From conventional aero-structures of today to cyber-physical assets of tomorrow

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Artificial Intelligence for Structures

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Pythia Team

Artificial Intelligence for Structures, Prognostics & Health Management

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INTRO to Design principles

Design principles of primary aero-structures

Safe Life (1900 -1940)

Limited hours of flight
No strength degradation

Fail Safe (1940 – today)

Structure must retain the required residual strength

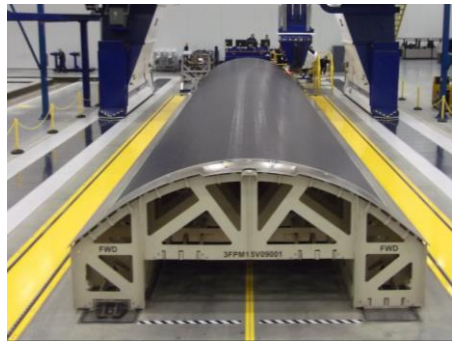
Damage Tolerance (1970 –today)

Structure sustain operational loads in the presence of damage until it is detected

CBM (2020 – 2050)

A practice that monitors in real-time
the health state of a structure
to determine when and what maintenance needs to be performed.

https://www.aero-mag.com/safran-landing-systems-landing-gear-design-manufacture-challenges/

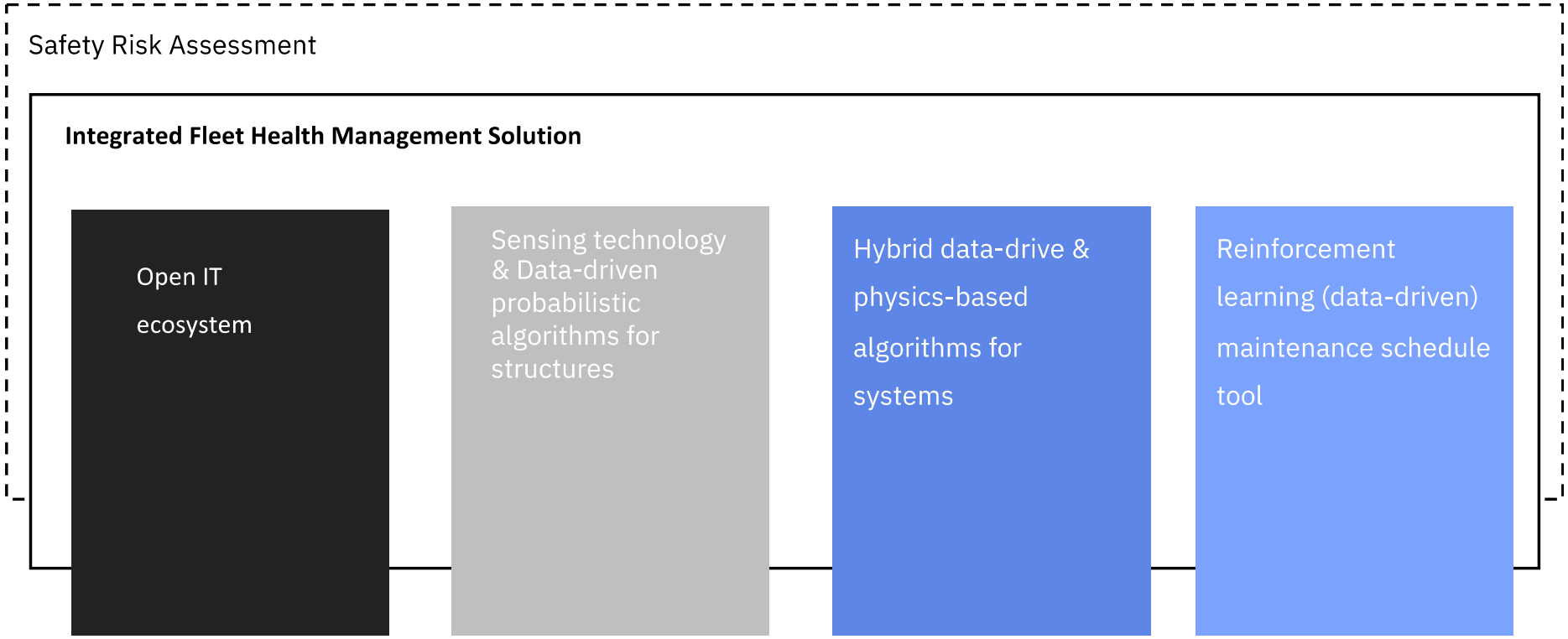


https://www.airbus.com/newsroom/news/en/2010/11

The Era of CBM

ReMAP

Real-time Condition-based Maintenance for Adaptive Aircraft Maintenance Planning



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ReMAP

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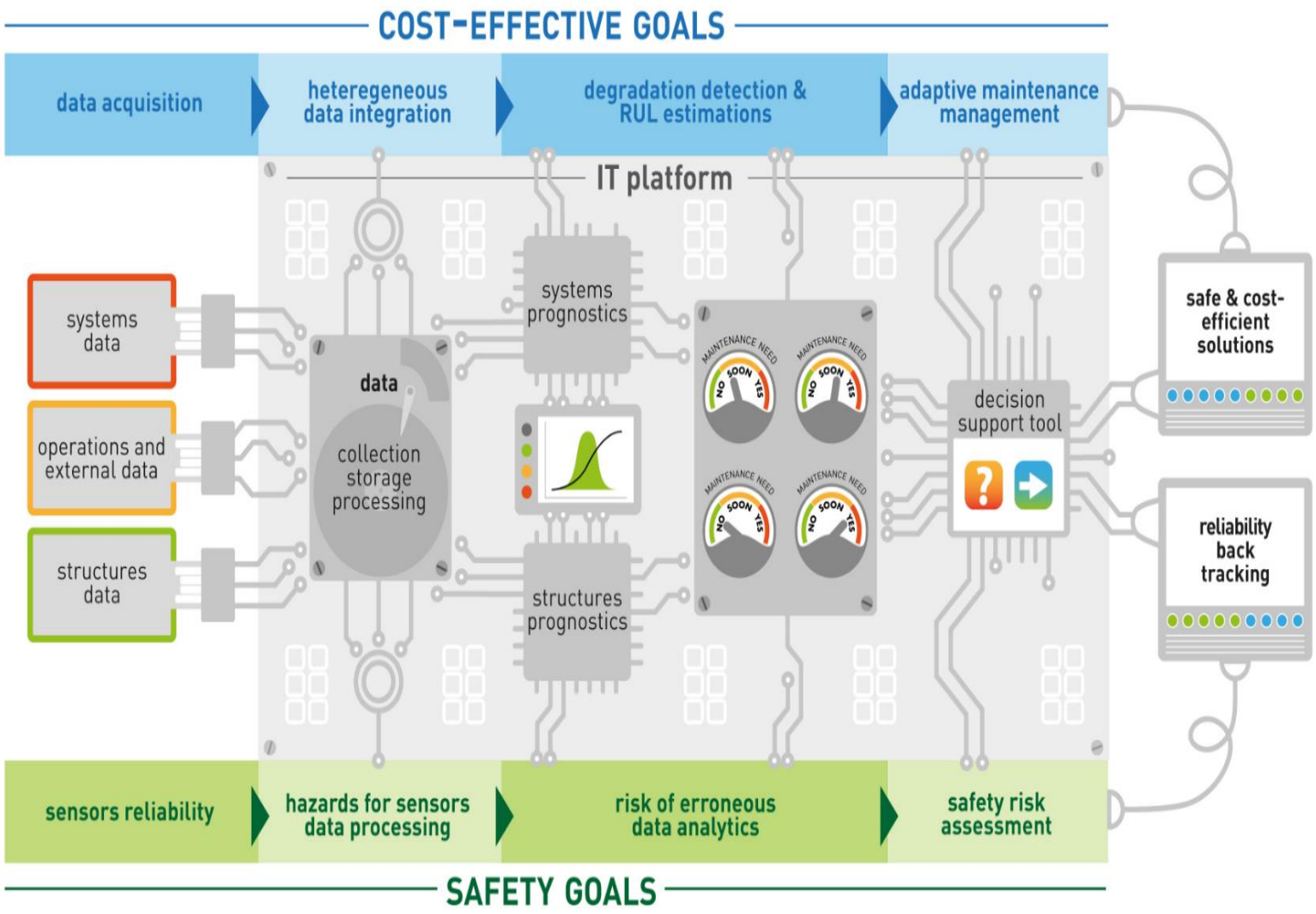

