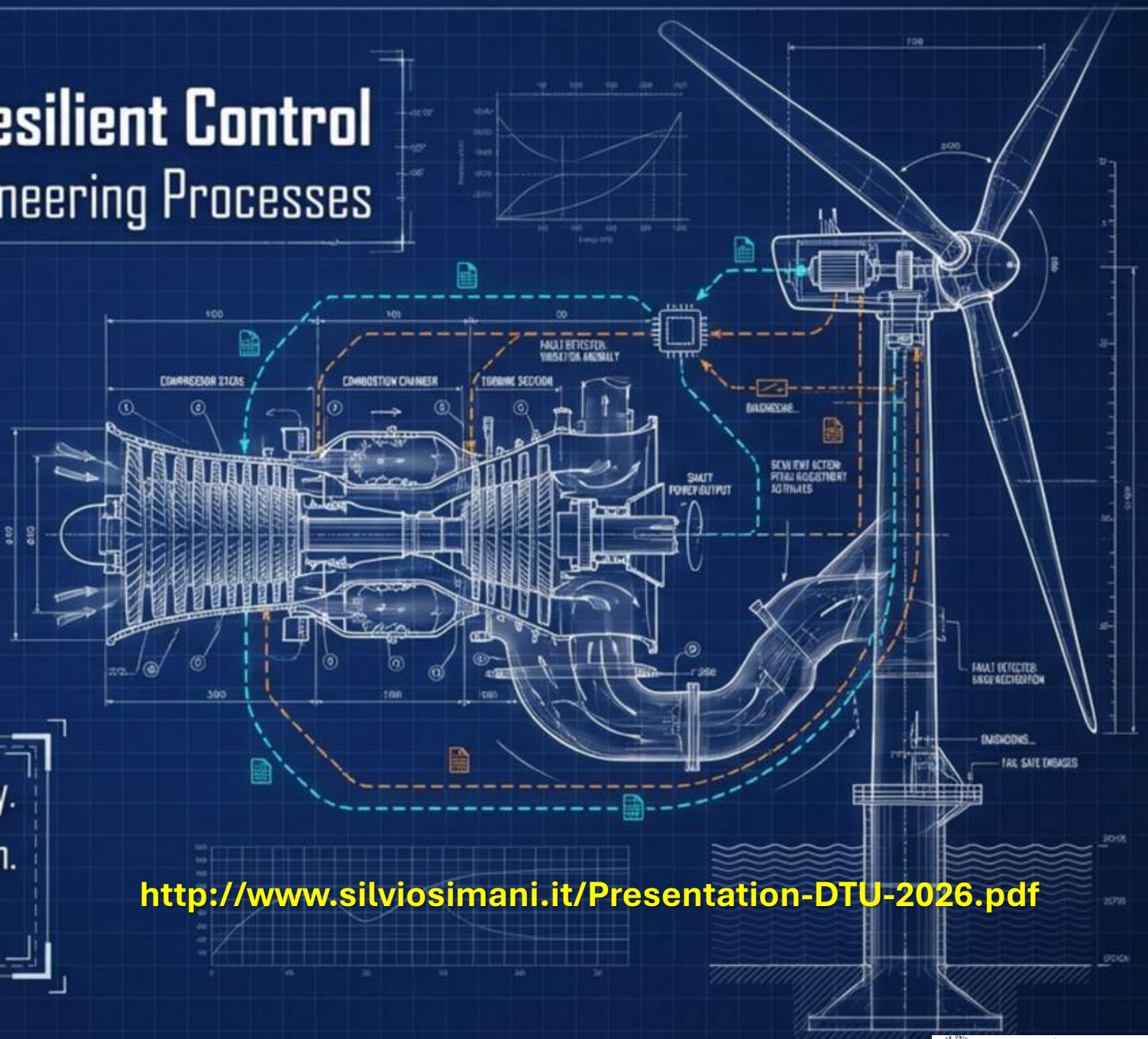
From Fault Diagnosis to Resilient Control

A Research Journey Across Engineering Processes

http://www.silviosimani.it/talks.html



- Professor Silvio Simani's research journey.
- Decades of engineering process innovation.
- Focus on resilient control systems.

http://www.silviosimani.it/Presentation-DTU-2026.pdf

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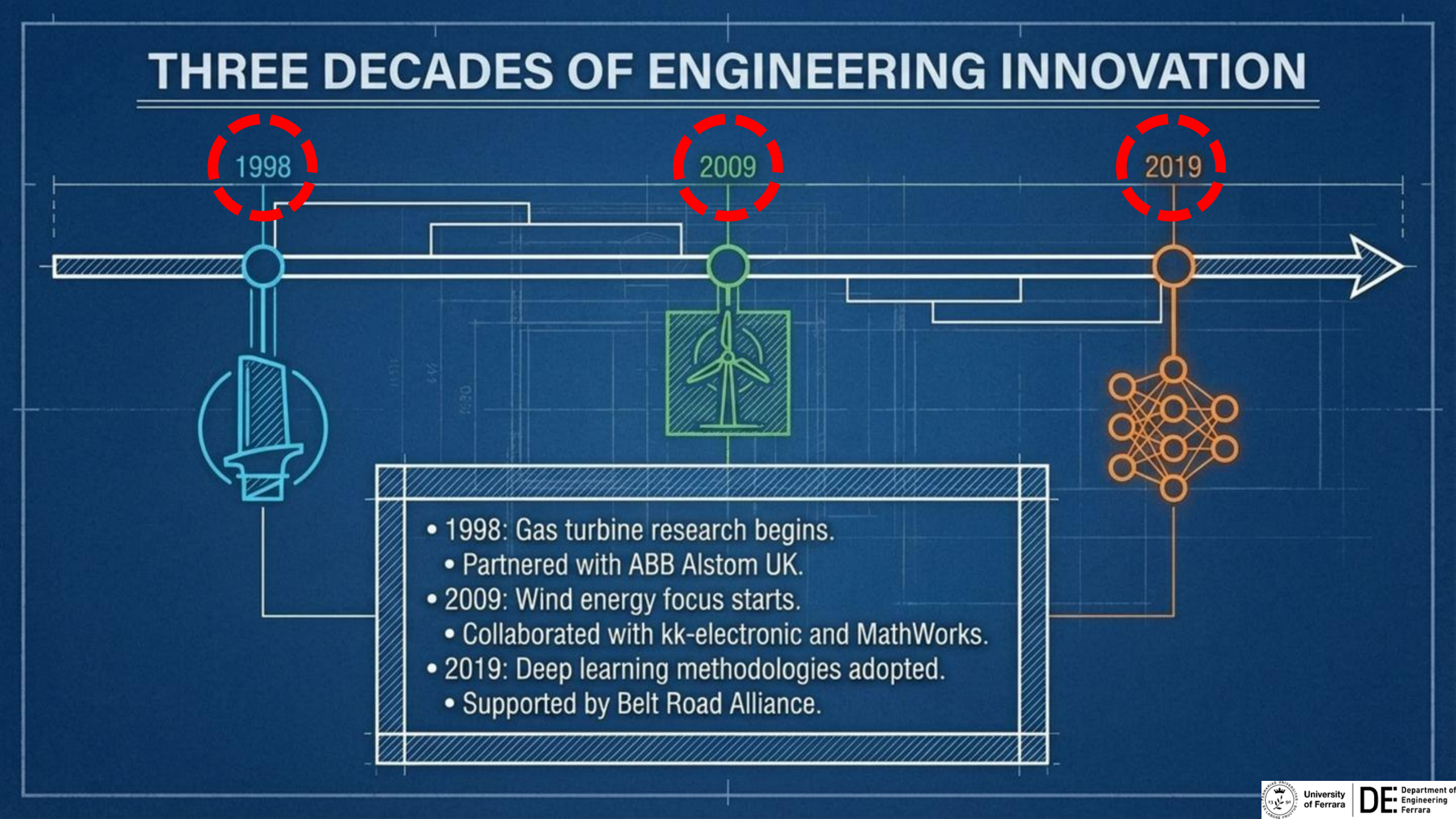
THREE DECADES OF ENGINEERING INNOVATION



PROVING FAULT DIAGNOSIS FEASIBILITY

Reactive Maintenance

Predictive Diagnosis

- Fault diagnosis feasibility studies conducted.
- Detect slowly developing incipient faults.
- Used predictive maintenance strategic tools.
- Applied model-based fault detection approaches.
- Minimised model and reality mismatches.
- Ensured proper customer operation validation.

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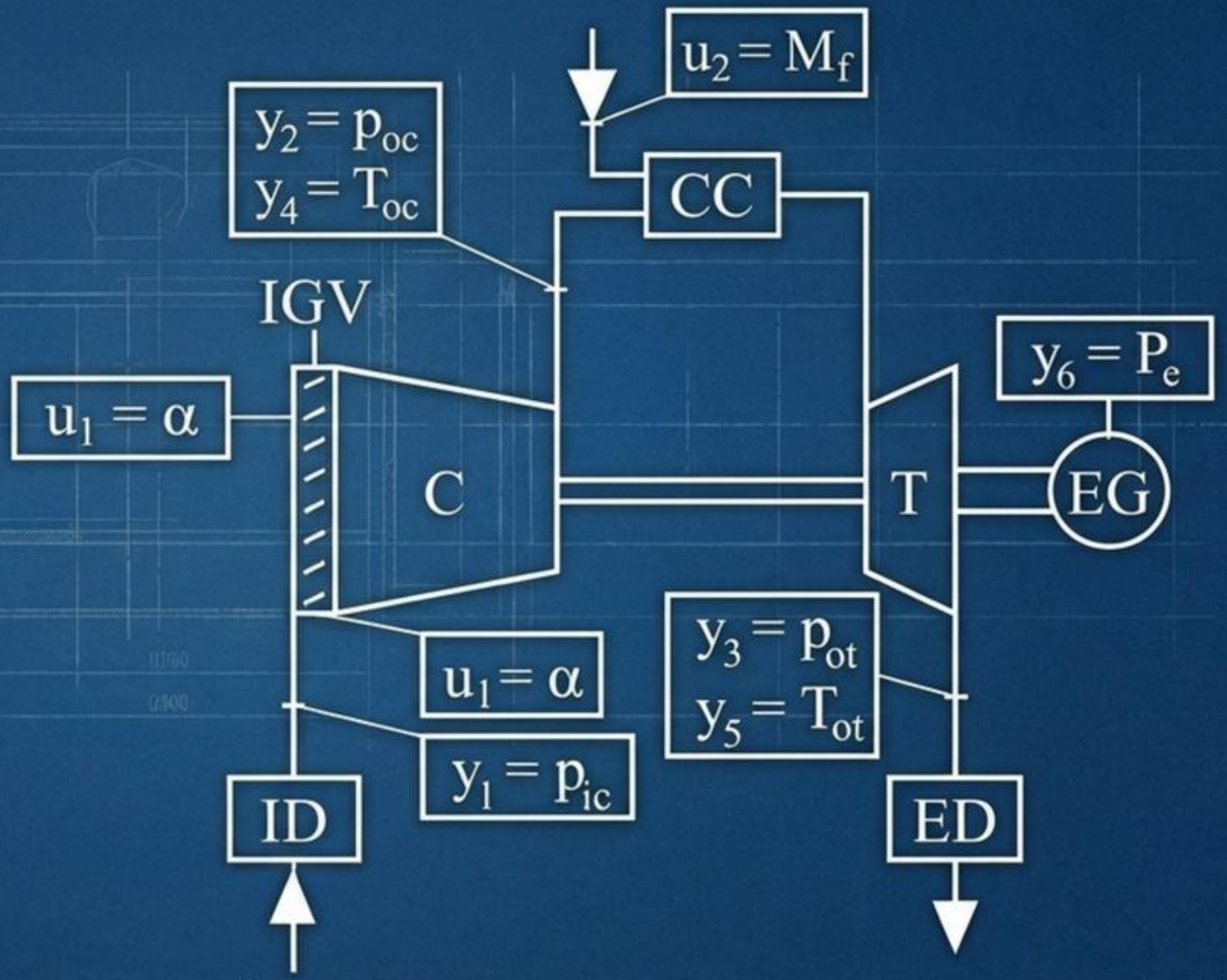
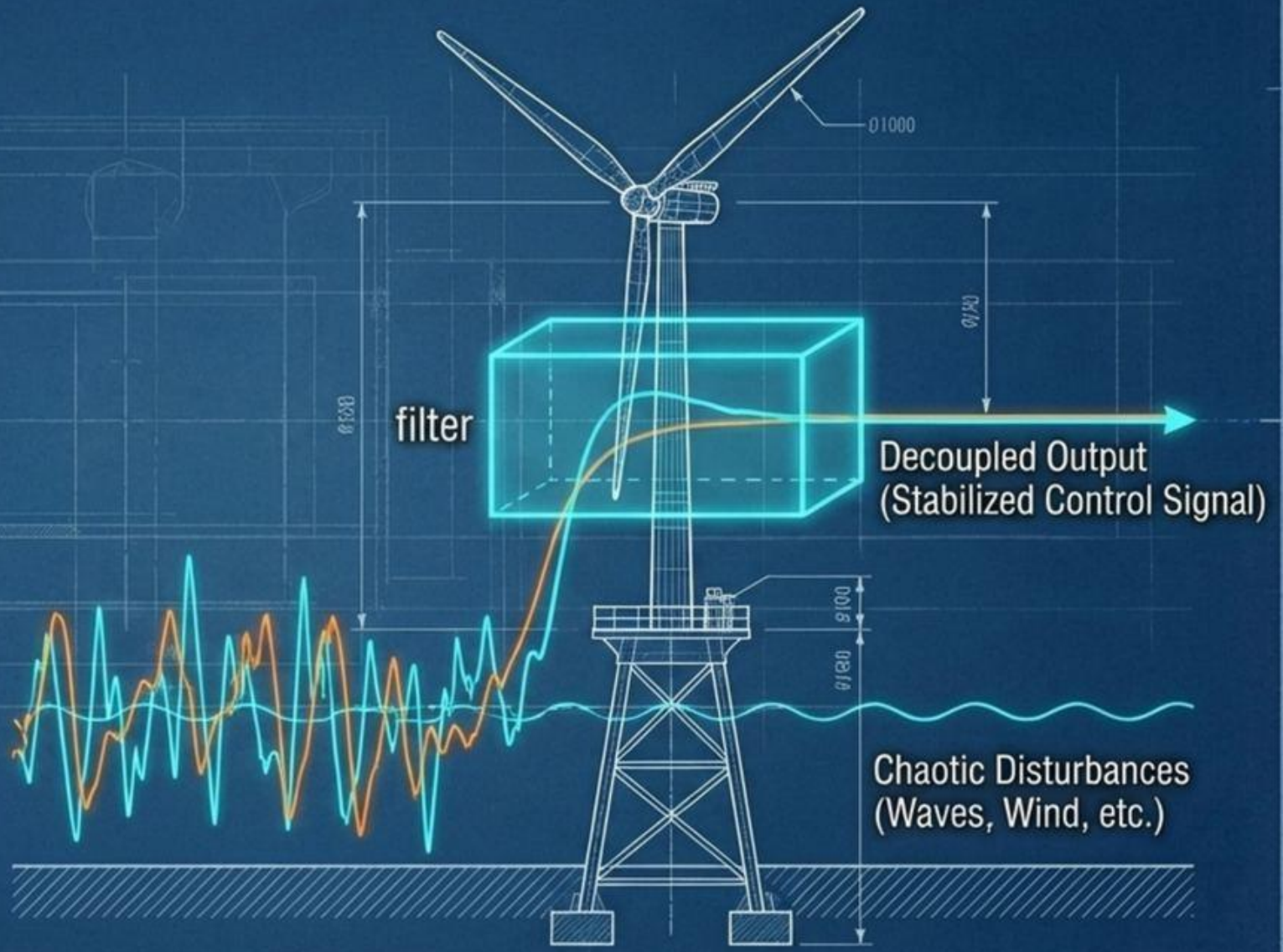
MODELLING COMPLEX GAS TURBINE BEHAVIOURS

- Developed comprehensive gas turbine simulators.
- Utilised Matlab and Simulink environments.
- Implemented fuzzy model identification techniques.
- Designed linear output residual generators.
- Optimised performance via Monte-Carlo analysis.
- Simulated compressor and sensor faults.



