary

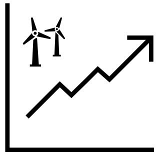


Why build a digital twin?

A digital representation of an asset, system, or process



Better understanding of **future** behaviour in response to environment



More intelligent decisions -> high ROI

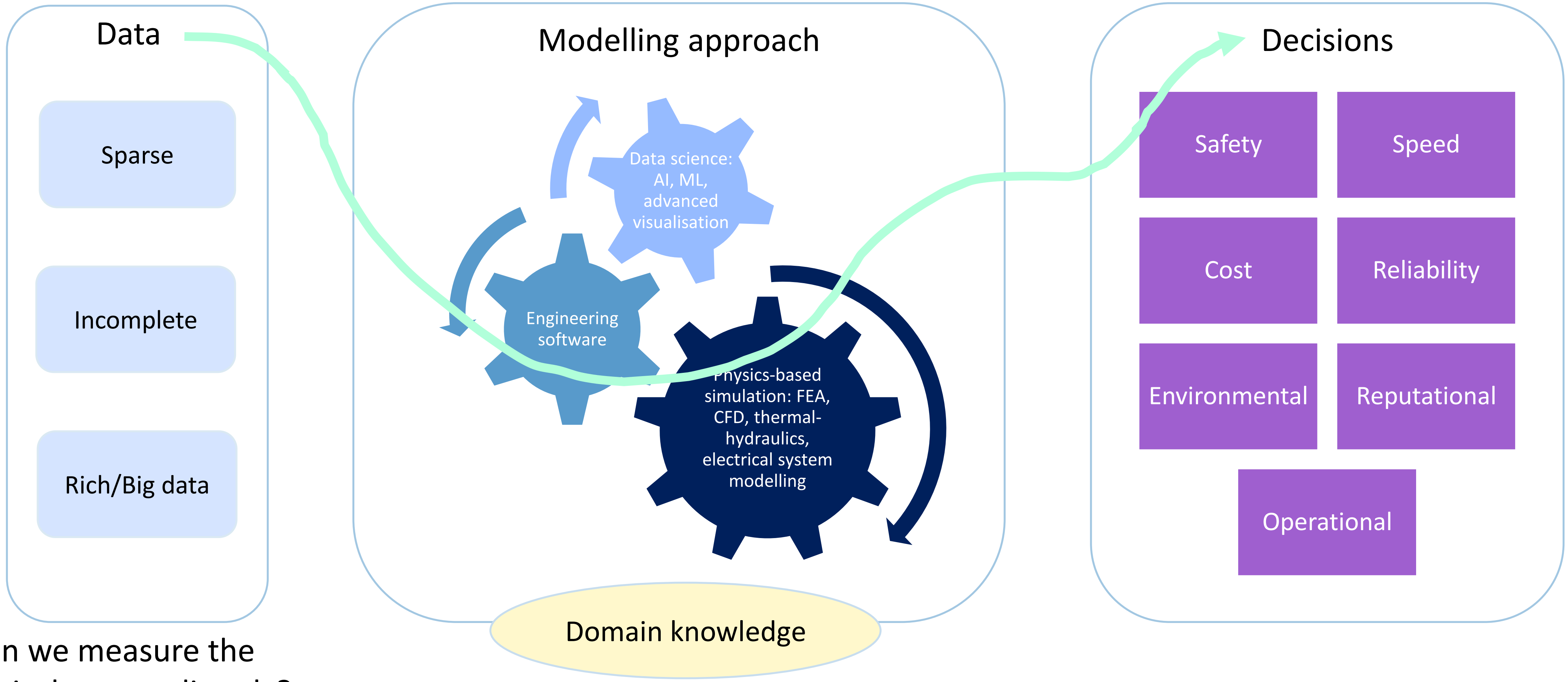
Key questions we often seek to answer:

- What is the current state of the asset, system, or process?
- How will it perform in the future?
- How will it perform under a range of hypothetical scenarios?
- What decisions can we take that will optimise future performance?

Understanding *why* helps scope the appropriate methodologies and model architecture to ensure a digital twin adds value

Creating a line of sight

Capturing and documenting connections can become complex if you can't measure what you want directly…



Can we measure the critical output directly?

Real time?

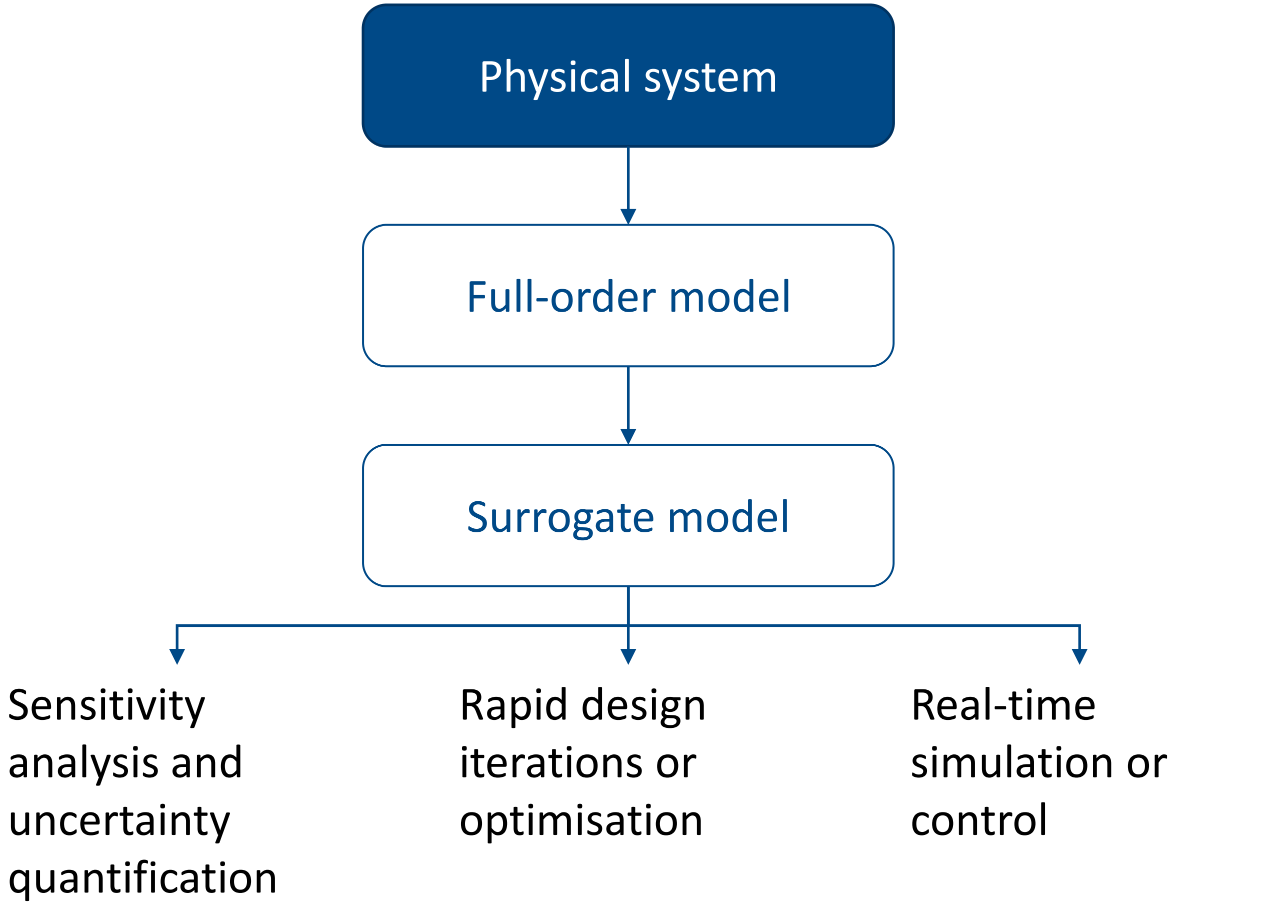
Predicting the future requires some notion of timescales.