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Condition Based Maintenance Impact

Data

- Generate around 1GB of health monitoring data per flight
- Edge computing and air-to-ground communication
  - Pre-diagnostics
  - Alerts

Wif-fi Communication with MCC

- Improved Health knowledge
- Improved safety
  - False alarms reduced to $1x10^{-6}$ /FH*
  - Missed failures reduced to 10%*

Health monitoring updated

Diagnostics / Prognostics / Alerts

- 20% unscheduled maintenance*
- 4% less technical delay events

€68 000 cost reduction per year

Optimized maintenance schedule and packing

- 8% less maintenance checks*
- 2,5% lower maintenance elapse times
- 10% less unscheduled removals per year*

€42 000 cost reduction per year

Updated and improved aircraft availability

- 1.2 extra days of operations
- 140 minutes of less delay per year

€160 000 extra revenue and lower costs per day

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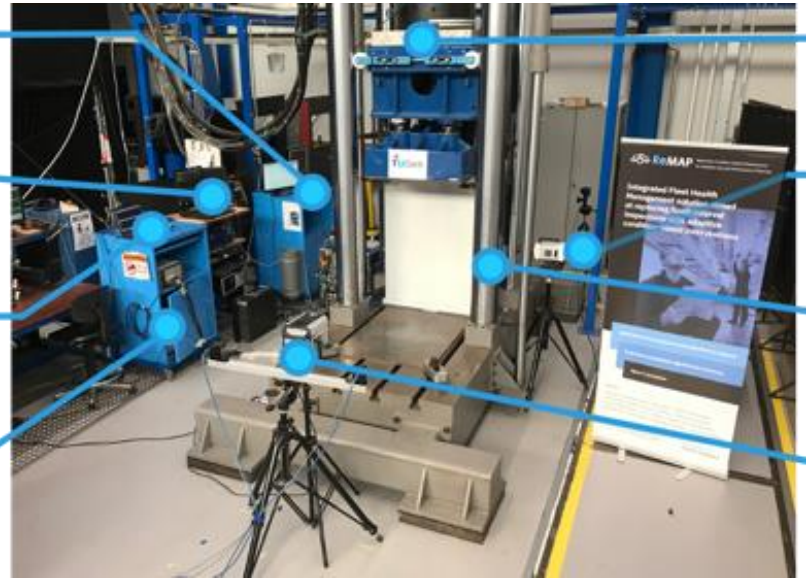
Structural Health Monitoring of the future

The first ever– worldwide – publicly available SHM database

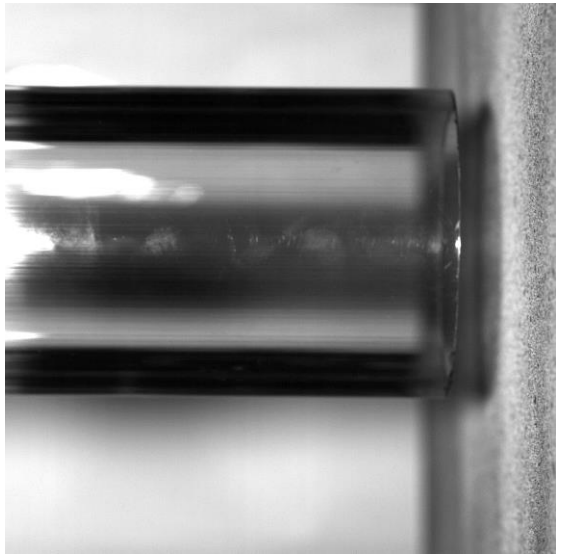
https://dataverse.nl/dataverse/ReMAP_H2020_SHM_data_repository

Database:

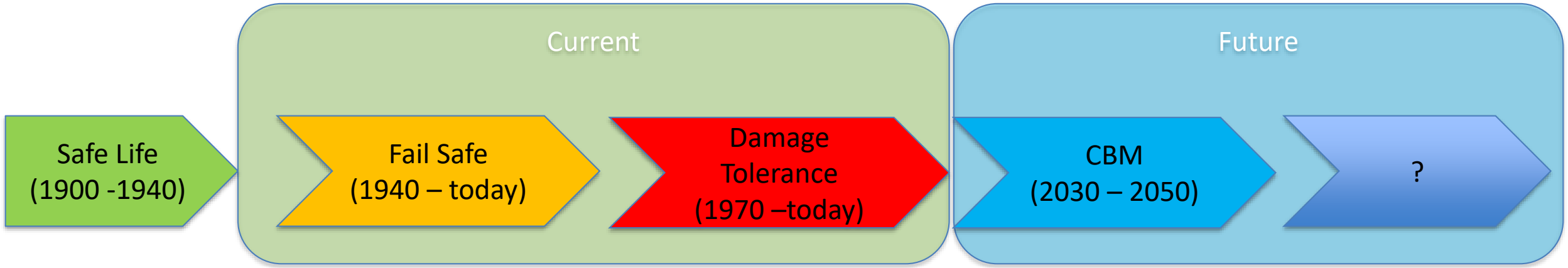
- Open-access
- Data from 7 sensing technologies
- Generic composite elements in realistic loading conditions
- For aviation researchers, manufacturers, operators
- For the advancement of condition-based maintenance methodologies


Guided waves
Strain sensing
Acoustic emission
Vibration
Test machine
High speed camera
Composite panel
Digital image correlation

Test machine
High speed camera
Composite panel
Impact gun



Beyond CBM


Current
Future
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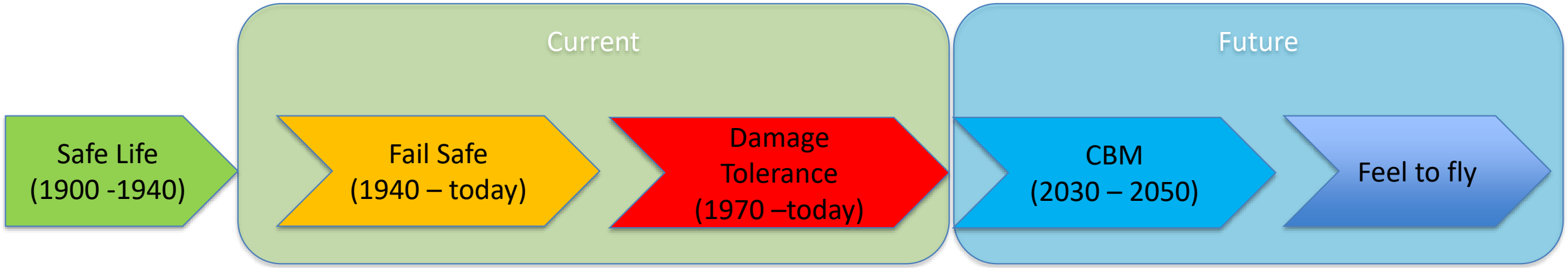
(1900 -1940)
Fail Safe
(1940 – today)
Damage
Tolerance
(1970 –today)
CBM
(2030 – 2050)
?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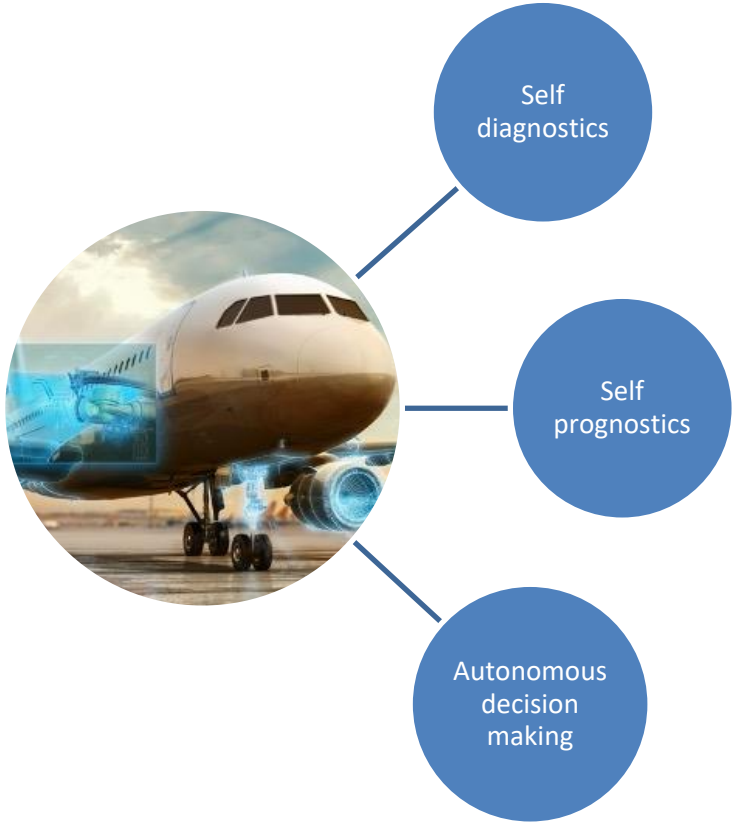
Self
diagnostics
Self
prognostics
Autonomous
decision
making