Overcoming Offshore Wind Turbine Challenges

- Focused on offshore wind installations.
- Addressed severe malfunction working conditions.
- Designed disturbance decoupled nonlinear filters.
- Estimated faults via active tolerance.
- Competed in international IFAC benchmarks.
- Validated strategies on complex turbines.

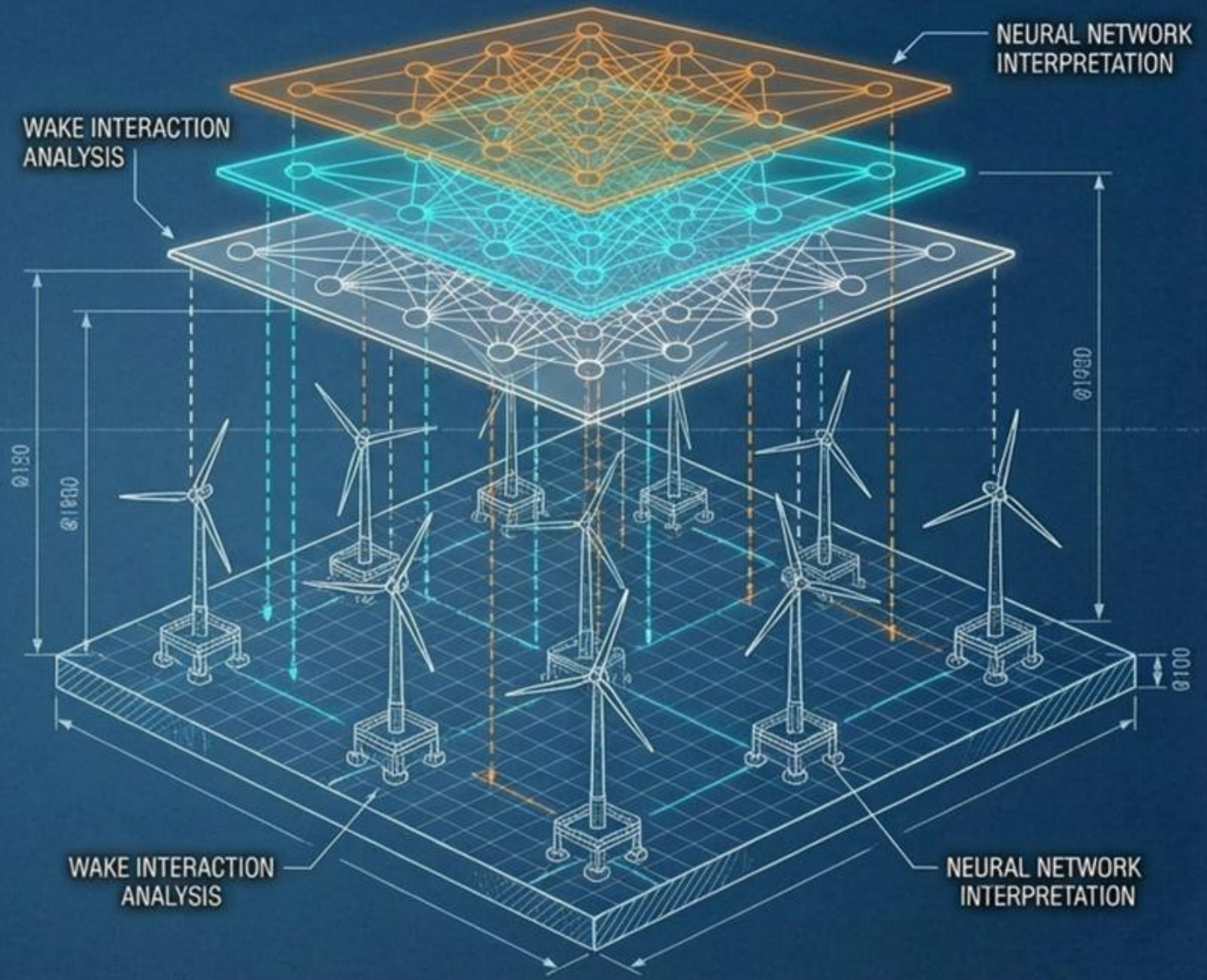


SHAPING INDUSTRY STANDARDS IN WIND ENERGY

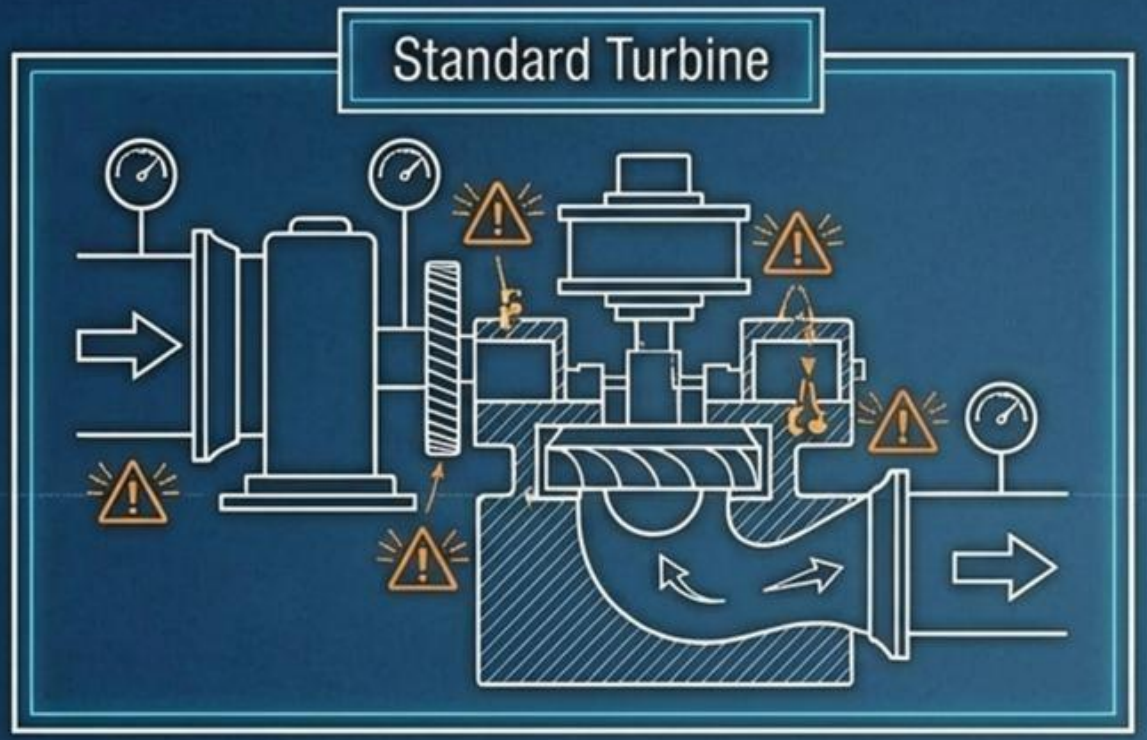
- Won international wind competition awards.
- Developed data-driven plug-and-play strategies.
- Organised IFAC workshops and plenaries.
- Sponsored by kk-electronic and MathWorks.
- Optimised operation and management costs.
- Promoted sustainable wind energy control.

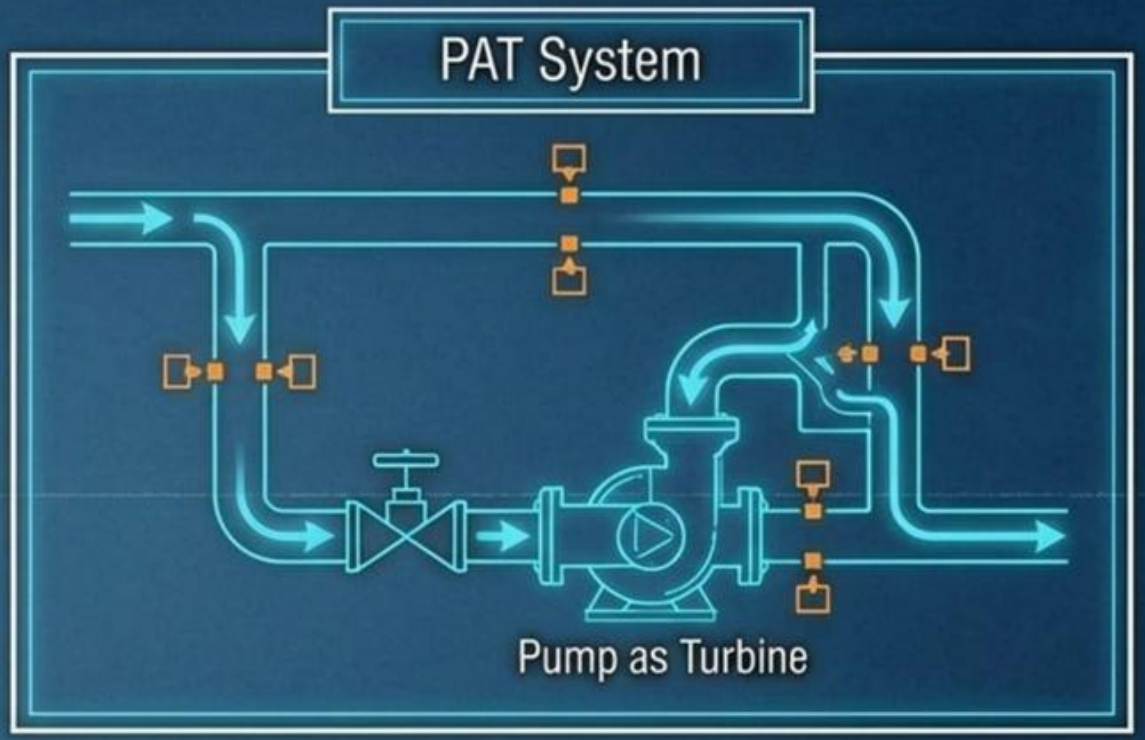
Integrating Deep Learning Methodologies

- Integrated deep neural network architectures.
- Partnered with Belt Road Alliance.
- Addressed complex floating offshore farms.
- Modelled wind and wake interactions.
- Applied interpretable machine learning ensembles.
- Enhanced fault detection accuracy significantly.



Innovations in Hydroelectric Water Distribution





- Modelled smart water distribution networks.
- Designed cheaper hydraulic turbine alternatives.
- Limited excessive network pressure effectively.
- Analysed parallel pumps as turbines.
- Managed challenging system control issues.
- Cooperated with Civil Engineering Groups.