Most classical engineering models (FEA, CFD etc.) are too slow and can restrict the utility of a digital twin.

Consider surrogate models:

- Physically-based reduced order models
- Machine learning approaches

Trade-off with impact on uncertainty?



It won’t be perfect

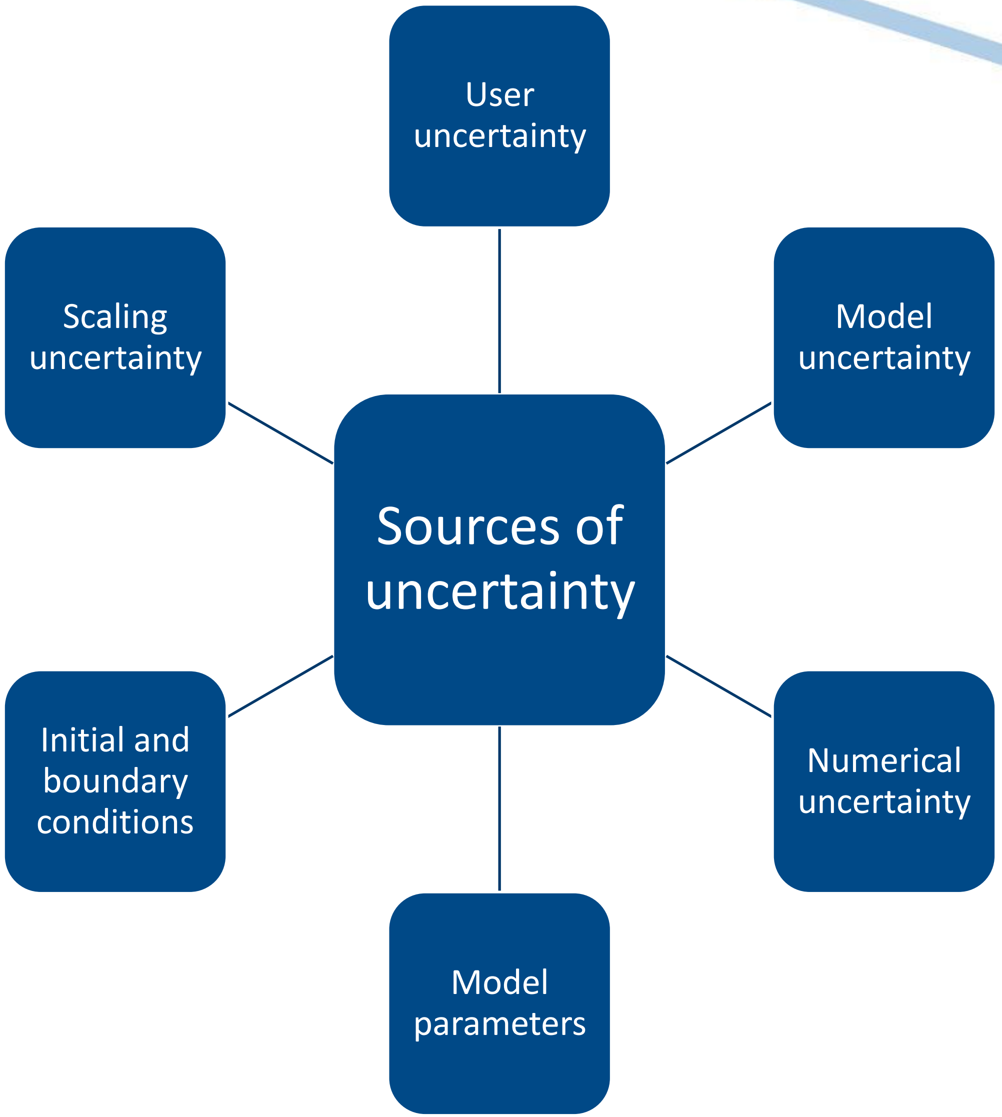
Comparing a digital twin’s predictions to reality is essential to build confidence

Agreement unlikely to be exact due to uncertainty

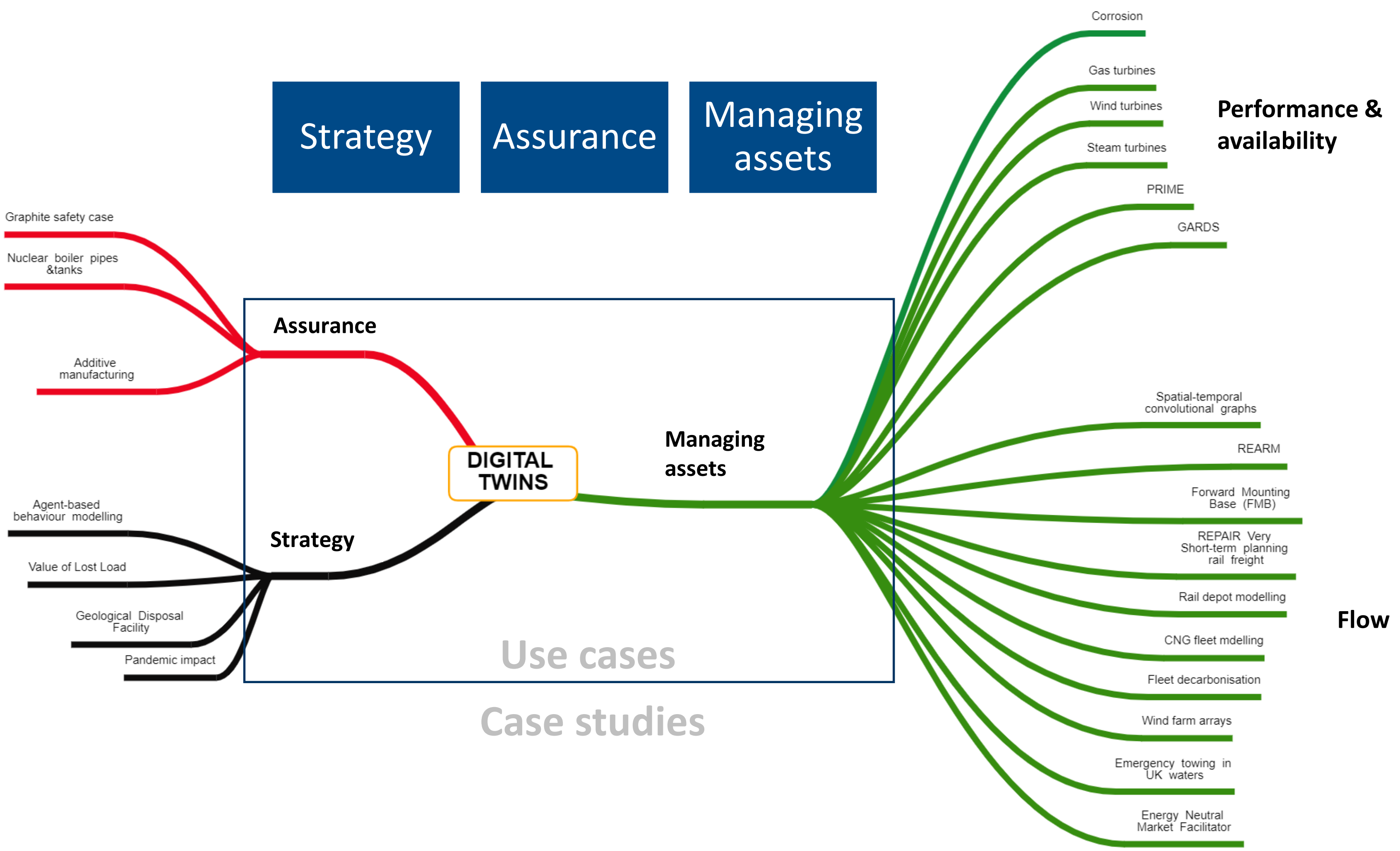
Effective validation and confidence building comes from defining:

- The behaviour range we expect to see?
- The range we’d be surprised to see?

An assessment of uncertainty is an essential part of building a digital twin



Use cases and case studies



Predictive maintenance for industrial gas turbines



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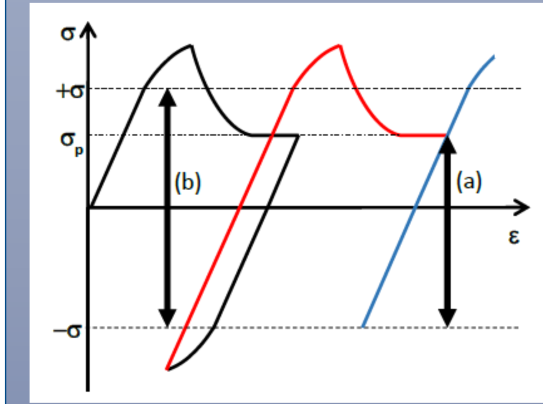
Predictive maintenance for industrial gas turbines

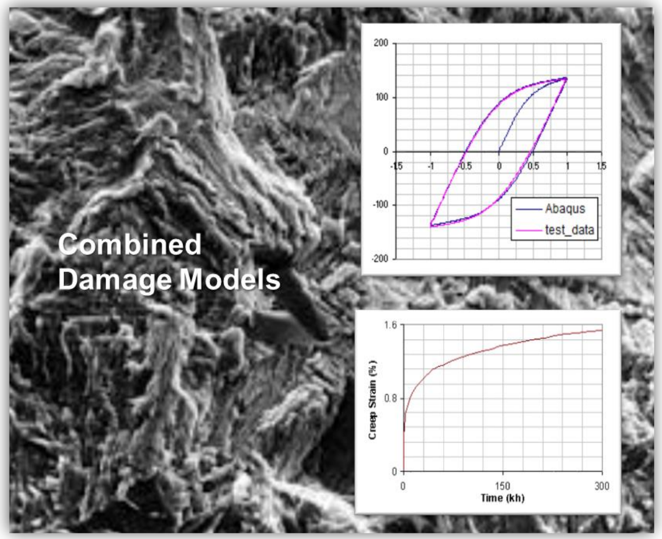
Scenario

Predictive maintenance for industrial gas turbines

Understand how a single crystal blade degrades to provide a rigorous foundation to optimising the intervention strategy