Key technologies

Computing

- Quantum
- Edge
- cloud
- High performance

efficiency

Data

- Sensing
- IoT
- Data management

Space domain

generalization

- Machine learning
- Federated Learning
- Automated decision-making

Artificial Intelligence

Costumization

- Augmented
- Virtual

Digital Reality

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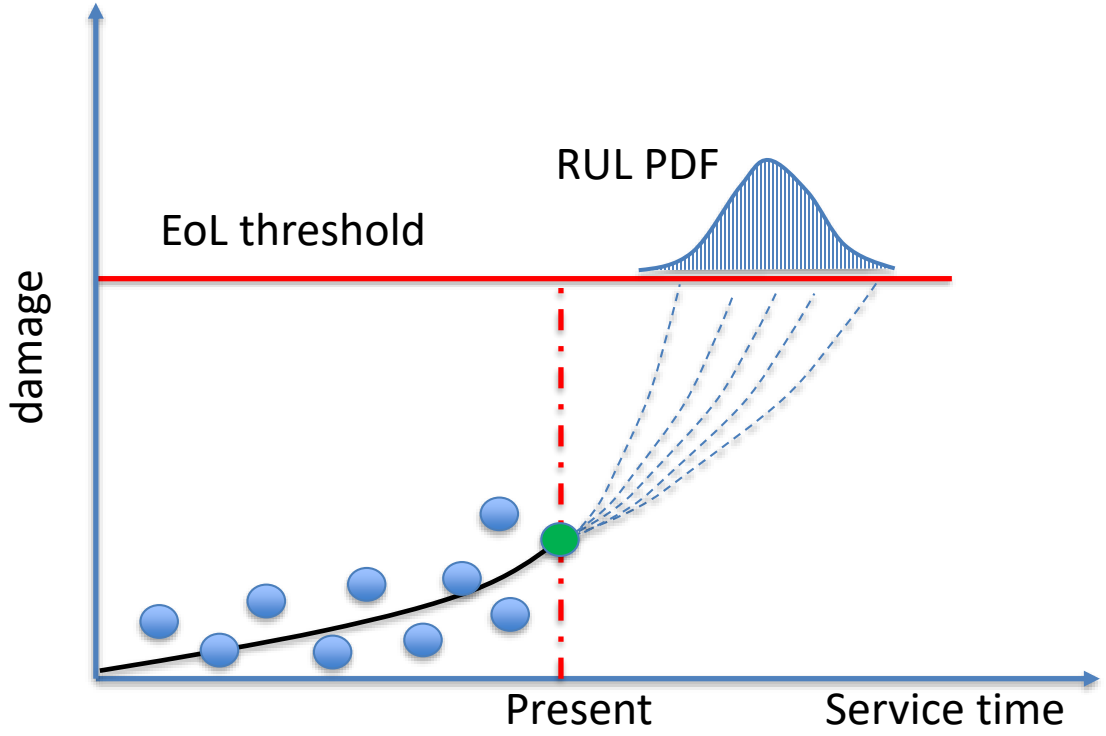
Vision: Enable structural state awareness for damage-informed decision making