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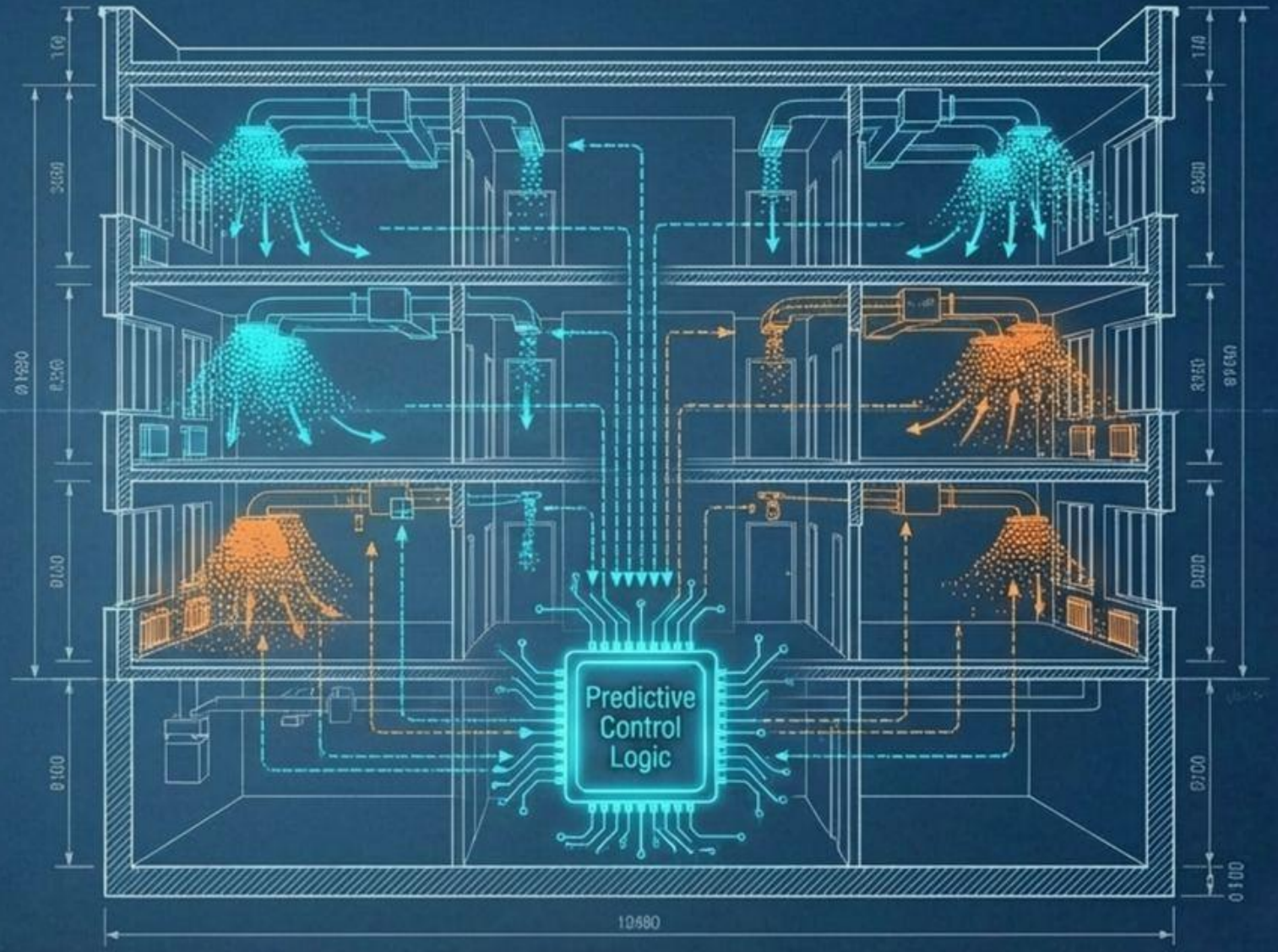
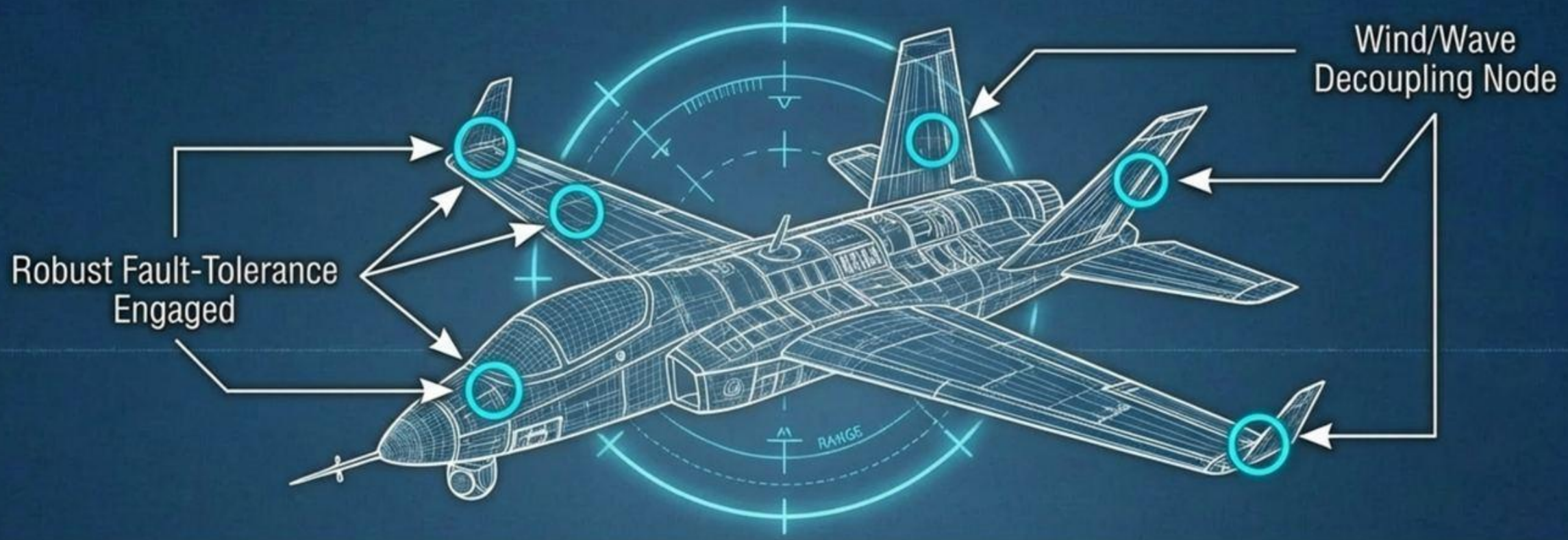
Advanced Thermal Unit Predictive Control

- Modelled thermal unit plant dynamics.
- Applied fuzzy and predictive controls.
- Integrated advanced neural network models.
- Developed smart building energy applications.
- Collaborated with Coventry and Izmir.
- Targeted Horizon Europe research calls.



Ensuring Aerospace Fault Tolerance



- Validated aircraft and satellite strategies.
- Assessed fault diagnosis operational performance.
- Decoupled wind and wave disturbances.
- Cooperated with UniBO Aerospace Department.
- Utilised LAURA technological flight demonstrator.
- Designed robust fault tolerance schemes.

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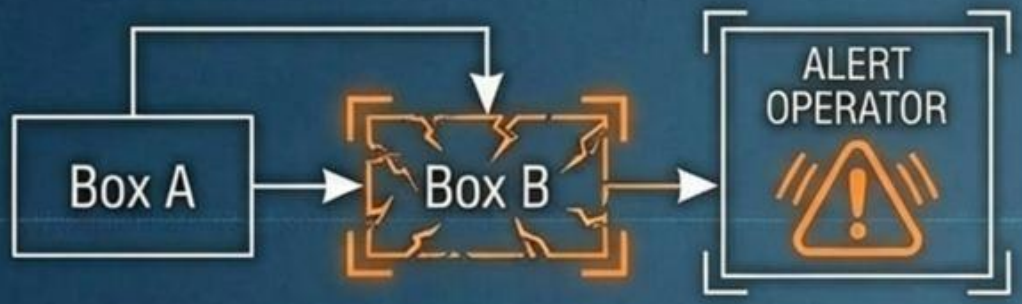
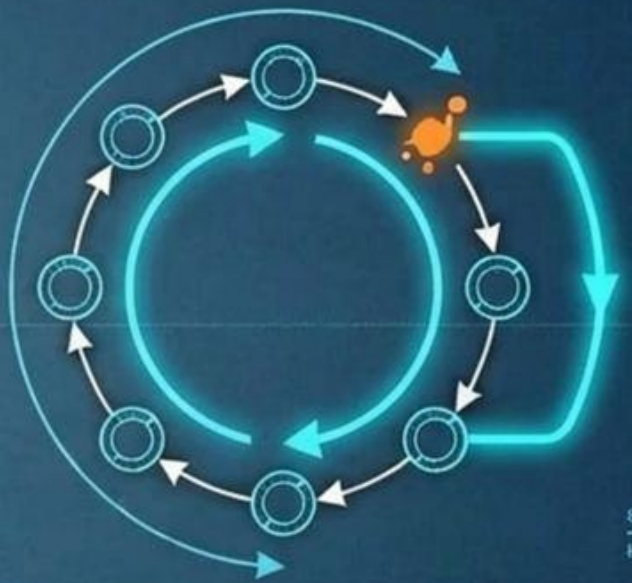
The Resilient Control Framework

Traditional Diagnosis



Simani's Resilient Control



- Co-designed fault diagnosis and control.
- Reduced operations and maintenance costs.
- Applied resilient models to reality.
- Merged identification with fault tolerance.
- Created reliable and viable procedures.
- Ensured sustainable dynamic system operation.

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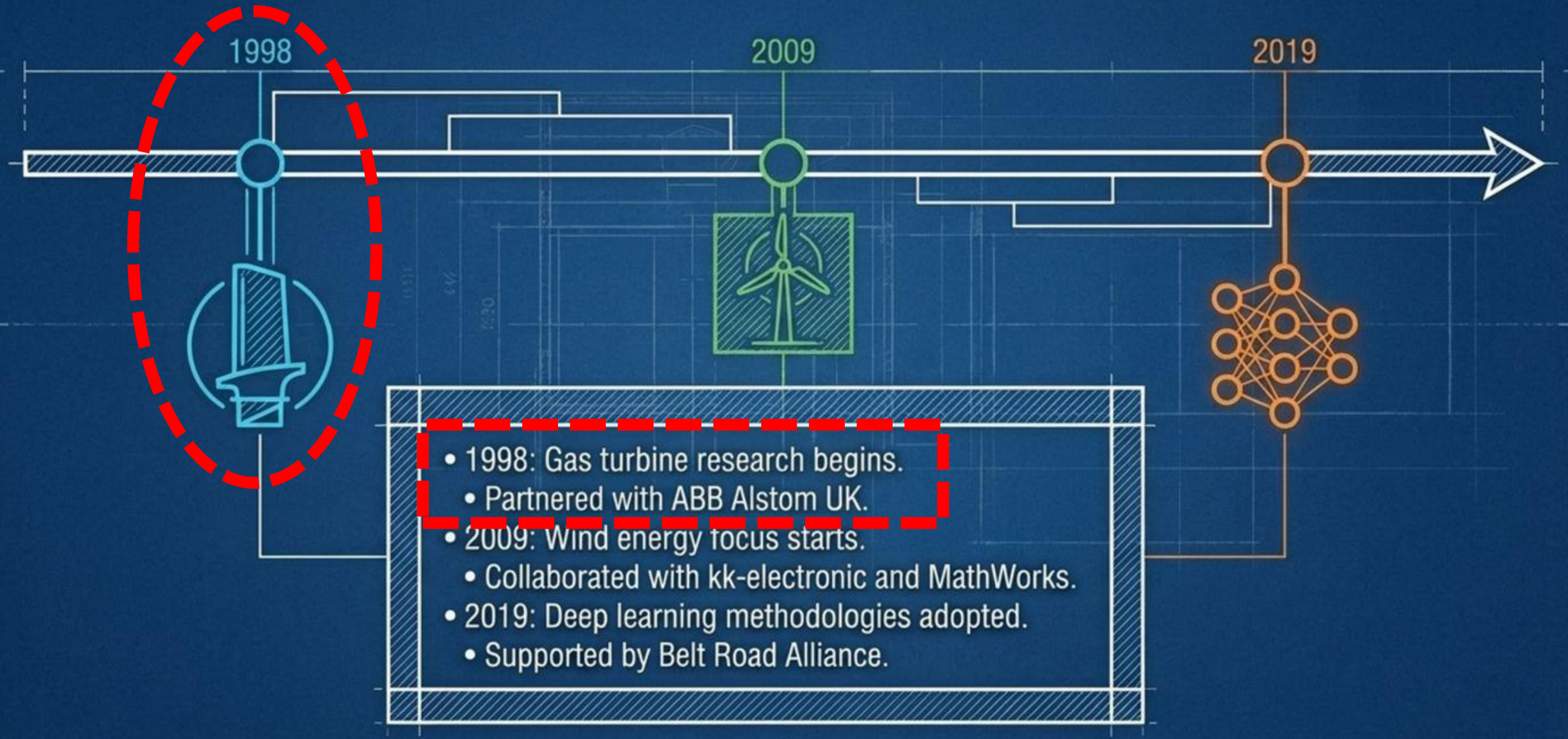
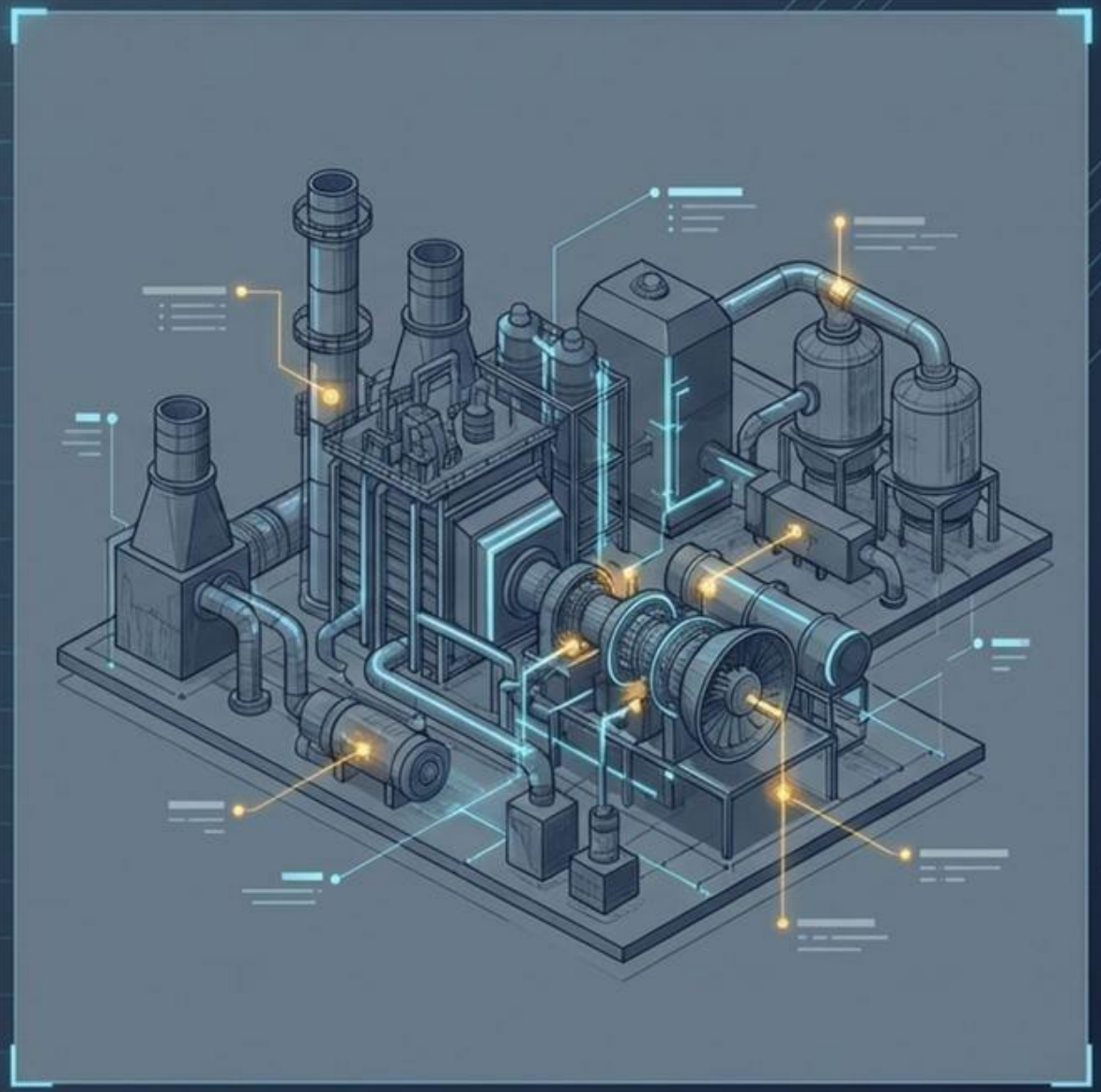
THREE DECADES OF ENGINEERING INNOVATION