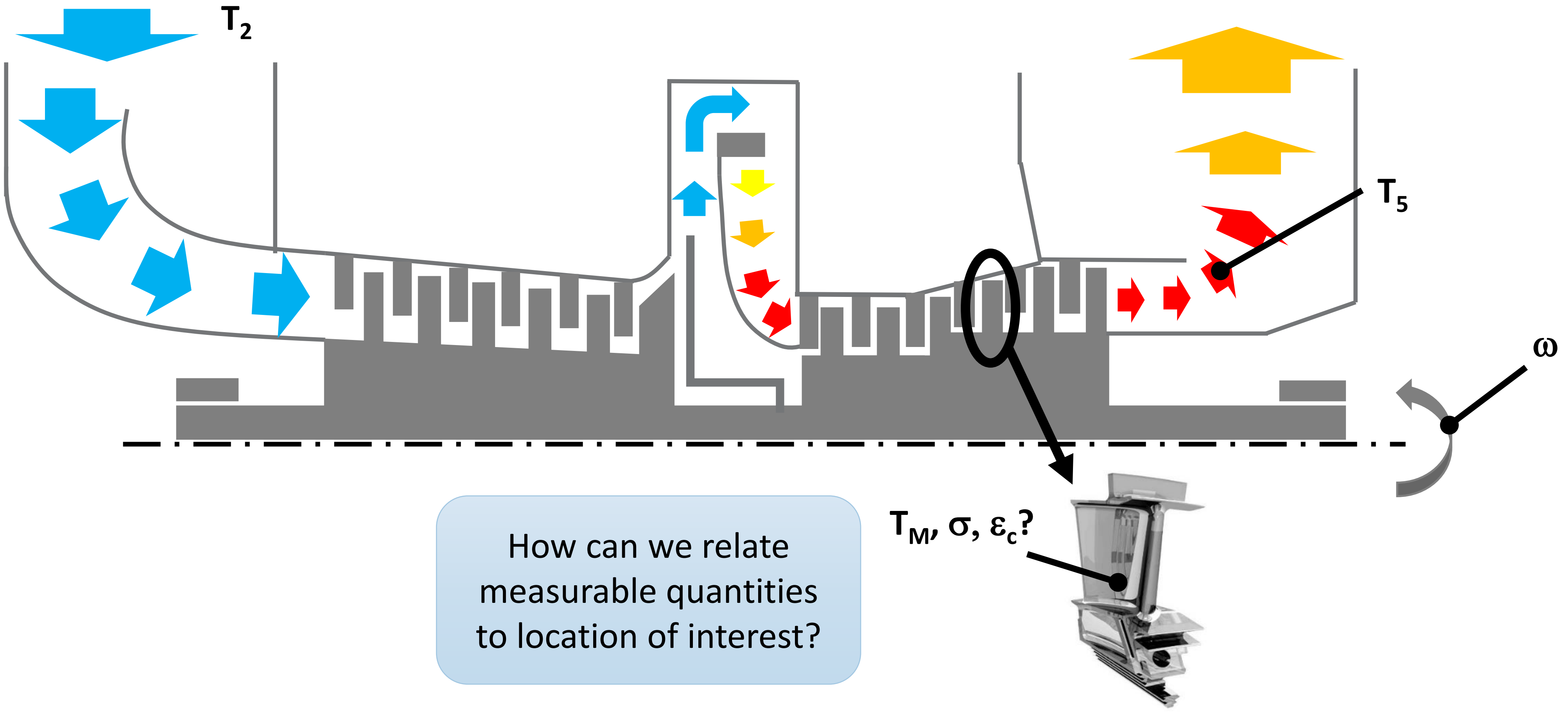


High temperature
Creep-fatigue interaction



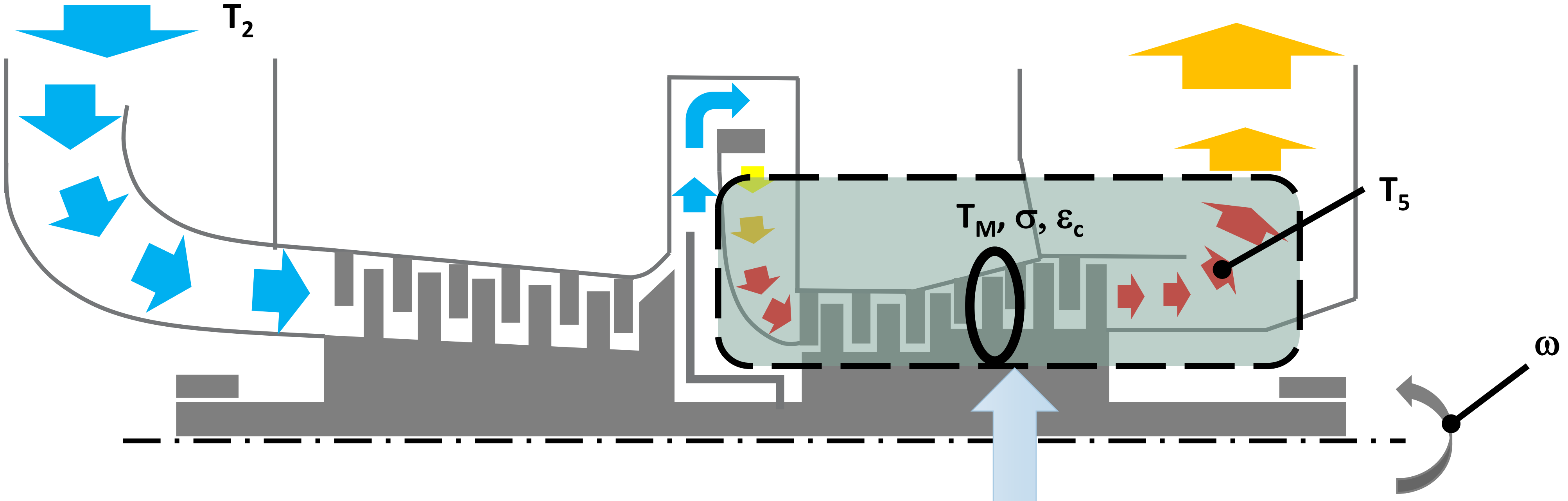
Validate against test specimens

Predictive maintenance for industrial gas turbines



How can we relate measurable quantities to location of interest?

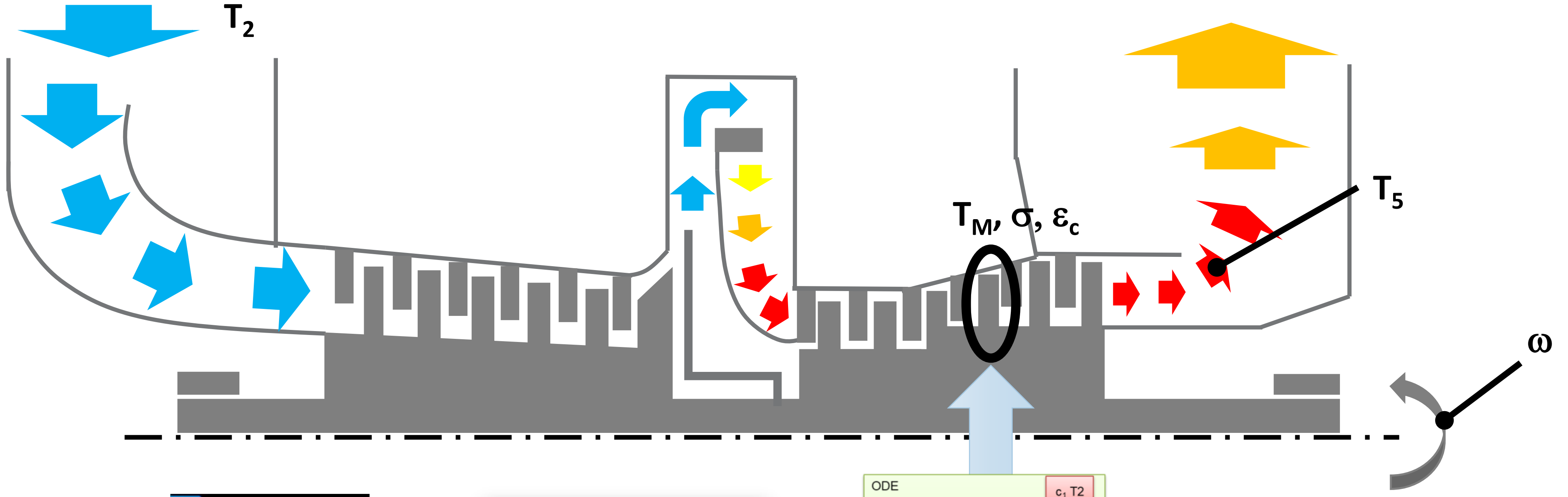
Predictive maintenance for industrial gas turbines



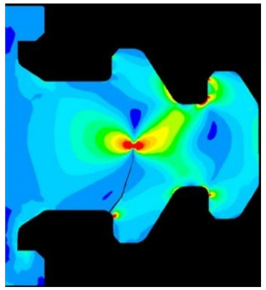
Validated against a fully-instrumented unit

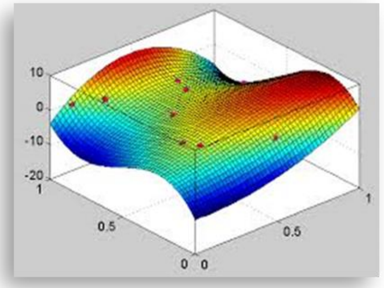
Detailed CFD and FE analysis to understand behaviour of hot gas path

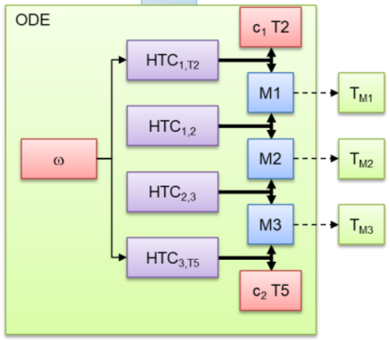
Predictive maintenance for industrial gas turbines