Goal: Real-time and autonomous assessment of damage state (diagnostics) and prediction of the remaining useful life (prognostics), taking into account realistic operational conditions



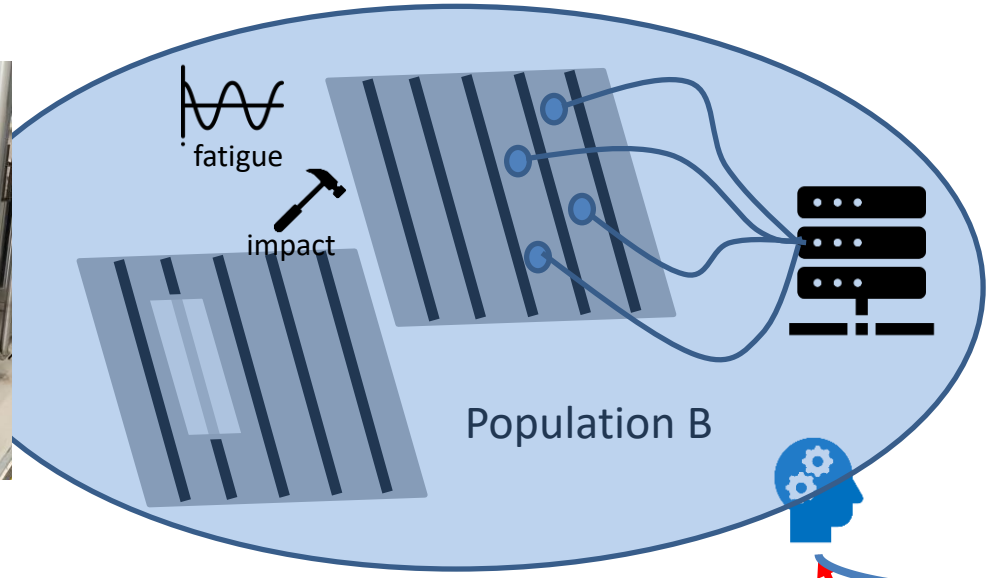
Health monitoring data

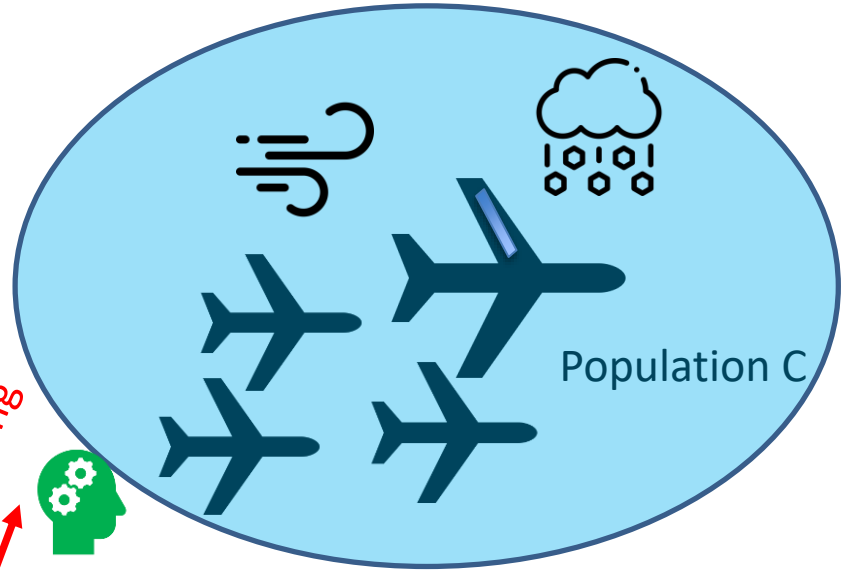
Structural mechanics

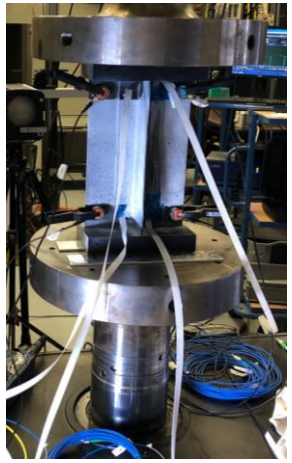
Diagnostics

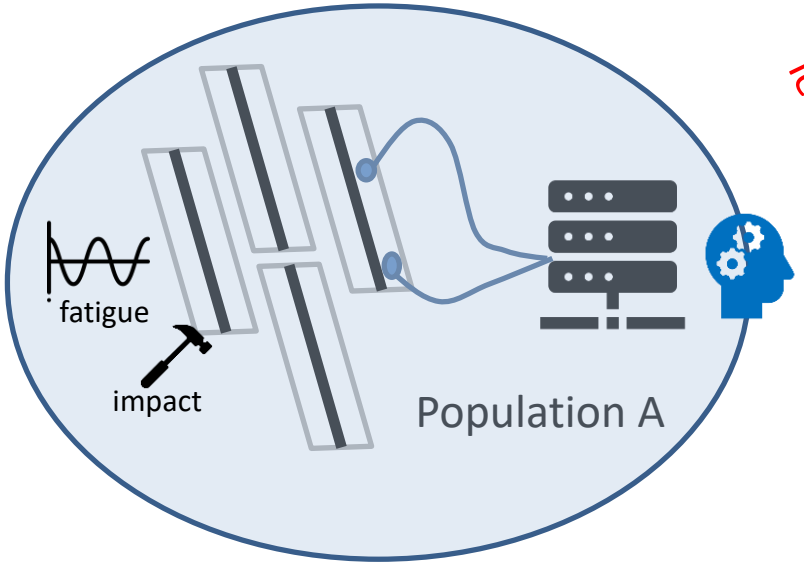
Degradation modeling

Prognostics