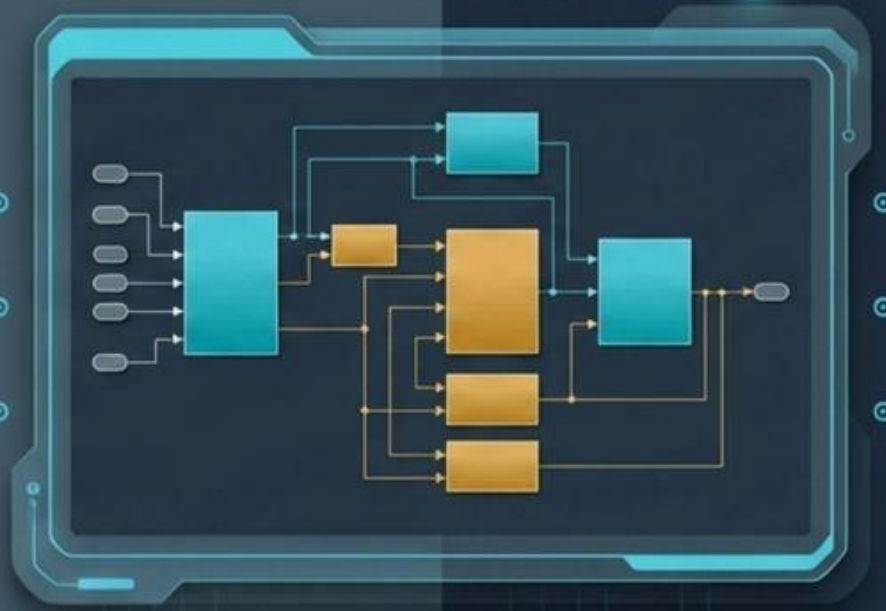
- Proposed by **ABB Alstom UK**
- Initiated in **1999**
- Led alongside **UK academic partners**
- Realistic **industrial application** focus
- Develop effective **diagnostic tools**
- Enable **predictive maintenance** strategies



High-fidelity digital twin

Matlab and Simulink environment

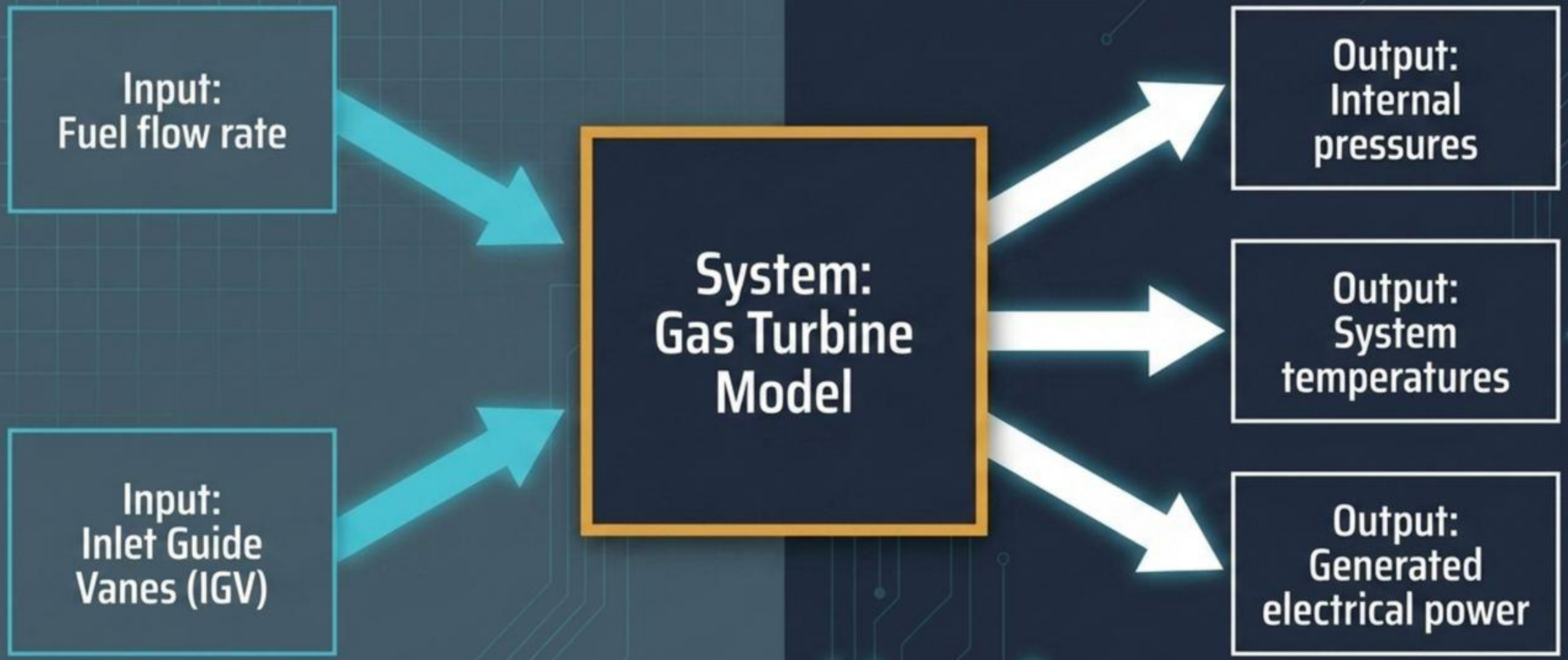
Initialised with fault conditions



Dynamic system simulation

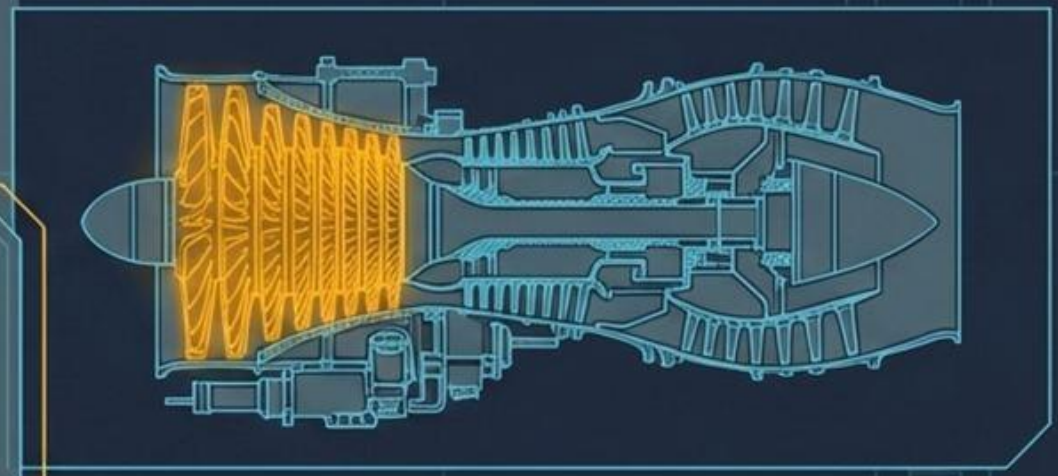
Realistic operational scenarios

Validating diagnostic methodologies


Input:
Fuel flow rate
Input:
Inlet Guide
Vanes (IGV)
System:
Gas Turbine
Model
Output:
Internal
pressures
Output:
System
temperatures
Output:
Generated
electrical power

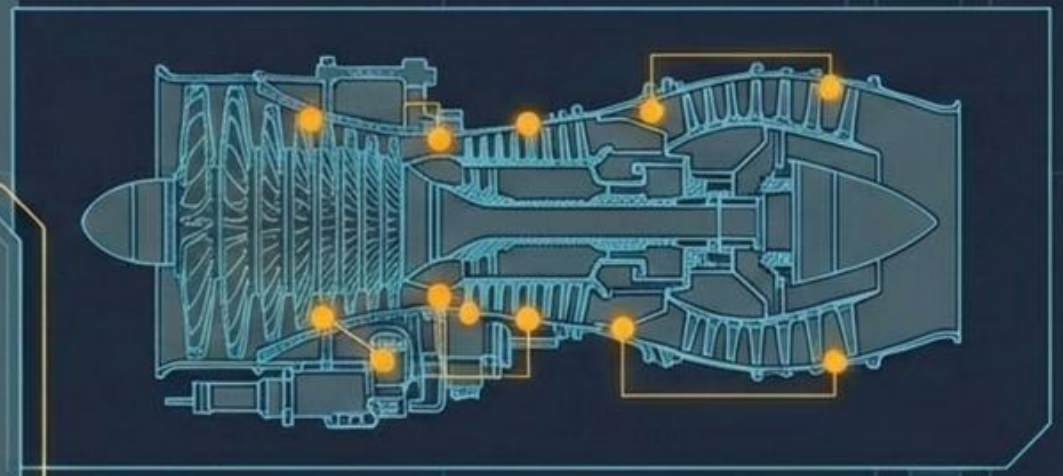
Incipient fault detection

- Simulated compressor contamination
- Slowly developing performance degradation
- Altered pressure output variables
- Detected during earlier occurrences
- Requires predictive maintenance intervention



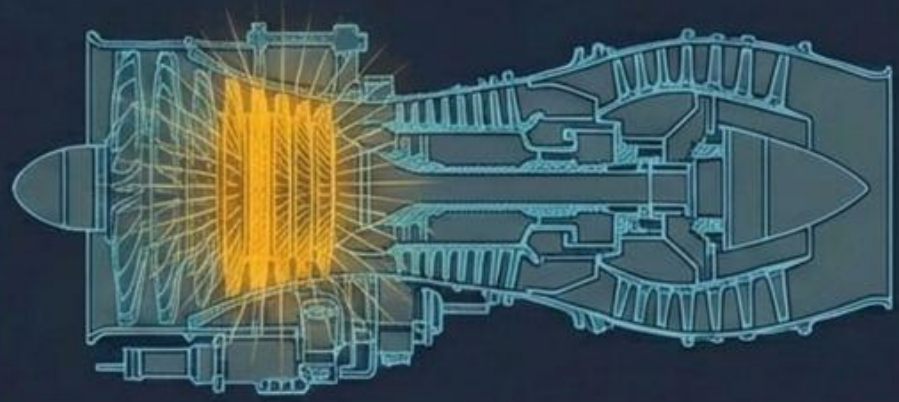
Sensor reliability assessment

- Thermocouple wear and faults
- Temperature reading deviations
- Corrupted output variables
- Immediate detection requirement
- Prevents cascading system failures



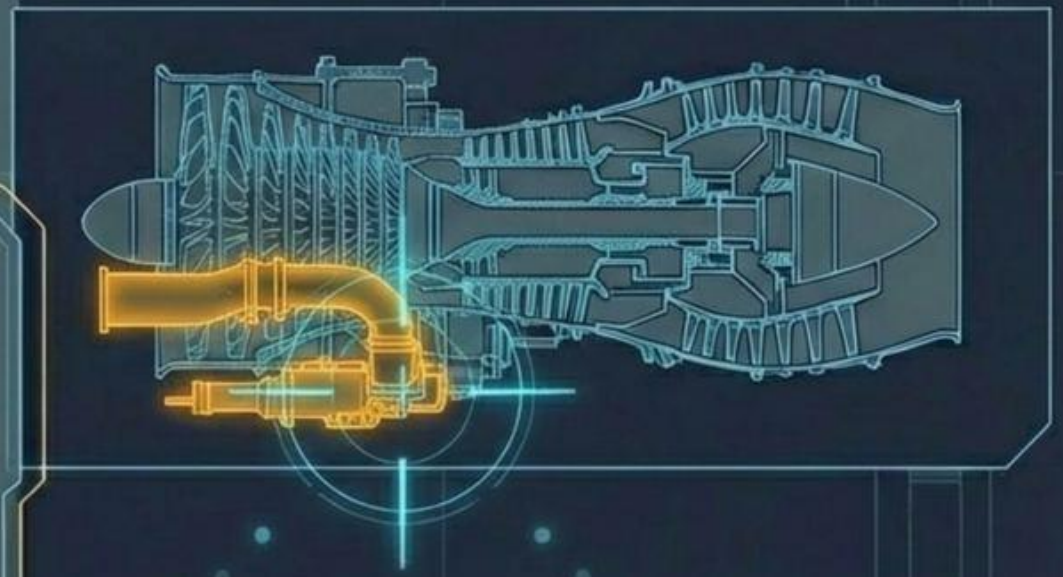
Mechanical integrity monitoring

- High-Pressure turbine seal damage
- Internal leakage simulation
- Gradual power output loss
- Critical for safe operations
- Reduces overall thermodynamic efficiency