Expensive, time consuming and inflexible

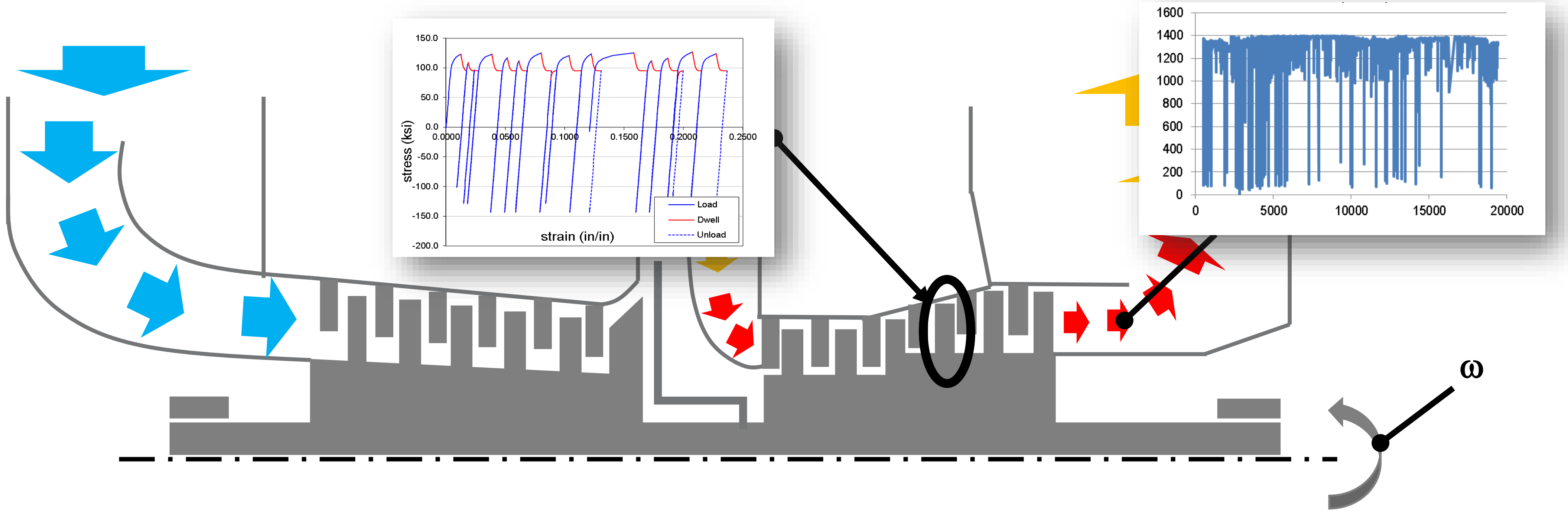






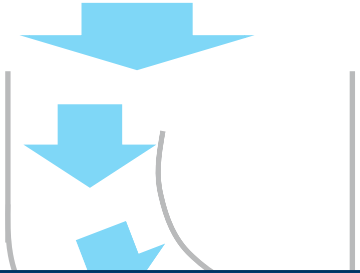
- Sufficiently accurate
- Adaptable and fast to solve
- Risk managed through probabilistic analysis

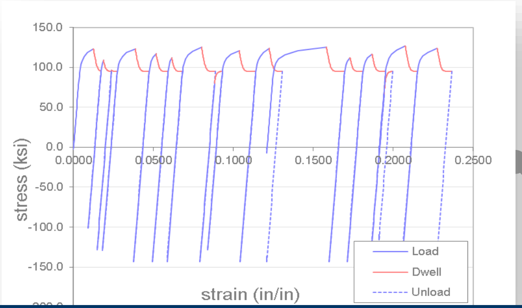
Predictive maintenance for industrial gas turbines

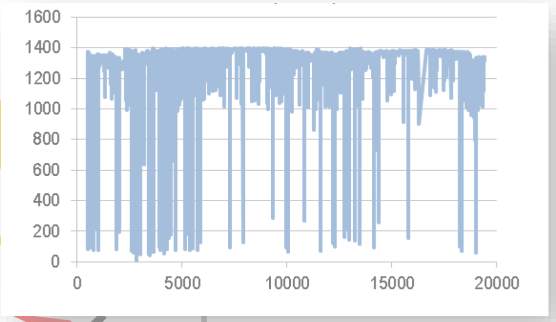


Measured T, ω → ROM → Blade T, σ, ε_c → ROM → Blade damage (life)

Predictive maintenance for industrial gas turbines







We can now quickly and reliably determine unit-specific blade damage from engine monitoring data

Measured
T, ω

→

ROM

→

Blade
T, σ, ε_c

→

ROM

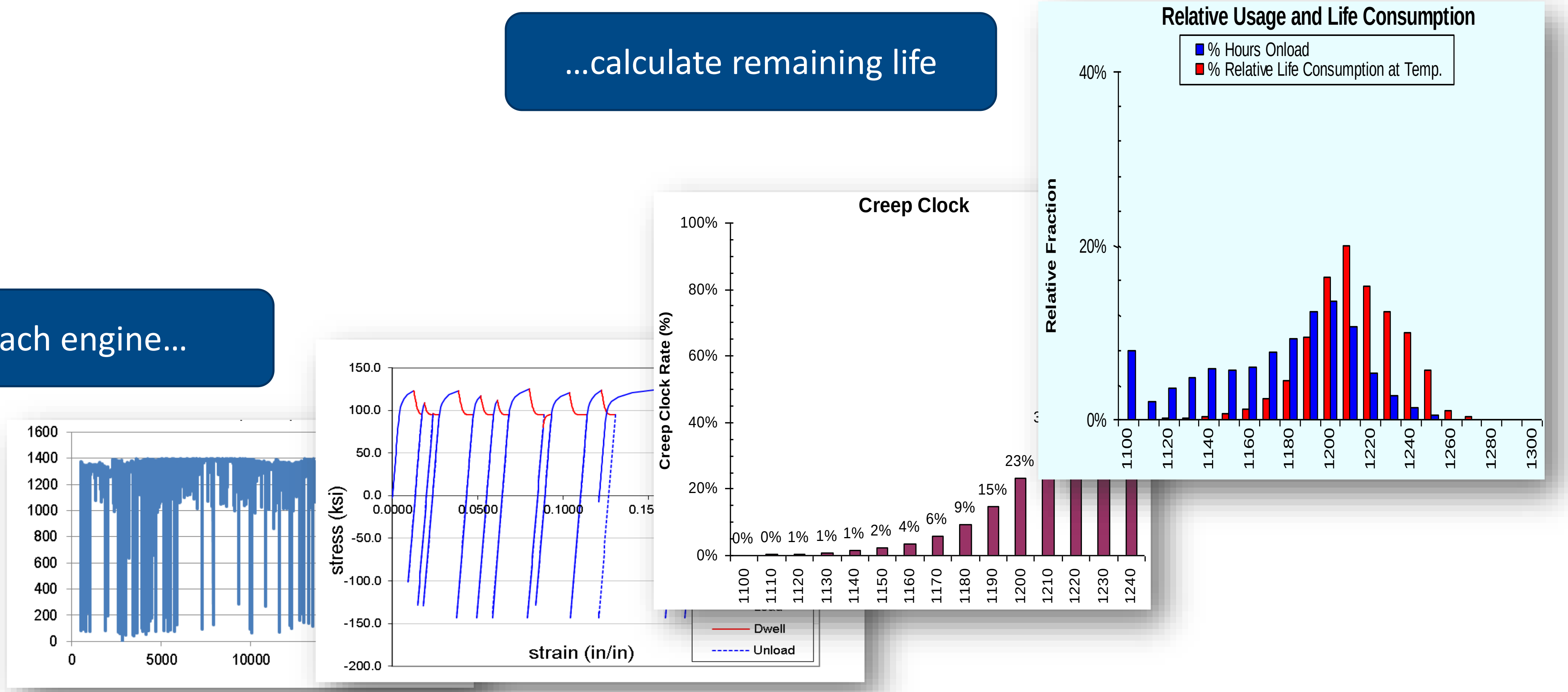
→

Blade damage (life)

