Process and Methods for E2E Maintenance Architecture

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*) Advanced Value and Service driven Architectures for Maintenance

- ***ADVANCEd* Aircraft maintenance**

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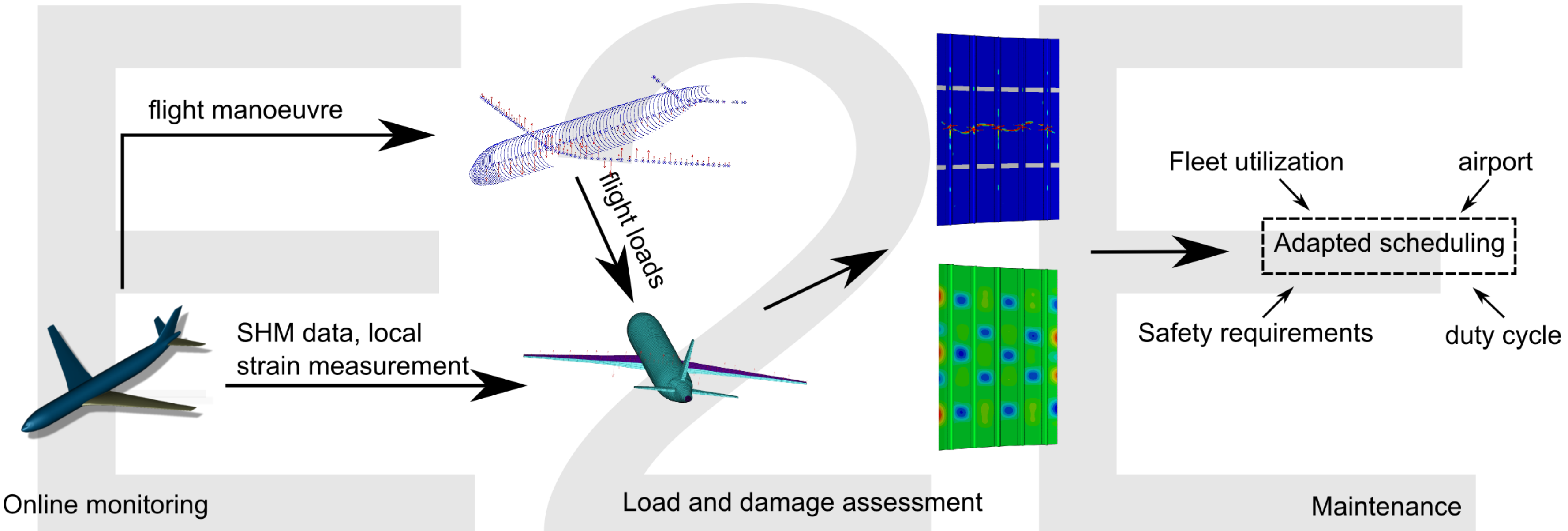
DEMETER

Process and Methods for E2E Maintenance Architecture development, demonstrations and solutions for technology integration