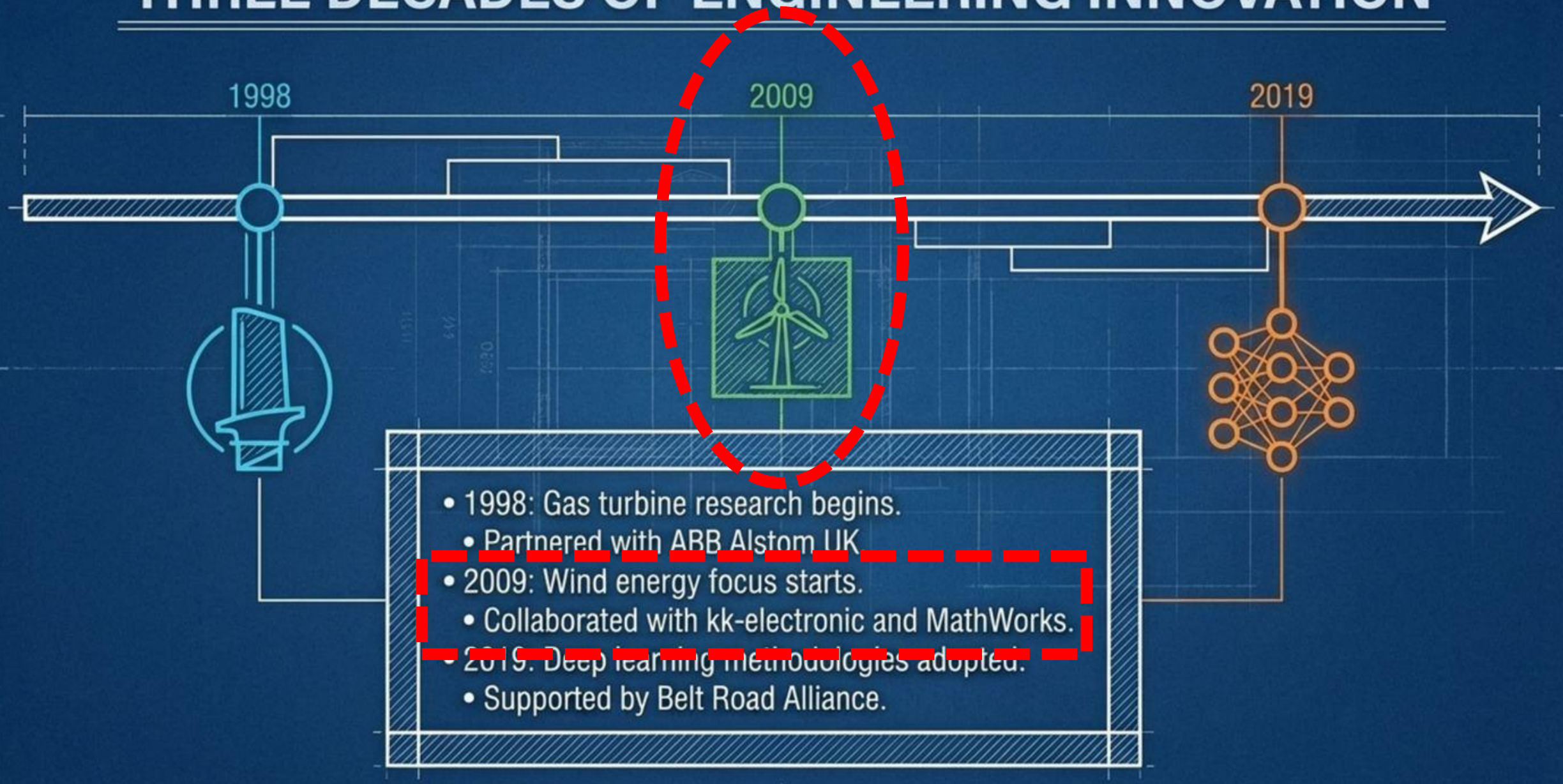


Actuator subsystem diagnostics

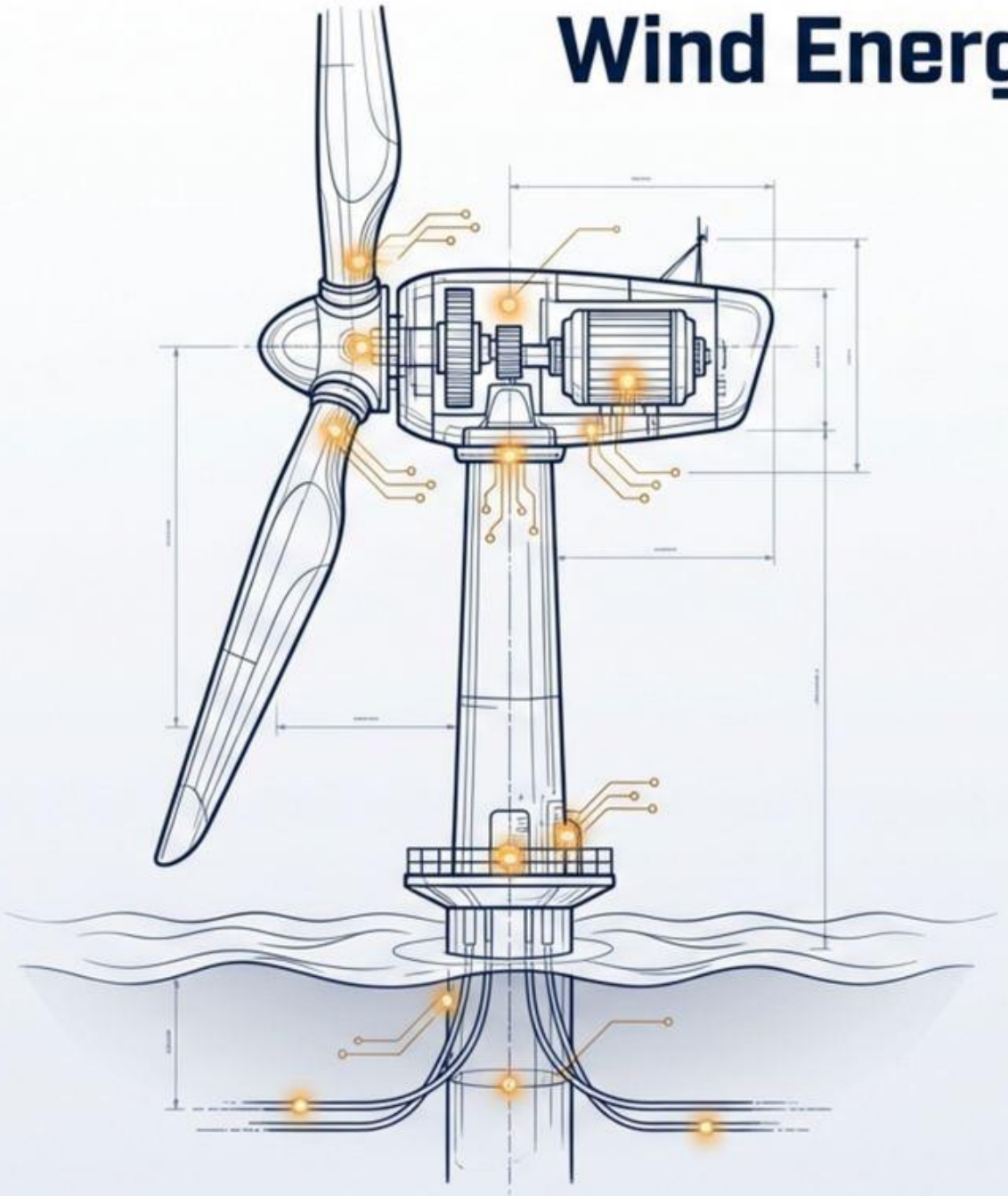
- Fuel valve friction increases
- Mechanical wear and tear
- Input flow rate inconsistencies
- Impairs responsive engine control
- Triggers automated isolation protocols



THREE DECADES OF ENGINEERING INNOVATION



Wind Energy Motivations



Offshore maintenance cost reduction.

Power generation reliability enhancement.

International Awards

IFAC SafeProcess 2012 Award winner.

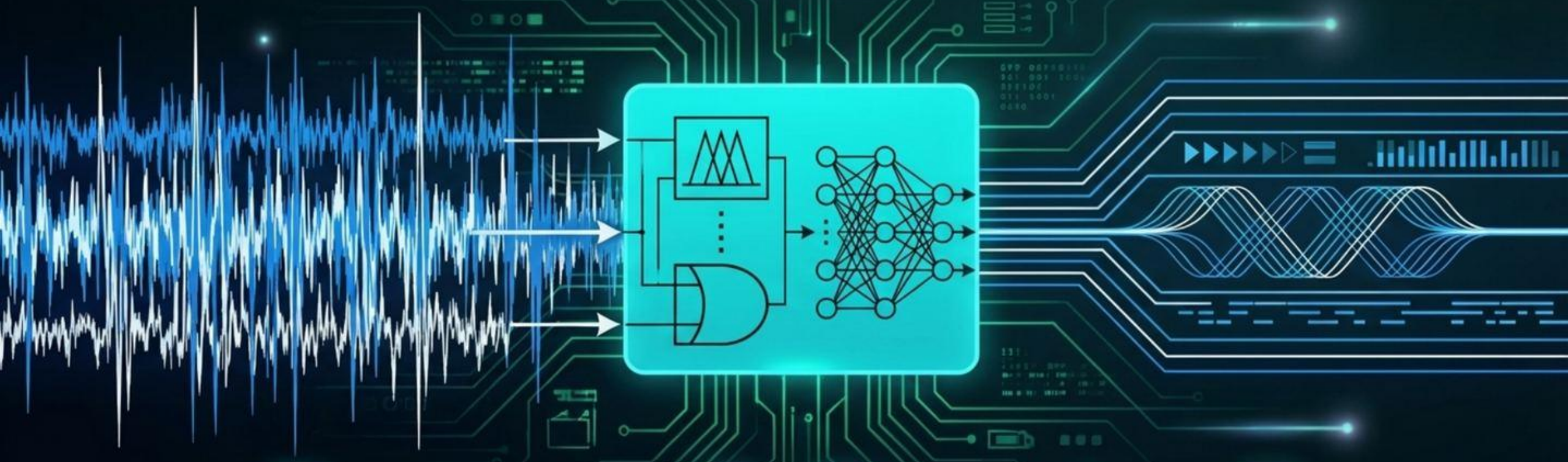
3rd prize in Mexico City.

IFAC Benchmarks

KK-electronic (DK) cooperation.

Complex wind turbine models.

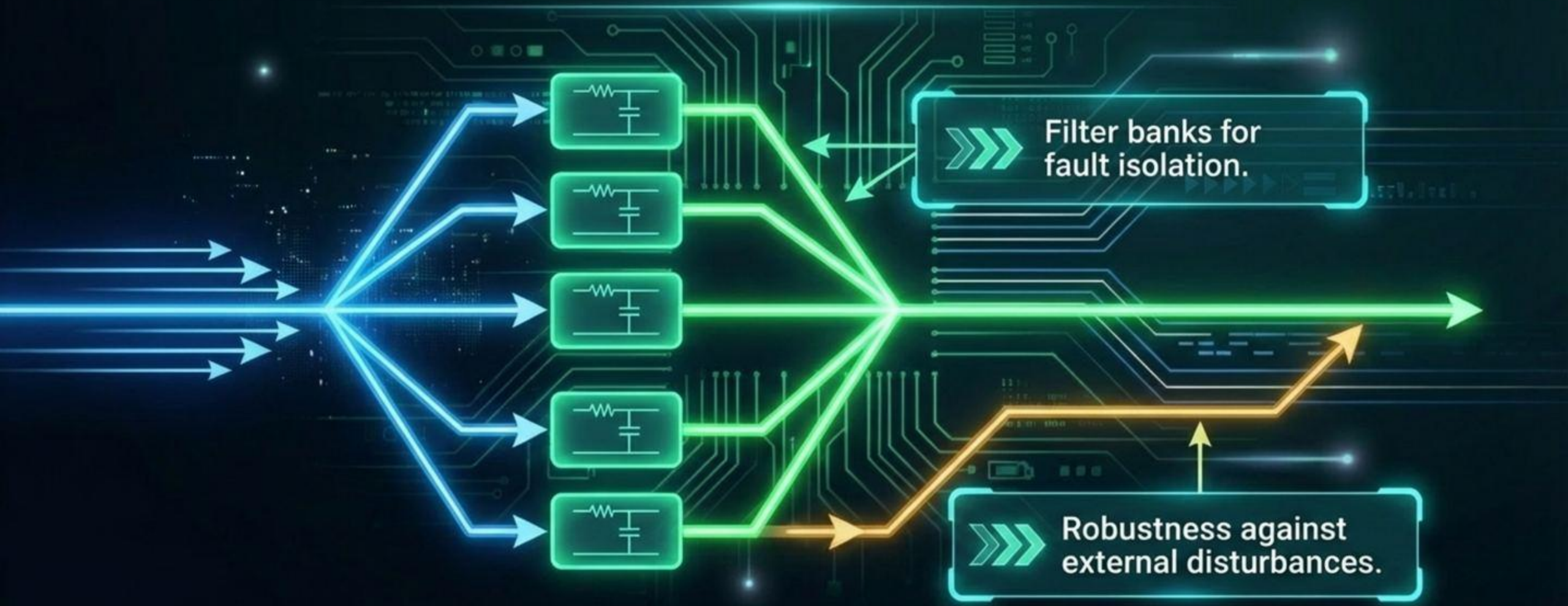
Fuzzy Model Identification



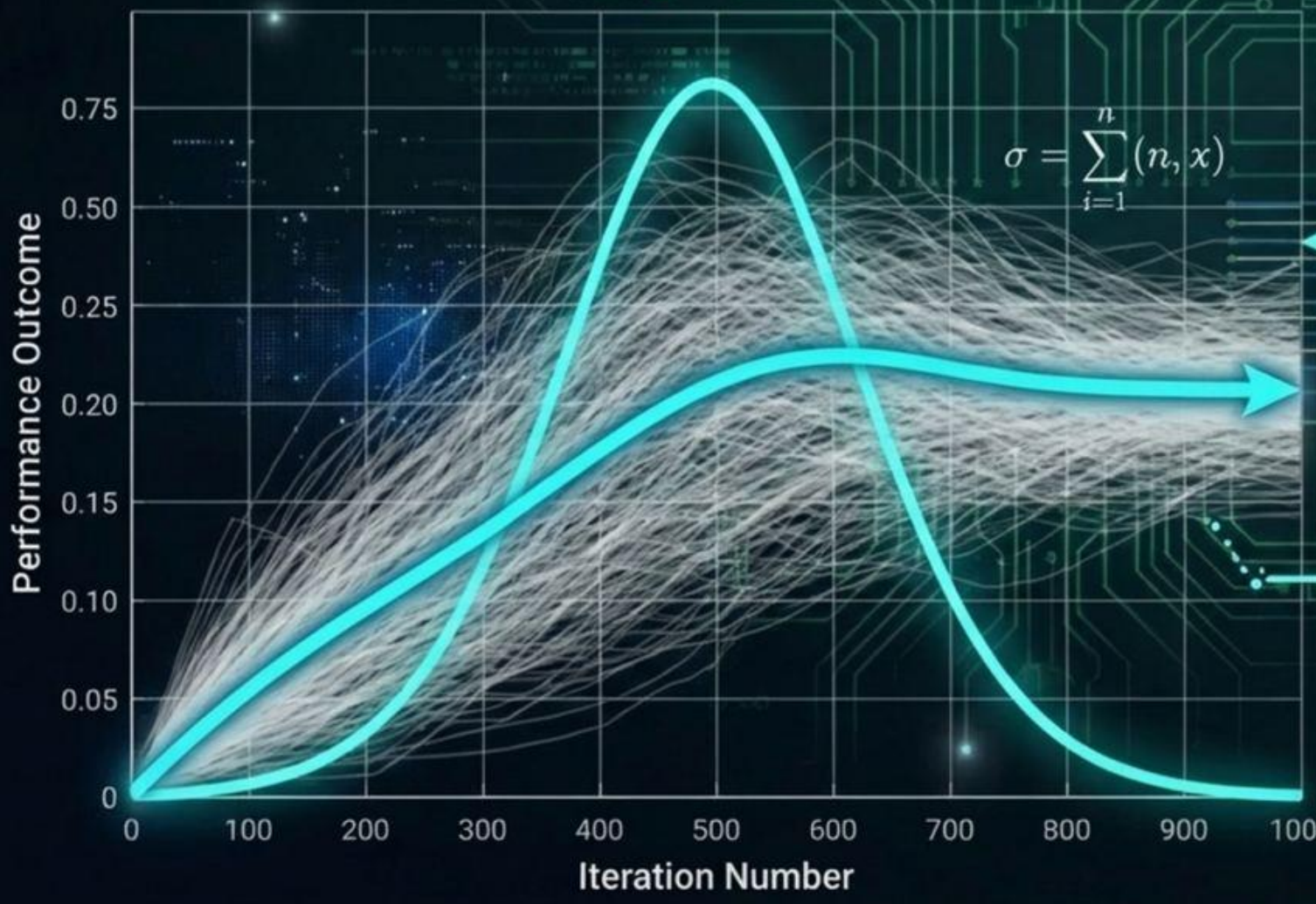
Identification from noisy industrial data.

Enhanced bank design.