Predictive maintenance for industrial gas turbines

…calculate remaining life

For each engine…



Predictive maintenance for industrial gas turbines

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Predicting brick cracking in advanced-gas cooled reactors

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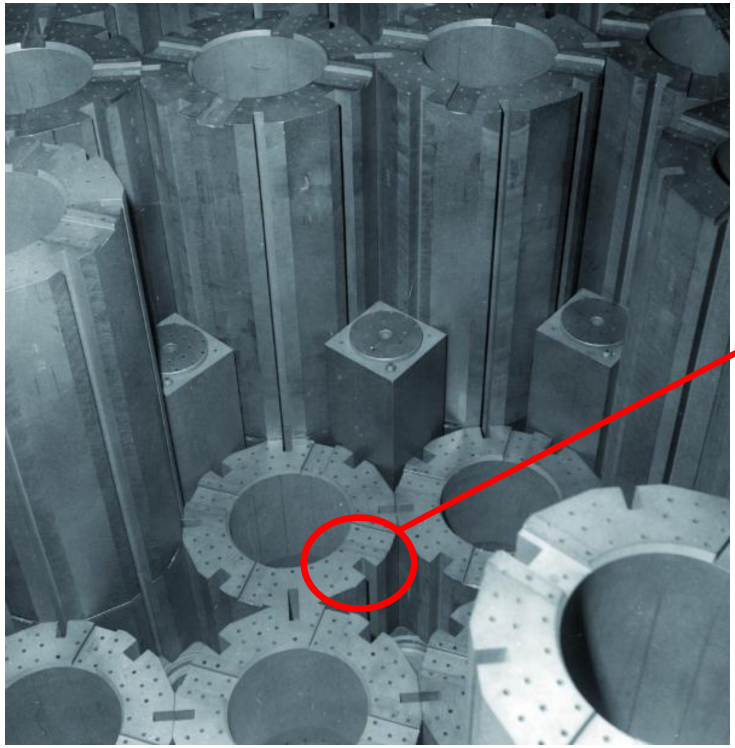
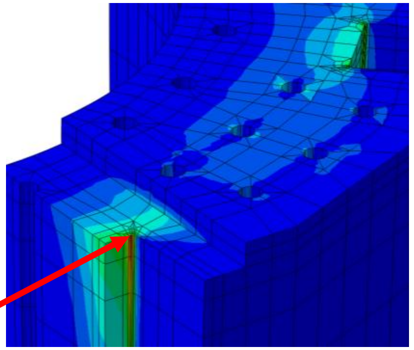
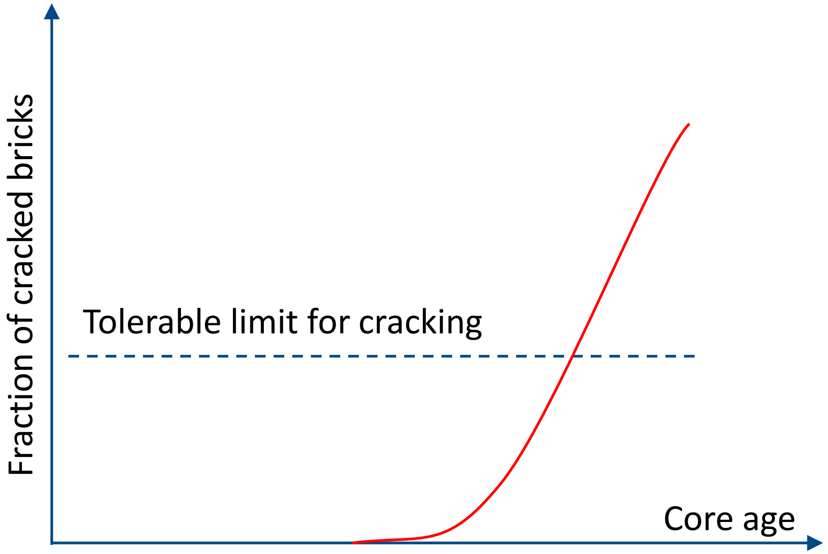
Advanced-Gas Cooled Reactors

Scenario







Advanced-Gas Cooled Reactors

Challenges	Solutions
Potential failure point cannot be monitored directly	DT's modelling and data chain predicts failure point
Limited measurements	Aggregation of additional data sources into DT
Inherent uncertainty	Model incorporated and quantified uncertainty
Expensive-to-run physical models	DT uses efficient surrogate models

Power Level

Limited Measured Temperature

Modelled Neutron Dose

Modelled Oxidation rate

Limited oxidation measurements

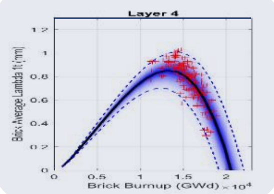
Modelled Stress and Distortion

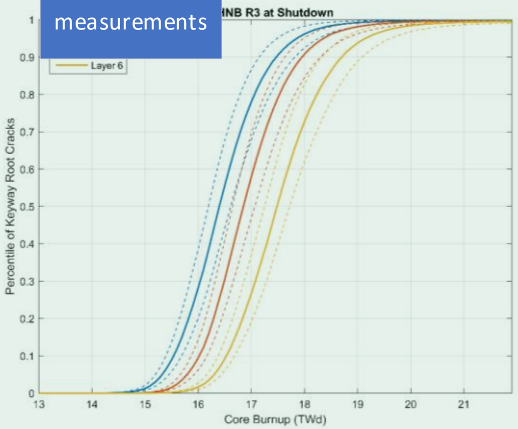
Surrogate Model

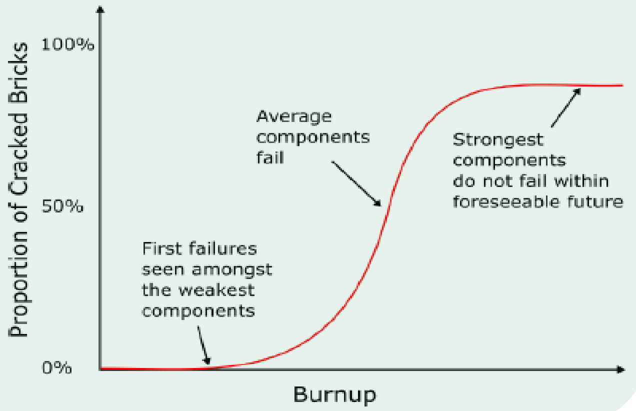
Limited distortion measurements

Modelled Cracking

Failure Probability







- Probabilistic forecasts suggest period between detectable cracking and safety limit
- Approach successful and extended generation significantly – many times ROI

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Understanding flight operations on an aircraft carrier