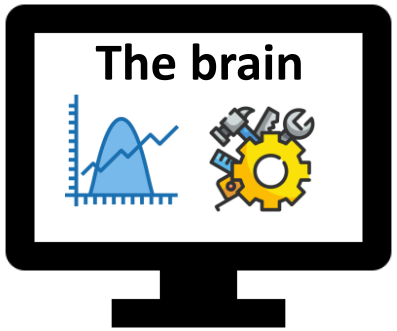
Transfer learning

training

Transfer learning

training

Real-time diagnosis & prognosis



Post prognosis & decision making

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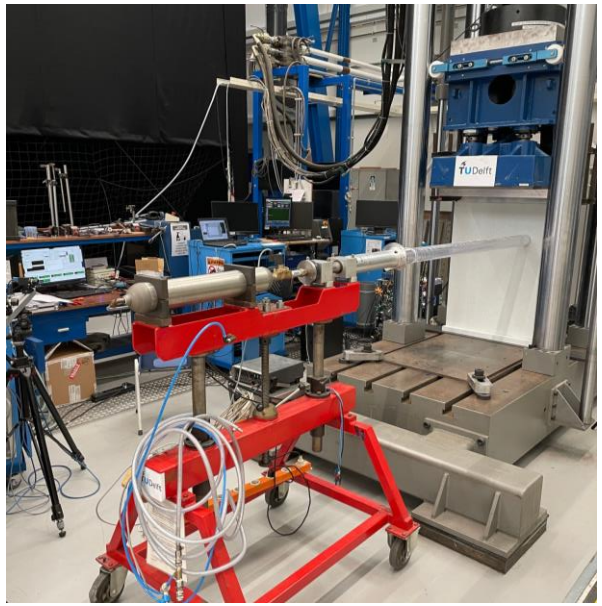
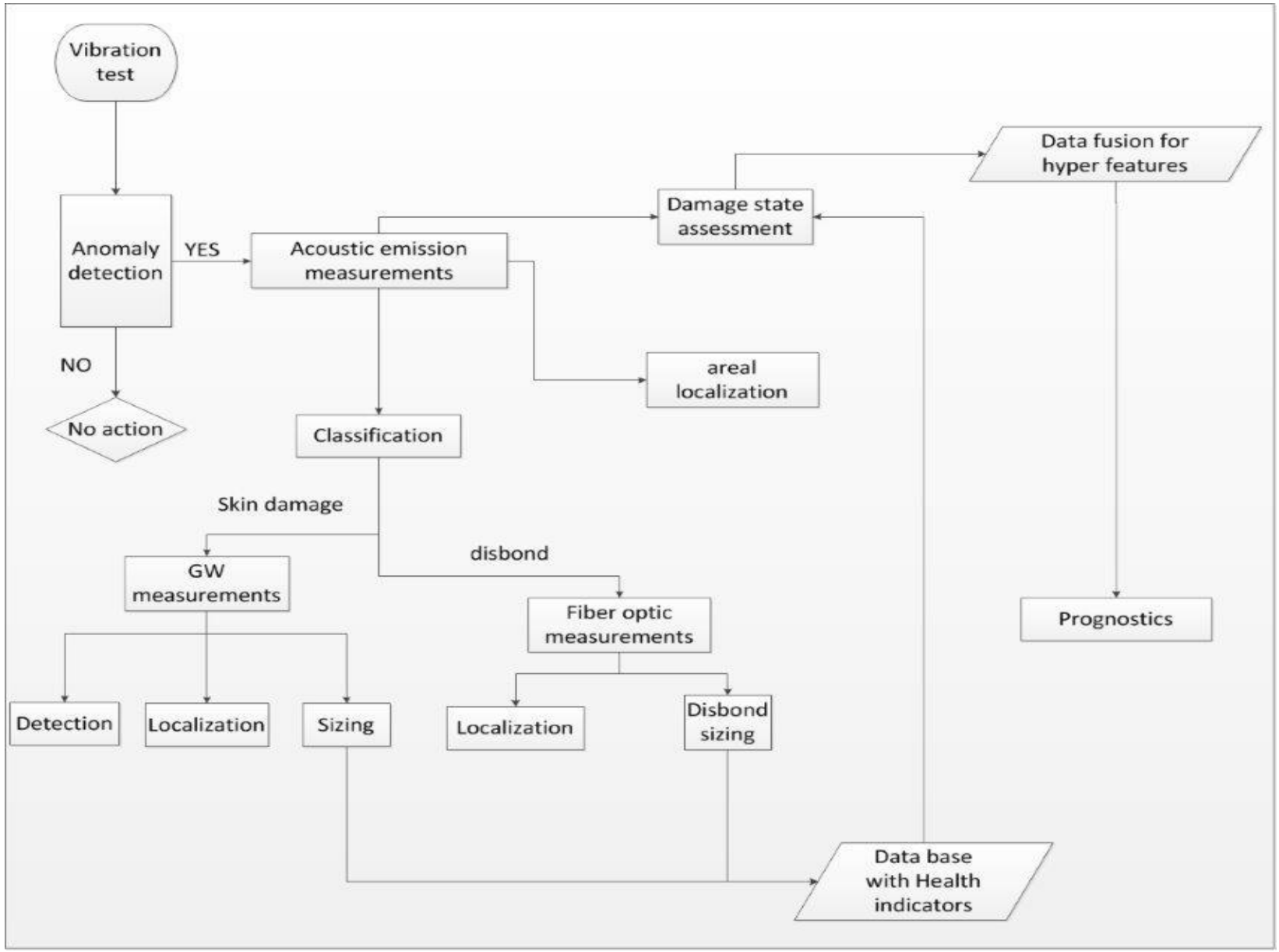
Conceptual design of the brain





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Future research and challenges (the next decade)

- Expand the space solution
- Explainable artificial intelligence
- Certification
  - Certify a process with AI
  - Certify the AI algorithm
- Edge computing
- Trustworthiness

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Ferda Cansu
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Prognostics with guided waves

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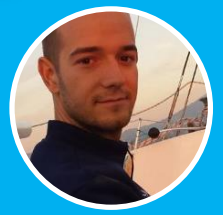
Associate Professor – Pythia team leader



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