Residual Generation



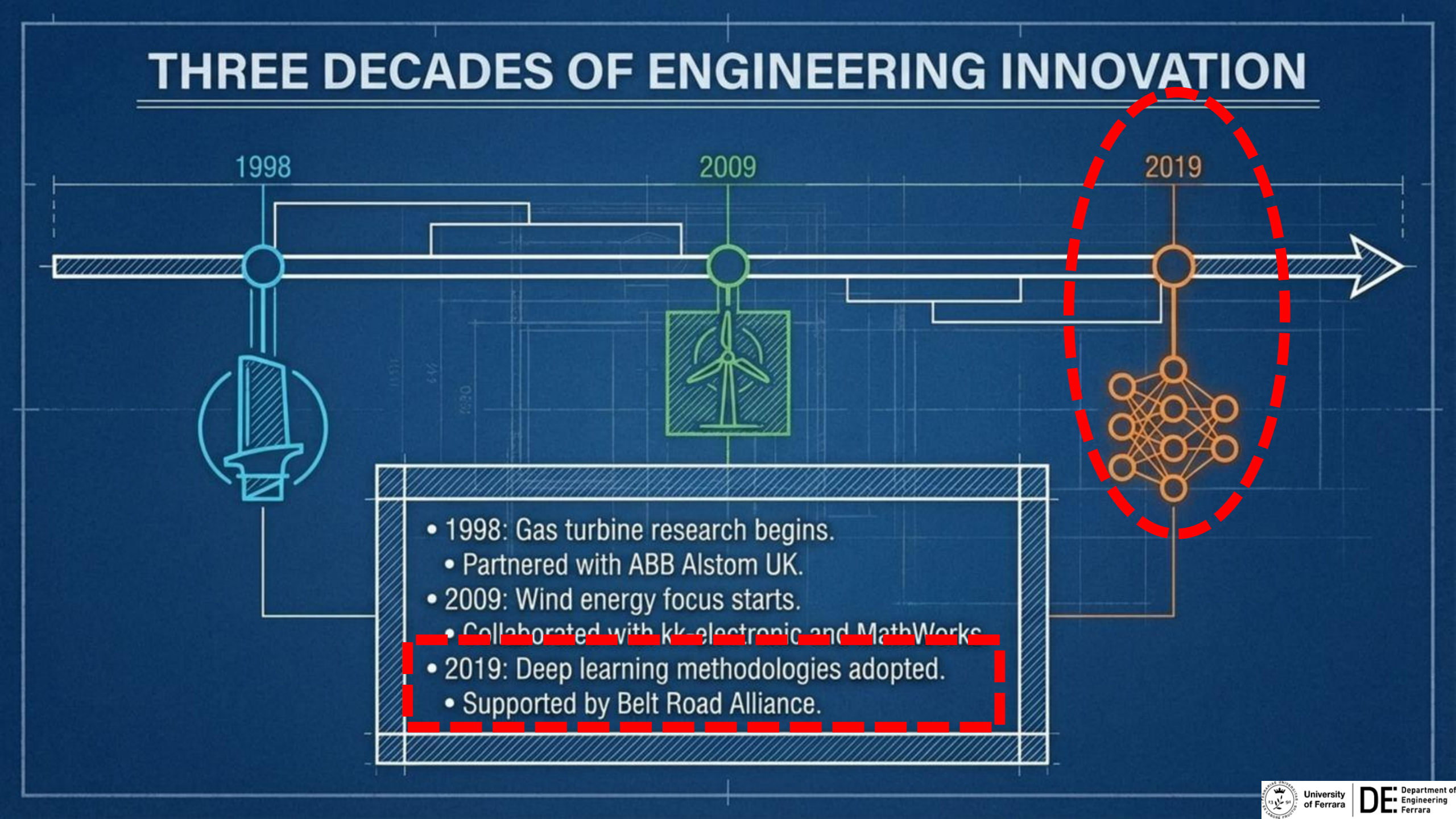
Monte-Carlo Analysis



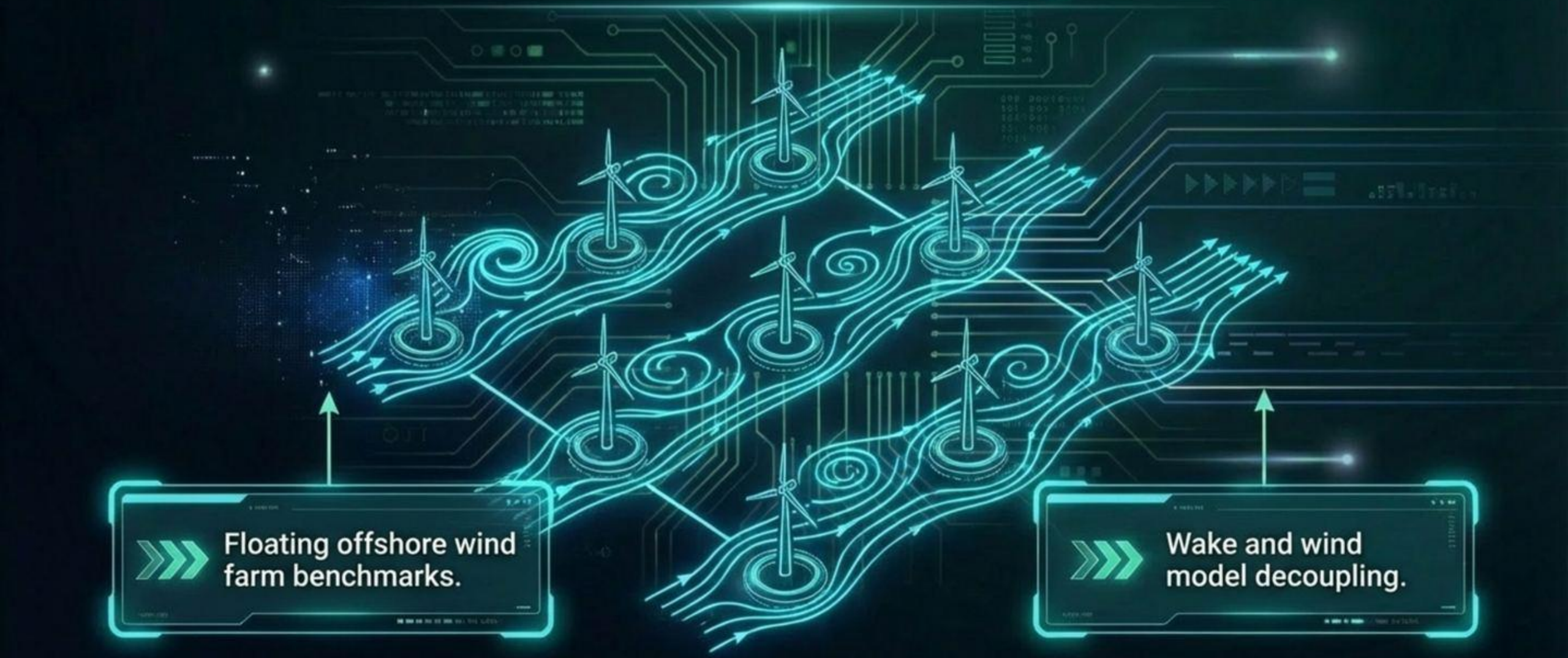
Performance optimisation via statistical trials.

Scheme robustness verification.

THREE DECADES OF ENGINEERING INNOVATION



Recent Offshore Developments



Floating offshore wind farm benchmarks.

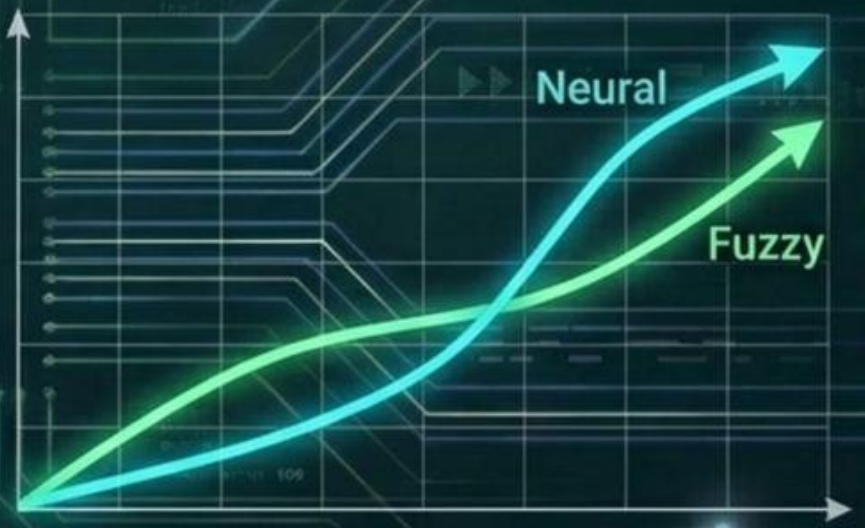
Wake and wind model decoupling.

Test-Rig Applications

Hardware-In-The-Loop

Hardware-In-The-Loop assessment.

Fuzzy vs Neural Networks



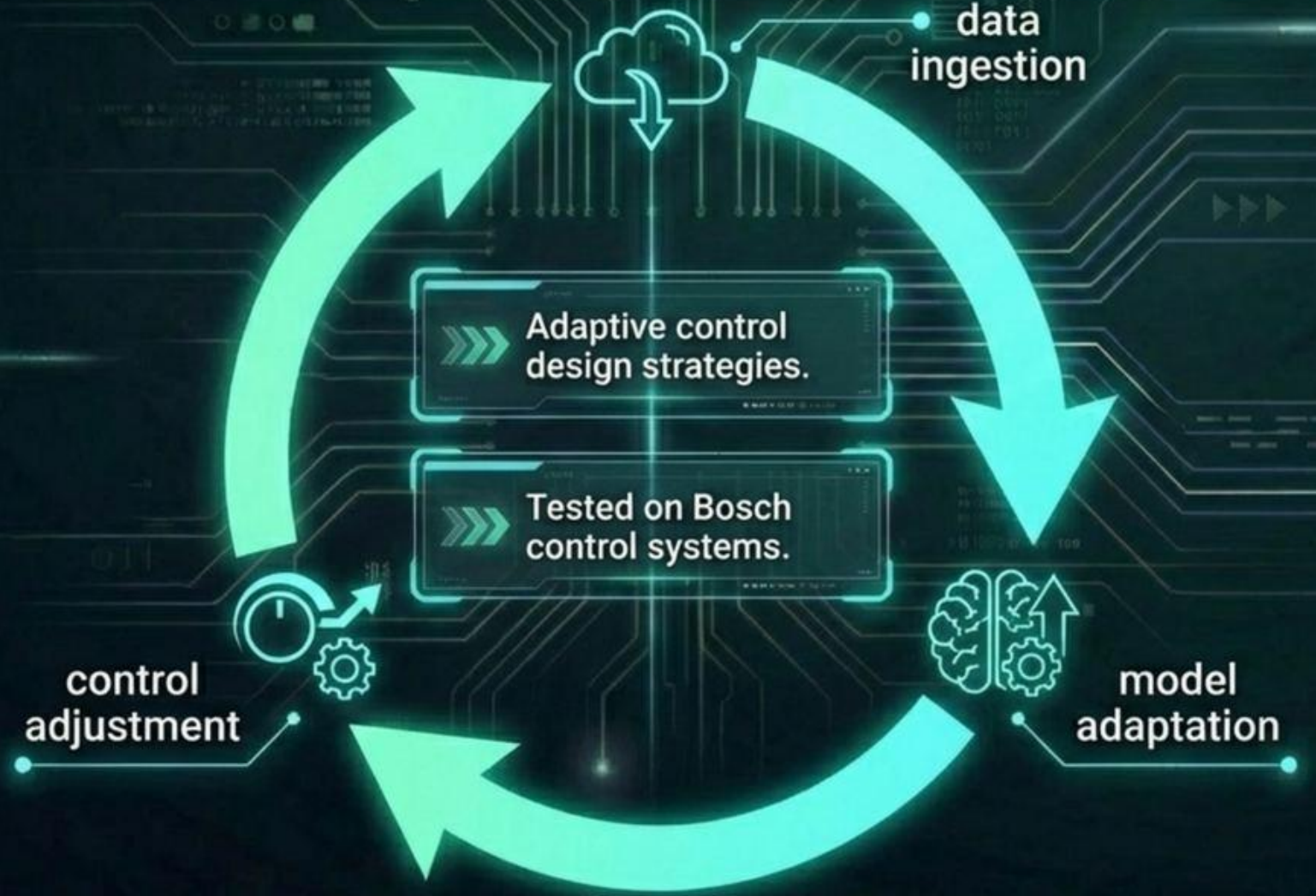
Fuzzy vs Neural Networks comparison.

Diesel Engine Research

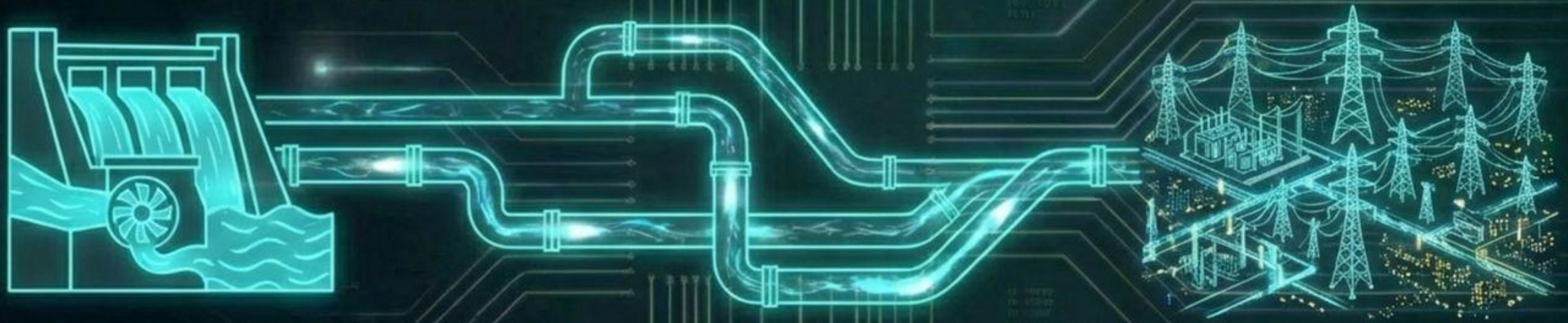
Automatic brake dynamometer tuning.

VM Motors (FCA) technology transfer.