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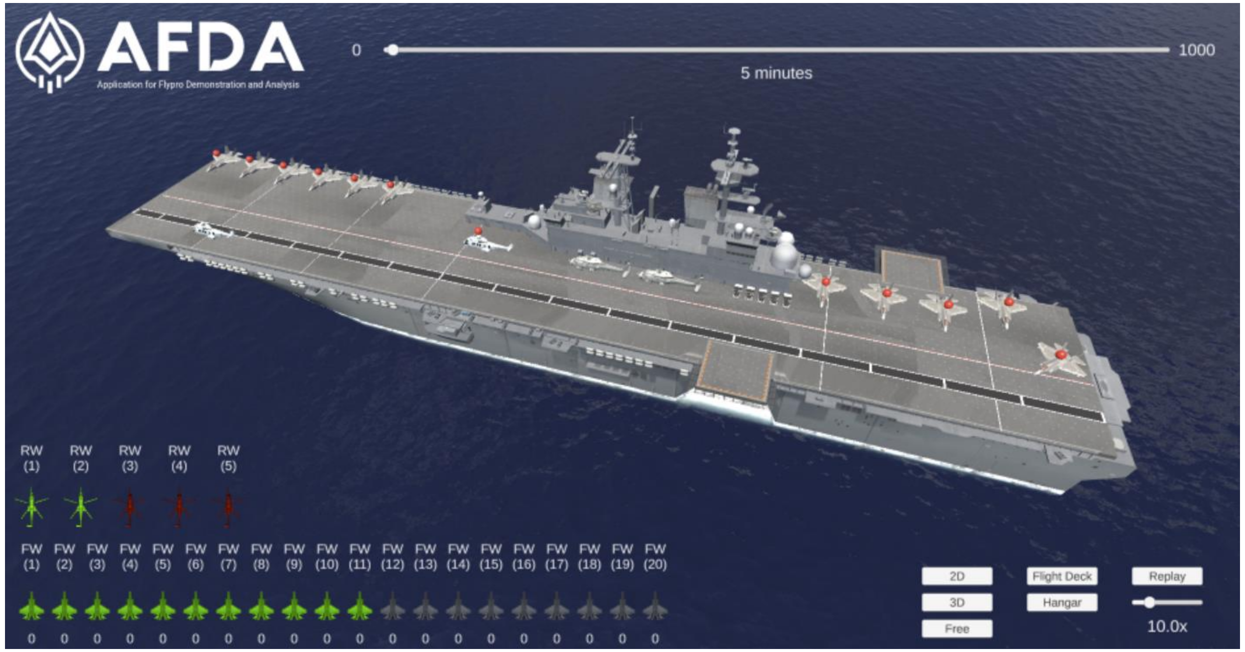
A simulation and agent-based approach

Questions



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Predicting future condition of an electrical power network

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'LV Predict': predicting future condition of an electrical power network

How can we predict the condition of underground Low Voltage (LV) cables?

- Asset integrity
- Innovative data sources
- Data science
- Visualisation

…that will enable…

Benefits

- Improved understanding of LV cable degradation
- Provide insight to maintenance planning
- Understand how Net-Zero will influence network condition

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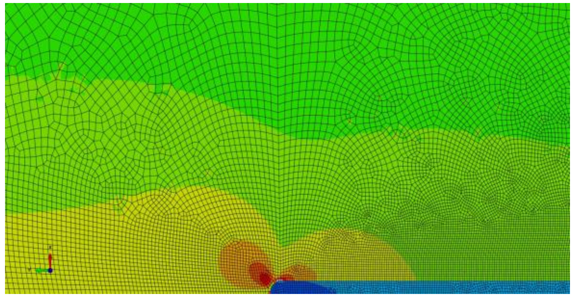
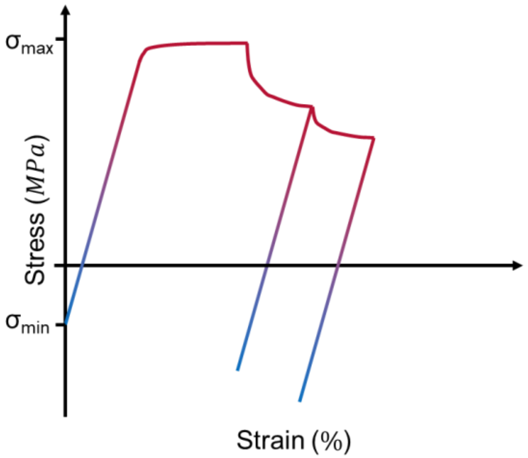
Asset integrity



Cyclic stress-strain curve



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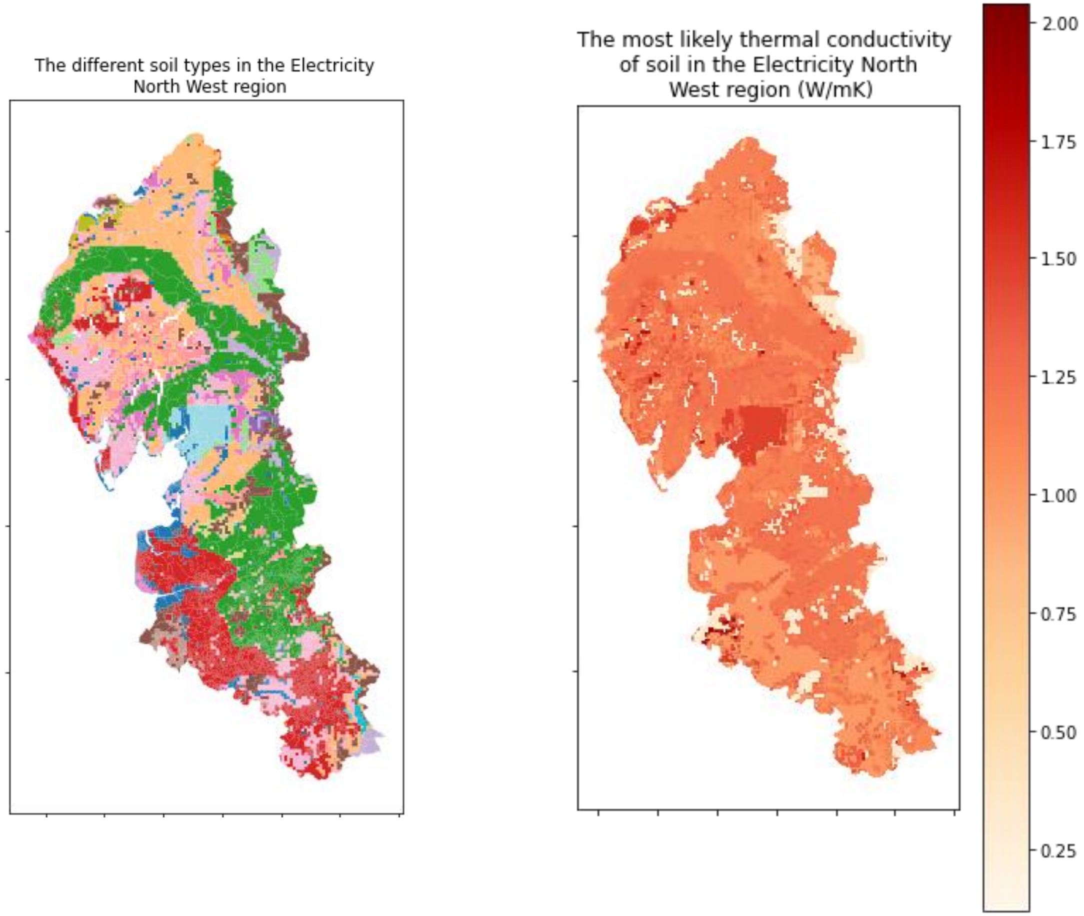