Online Identification



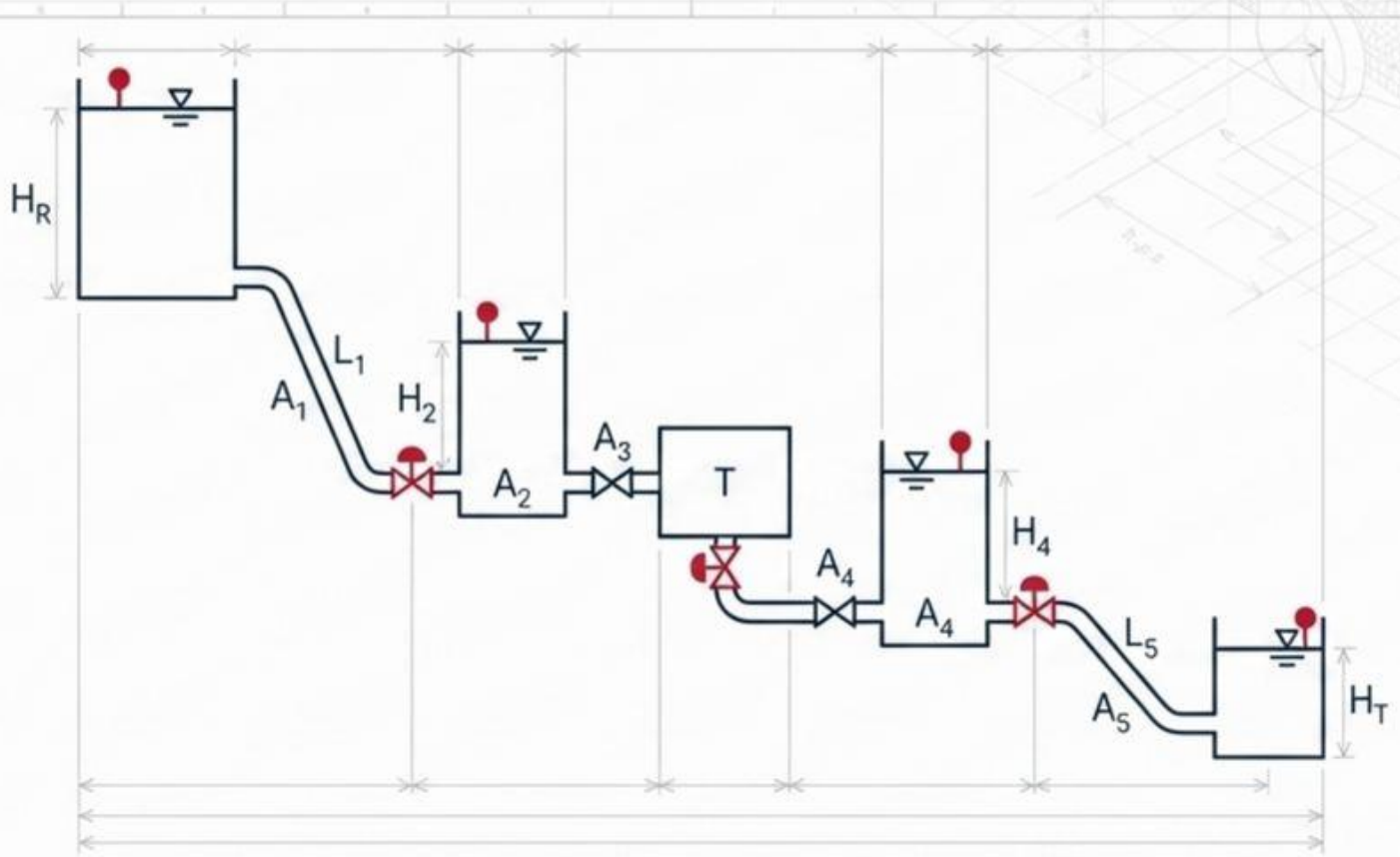
Hydroelectric Systems



- Modelling grid-connected power plants.
- Cooperation with Hydraulic Departments.

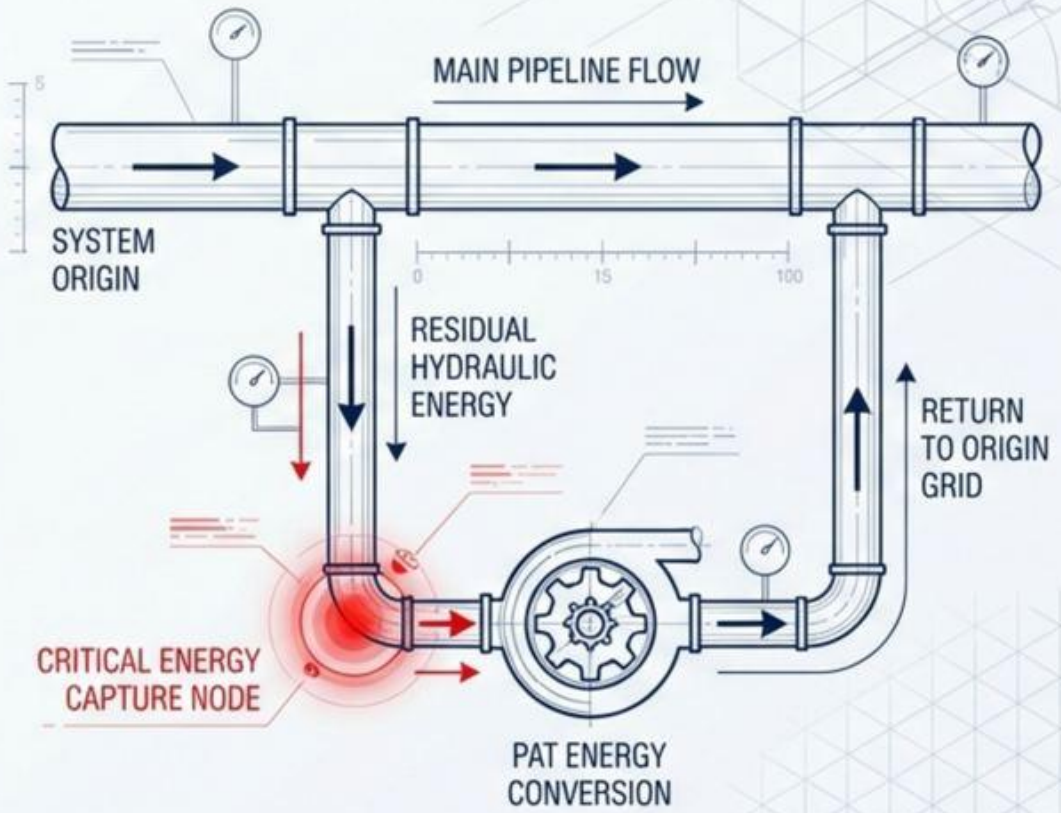
Hydroelectric Scheme

- Grid-connected hydroelectric systems.
- Reservoir, penstock, turbine, tail.
- Modelling, FDI, and FTC.
- Fault-tolerant control results.



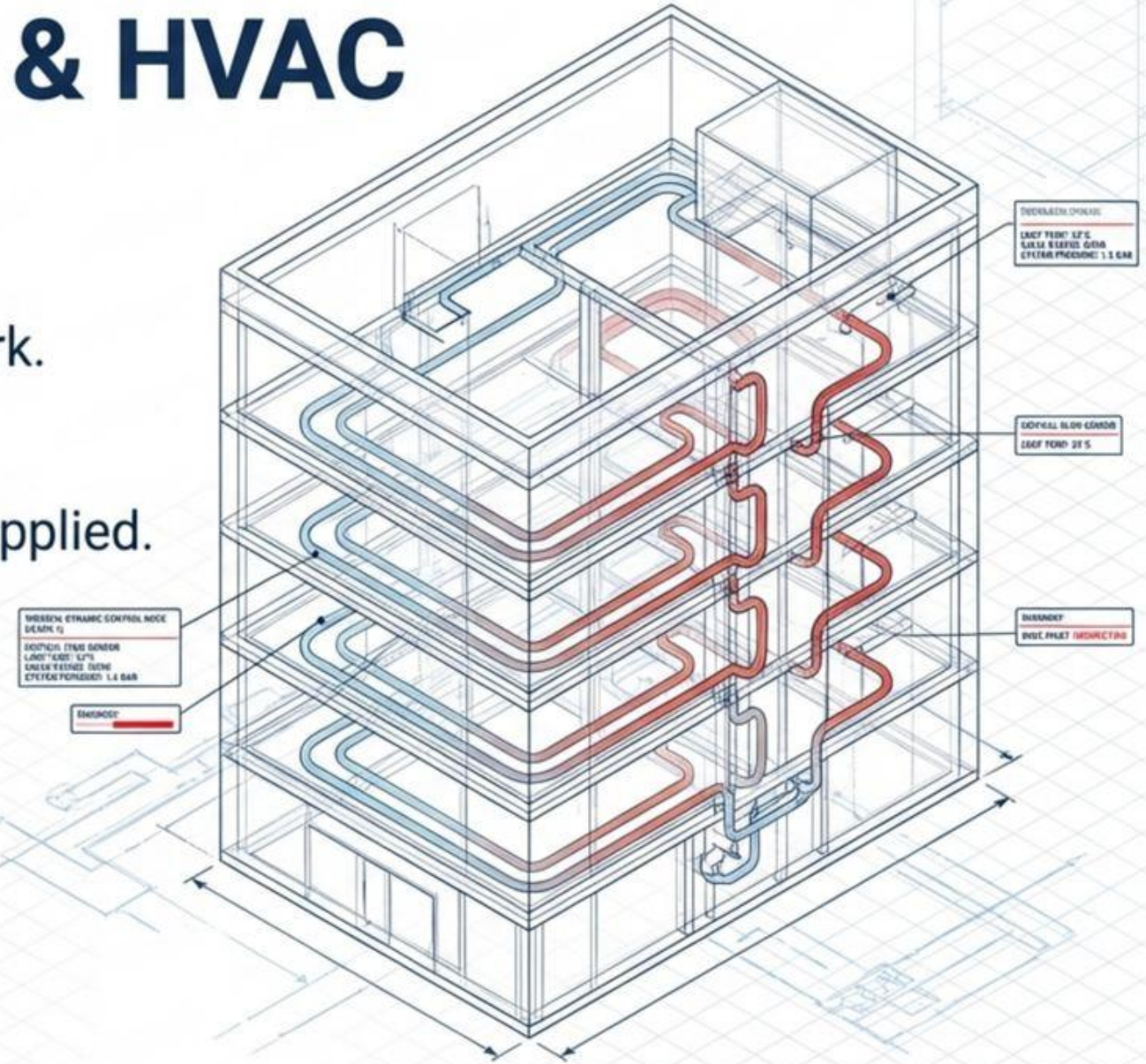
PUMPS AS TURBINES

- Pumps As Turbines (PAT).
- Exploiting residual hydraulic energy.
- Pressure control challenging issues.
- Extension to PAT networks.



THERMAL UNITS & HVAC

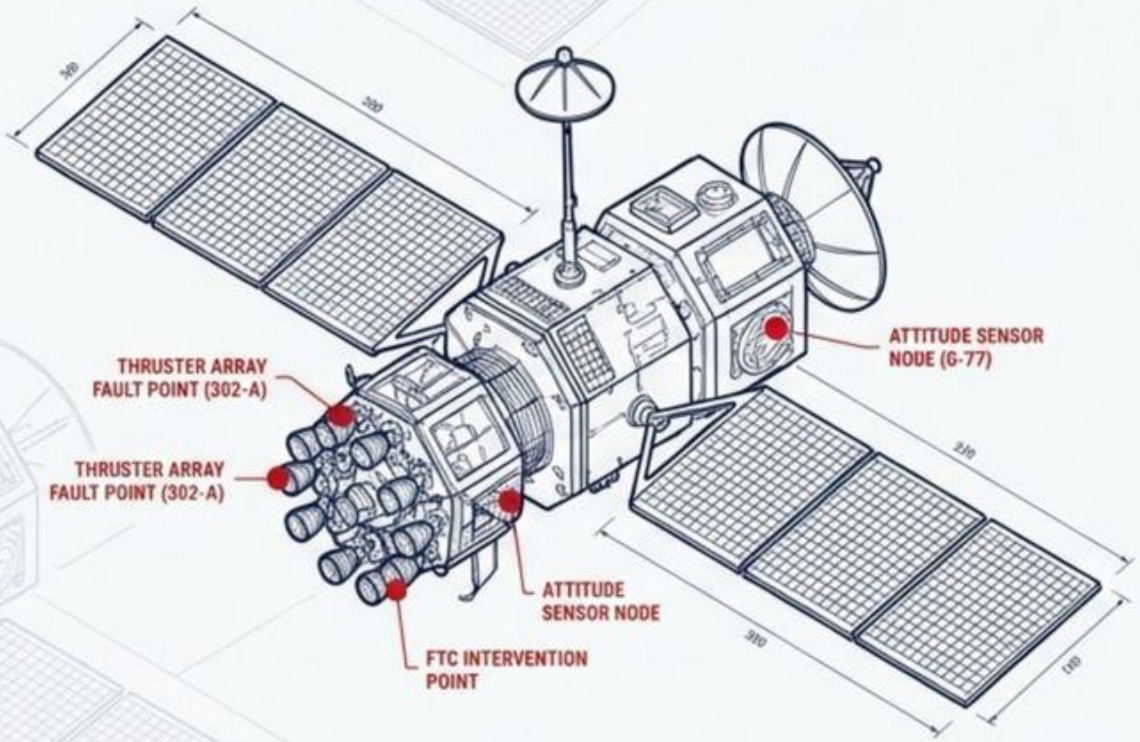
- Thermal units and HVAC.
- Smart building modelling framework.
- Complex plant model extensions.
- Advanced control methodologies applied.

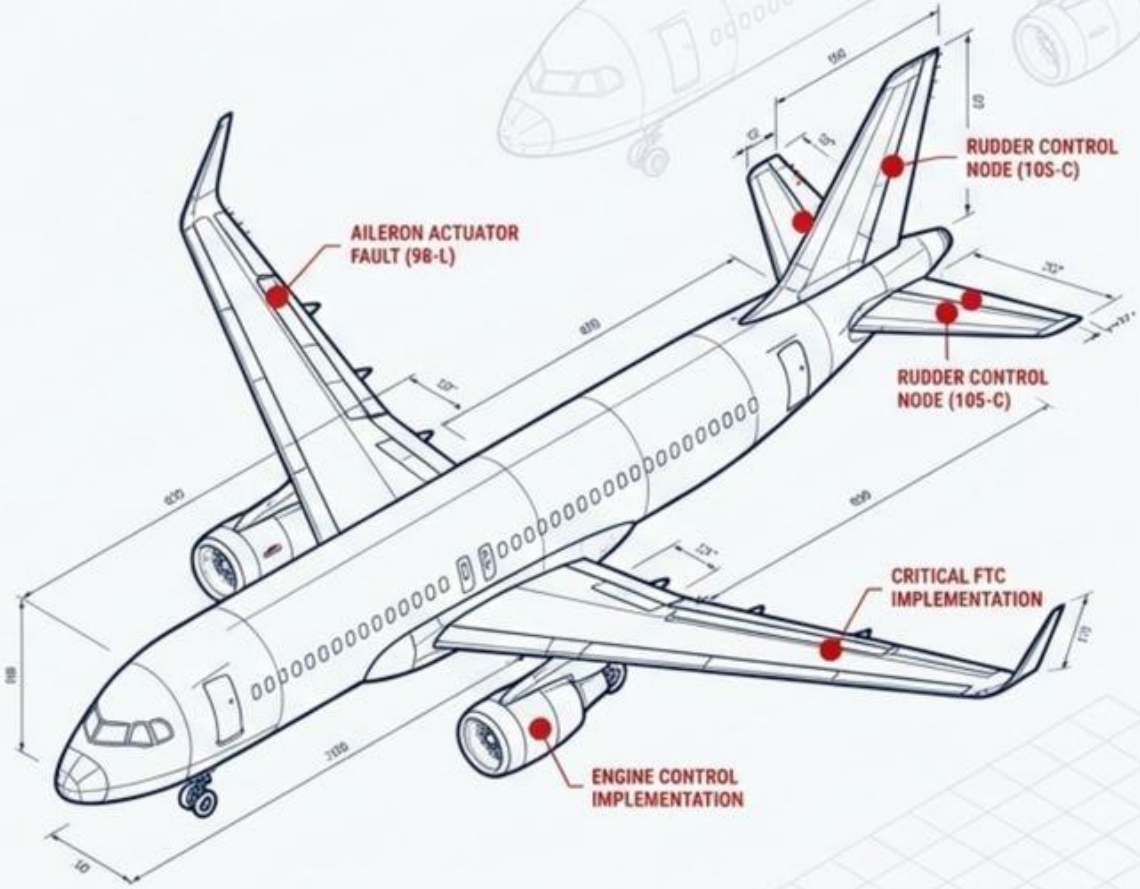


INTERNATIONAL HVAC PROJECTS

- International HVAC research projects.
- Coventry University (UK) collaboration.
- Izmir University (Turkey) partnership.
- Global modelling standardisation.

AEROSPACE SYSTEMS





Aerospace systems control research.

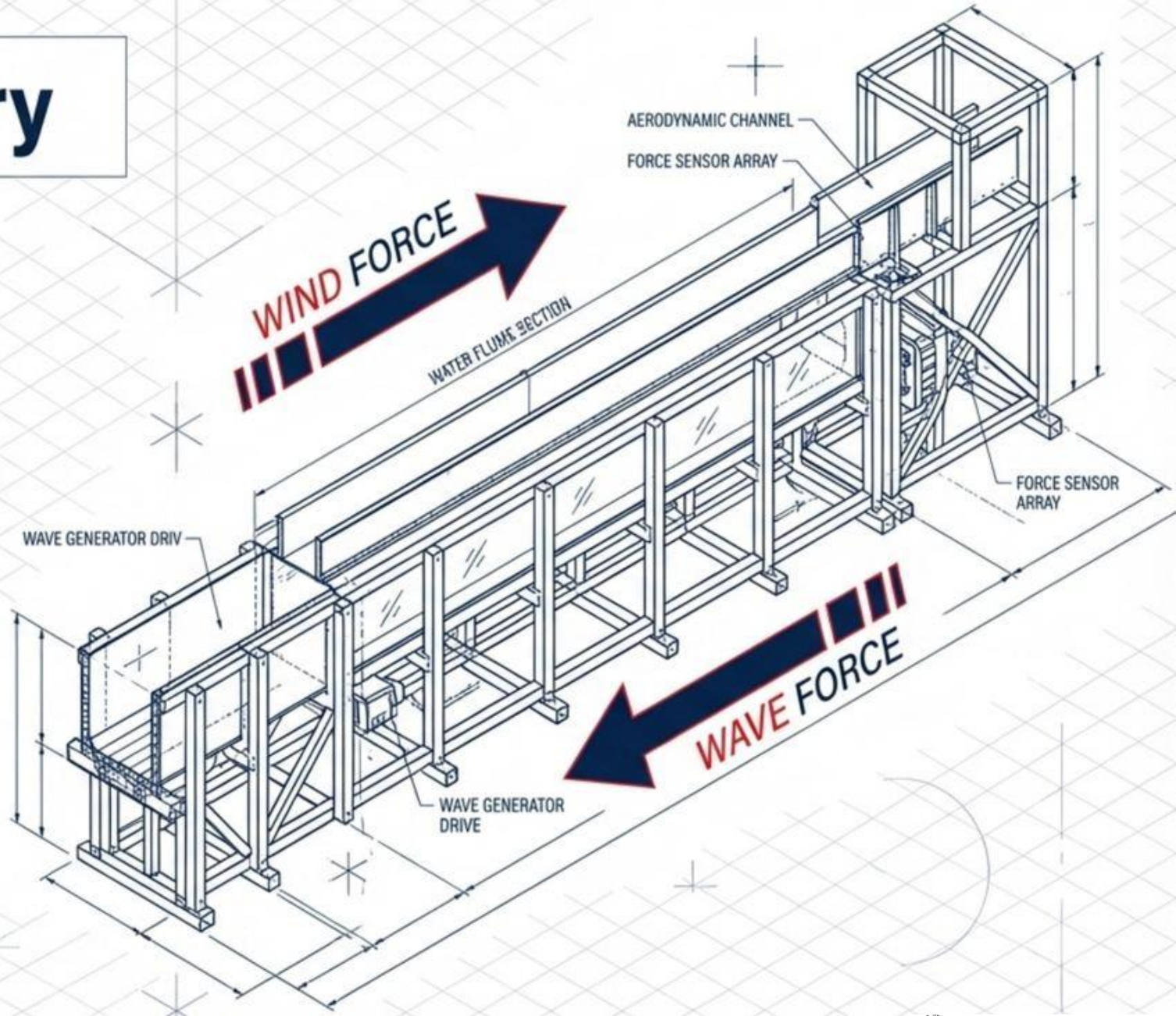
FDI/FTC for satellites.

Aircraft diagnostic control applications.

Aerospace Dept. (UniBO) cooperation.

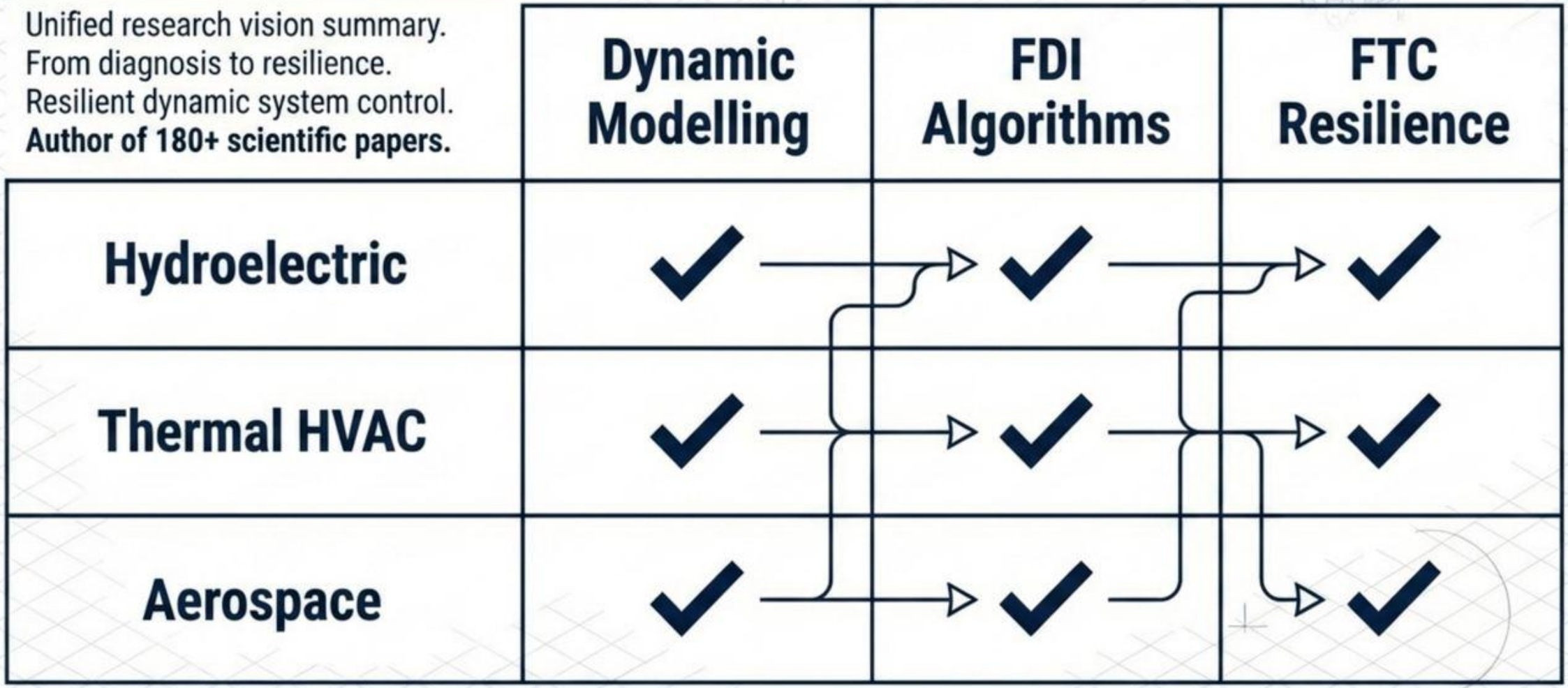
LAURA Laboratory

- LAURA Laboratory research facility.
- Aerospace technological demonstrator setup.
- Wind and wave decoupling.
- Advanced environmental dynamic studies.

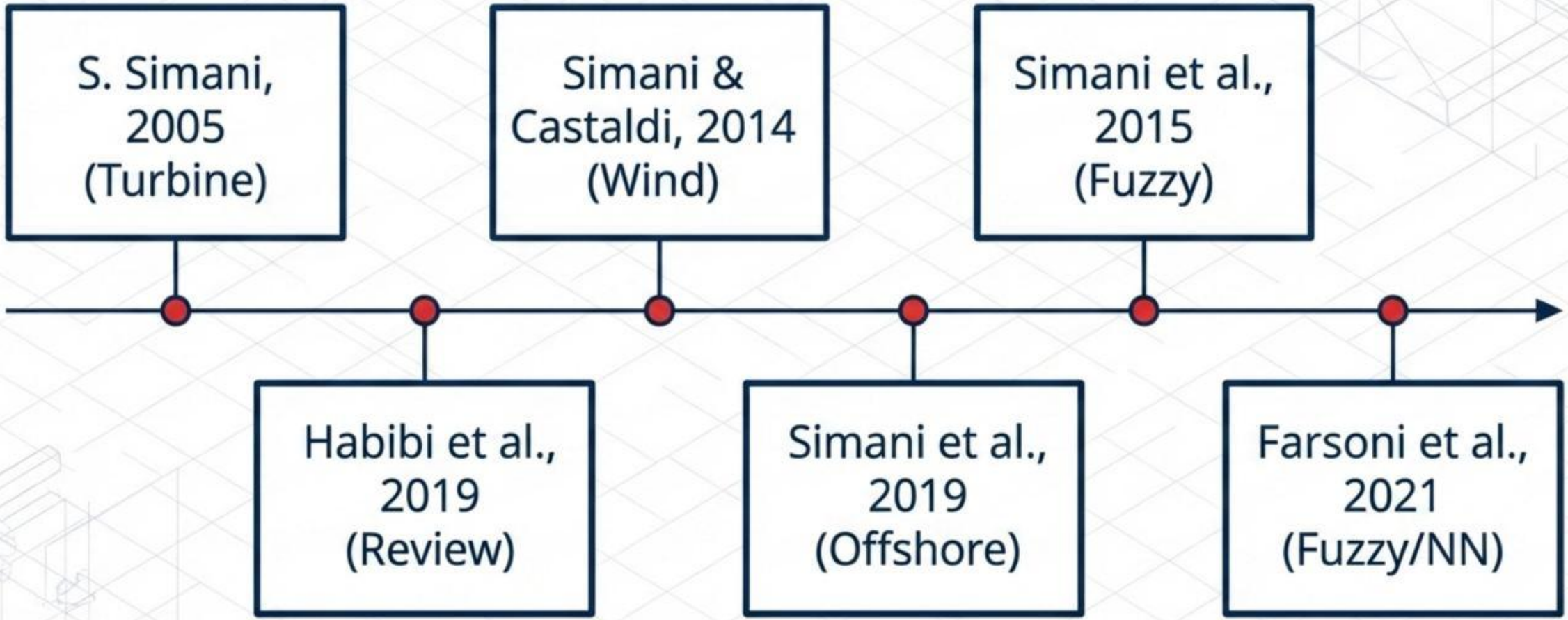


Vision Summary

Unified research vision summary.
From diagnosis to resilience.
Resilient dynamic system control.
Author of 180+ scientific papers.



Selected References I



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1. **S. Simani**, "Identification and Fault Diagnosis of a Simulated Model of an Industrial Gas Turbine," *IEEE Transactions on Industrial Informatics*, vol. 1, no. 3, pp. 202–216, 2005.
2. **S. Simani** and **P. Castaldi**, "Active Actuator Fault-Tolerant Control of a Wind Turbine Benchmark Model," *International Journal of Robust and Nonlinear Control*, vol. 24, no. 8–9, pp. 1283–1303, 2014.
3. **S. Simani**, **S. Farsoni**, and **P. Castaldi**, "Fault Diagnosis of a Wind Turbine Benchmark via Identified Fuzzy Models," *IEEE Transactions on Industrial Electronics*, vol. 62, no. 6, pp. 3775–3782, 2015.
4. **H. Habibi**, **I. Howard**, and **S. Simani**, "Reliability Improvement of Wind Turbine Power Generation Using Model-Based Fault Detection and Fault Tolerant Control: A Review," *Renewable Energy*, vol. 135, pp. 877–896, 2019.
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8. **R. Johnson, J. J. Zhang, F. K. Manchu,** and **S. Simani,** "Advancing Fault Detection in Floating Offshore Wind Turbines: An Interpretable Machine Learning Ensemble Approach," *Proc. 6th International Conference on Control and Fault-Tolerant Systems (SysTol)*, 2025.

9. **M. Benini, M. Bonfè, P. Castaldi, W. Geri,** and **S. Simani,** "Design and Analysis of Robust Fault Diagnosis Schemes for a Simulated Aircraft Model," *Journal of Control Science and Engineering*, vol. 2008, Article ID 274313, 2008.

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12. **S. Simani**, **S. Farsoni**, and **P. Castaldi**, "Application of Data-Driven Fault Diagnosis Design Techniques to a Wind Turbine Test-Rig," in *Intelligent Computing, Lecture Notes in Networks and Systems*, 2021.

13. **S. Simani** and **S. Farsoni**, "Hardware-In-The-Loop Assessment of Fuzzy and Neural Network Fault Diagnosis Schemes for a Wind Turbine Model," *IFAC-PapersOnLine*, vol. 55, no. 6, pp. 91–95, 2022.

Thank you for your attention!

Advancing fault-tolerant dynamic systems.
Over two decades of research.
Collaborations across engineering domains.

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