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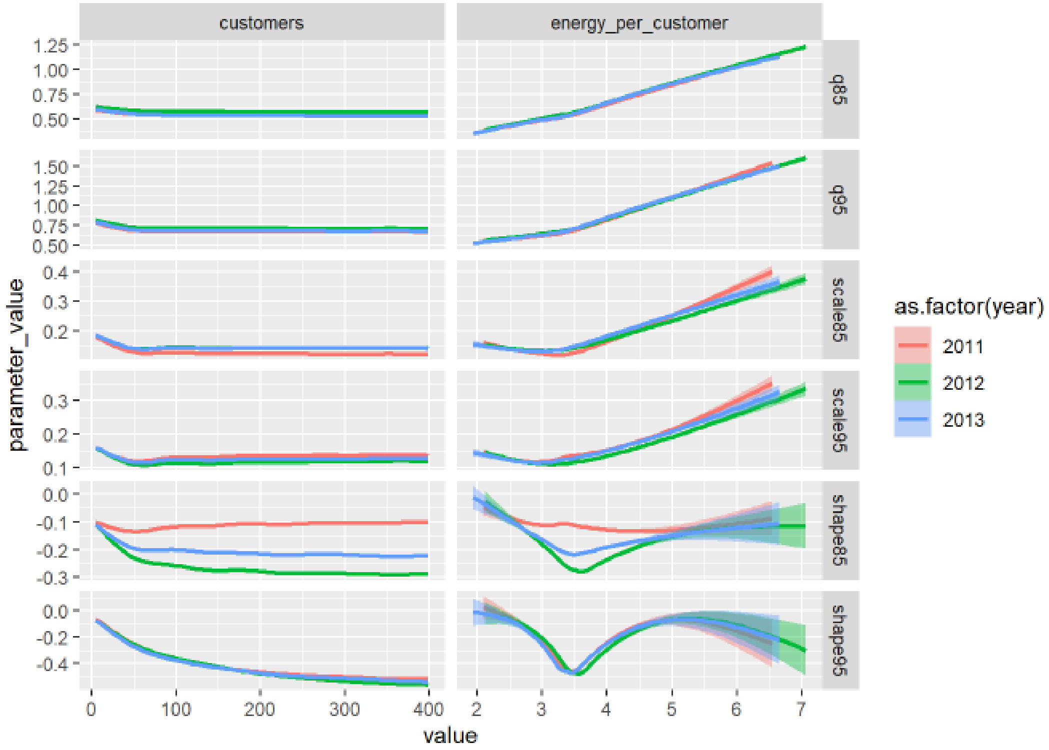

‘LV Predict’: predicting future condition of an electrical power network

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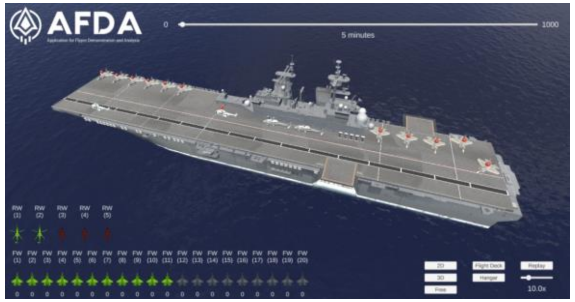
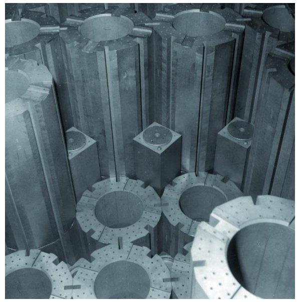
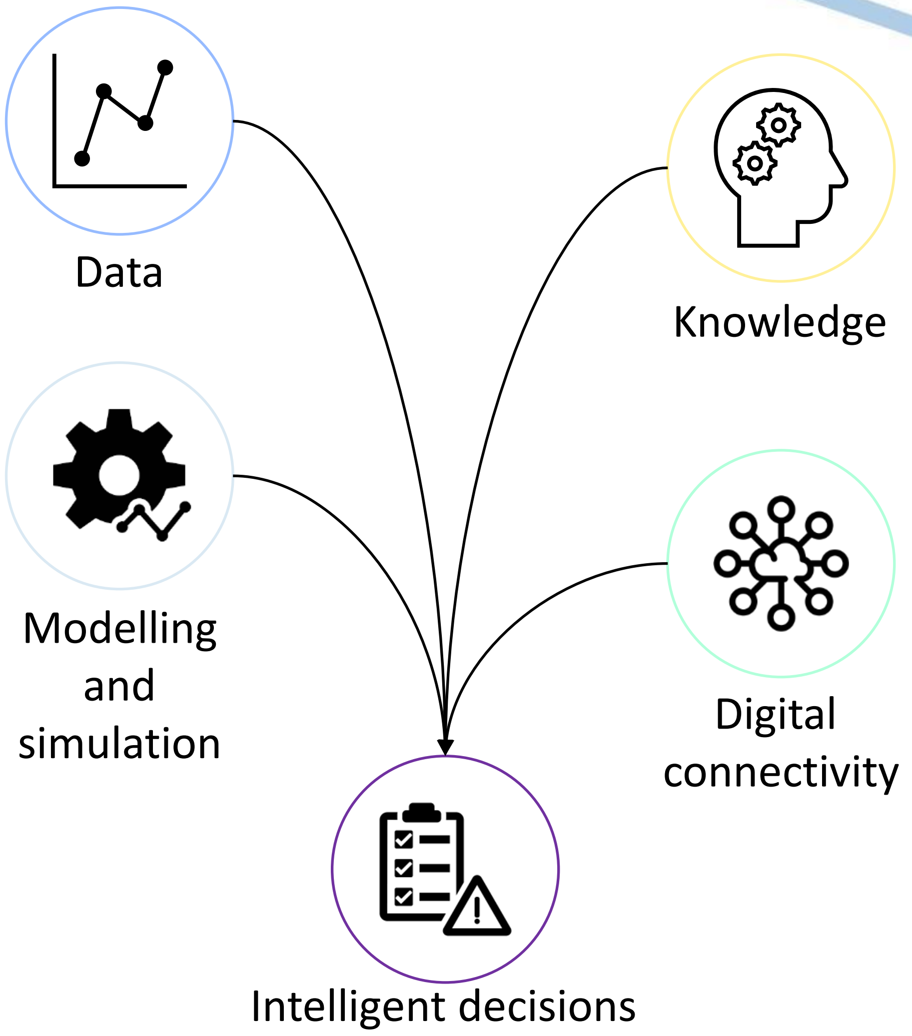
Visualisation

https://lv-predict.fnc.digital/

Summary


AFDA
5 minutes




Data
Knowledge
Modelling and simulation
Digital connectivity
Intelligent decisions

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