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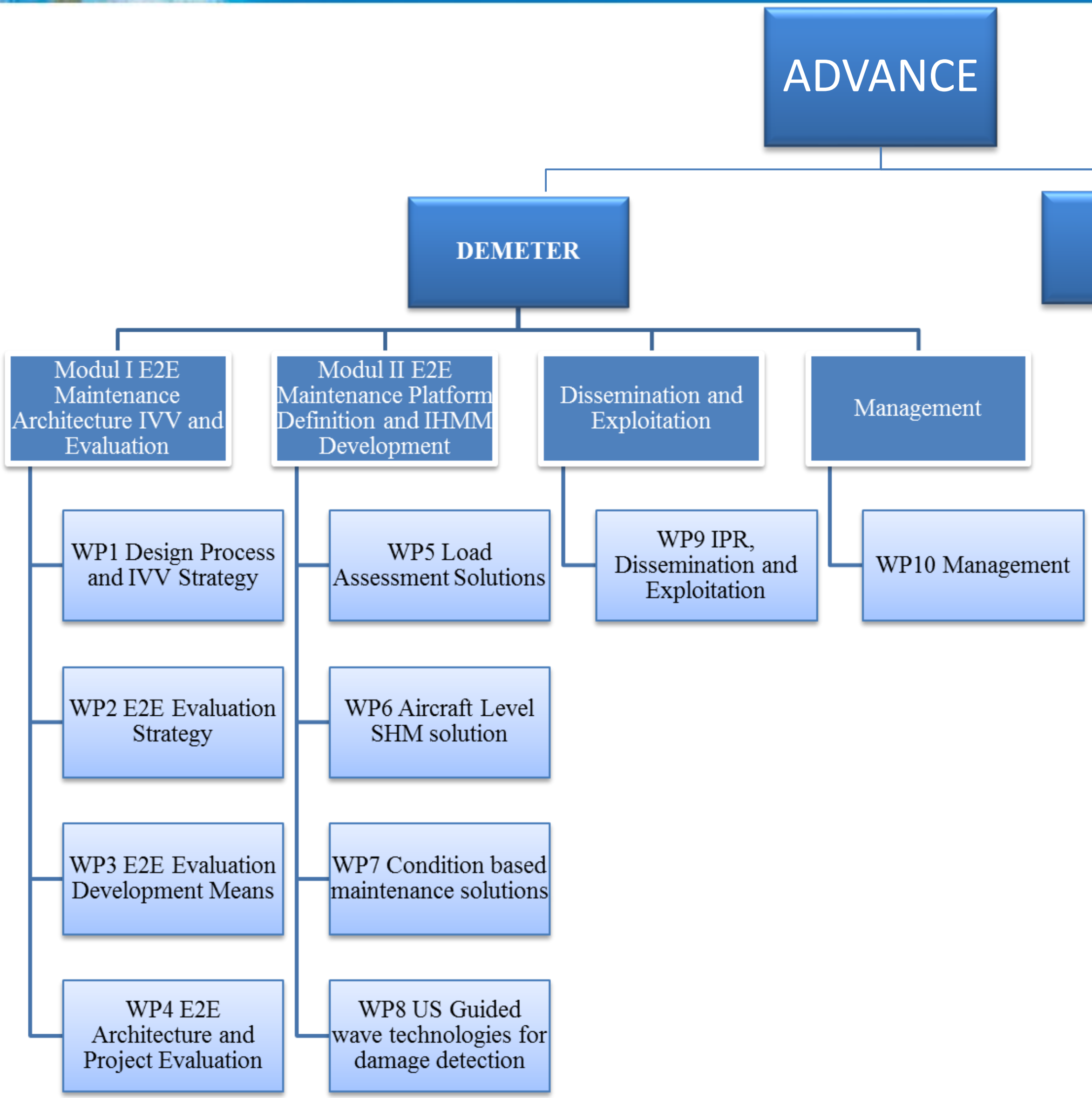
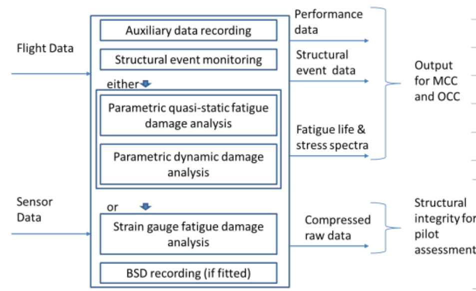
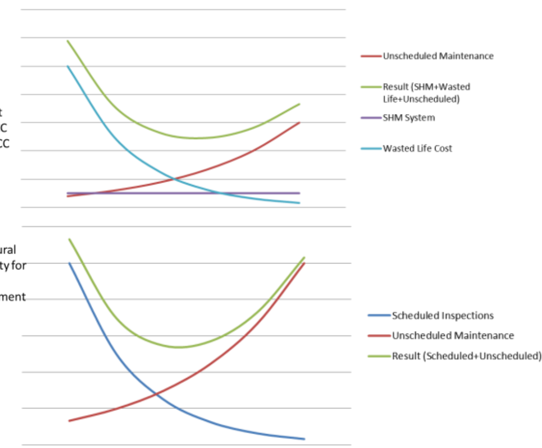
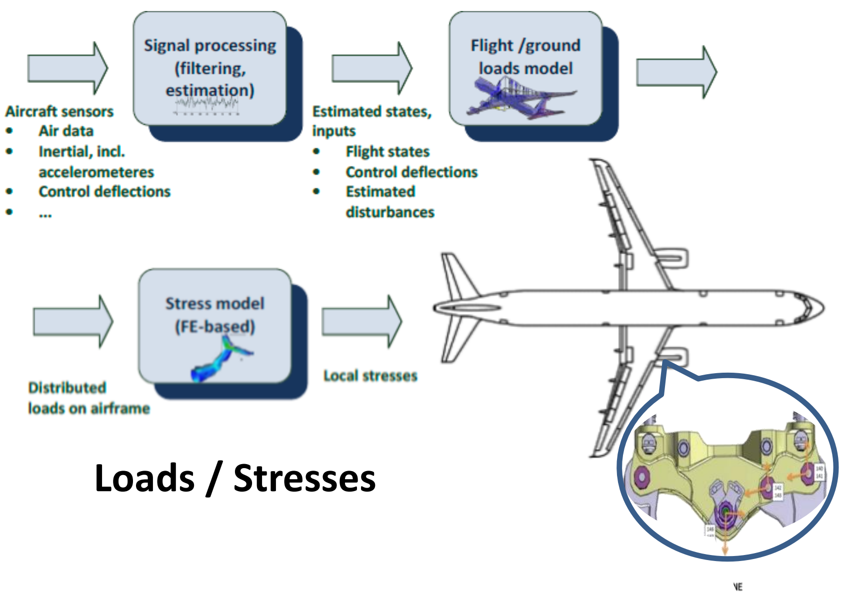

ADVANCE
DEMETER
PACMAN
AIRMES
Modul I E2E Maintenance Architecture IVV and Evaluation
Modul II E2E Maintenance Platform Definition and IHMM Development
Dissemination and Exploitation
Management
WP1 Design Process and IVV Strategy
WP2 E2E Evaluation Strategy
WP3 E2E Evaluation Development Means
WP4 E2E Architecture and Project Evaluation
WP5 Load Assessment Solutions
WP6 Aircraft Level SHM solution
WP7 Condition based maintenance solutions
WP8 US Guided wave technologies for damage detection
WP9 IPR, Dissemination and Exploitation
WP10 Management

Indirect Monitoring Systems

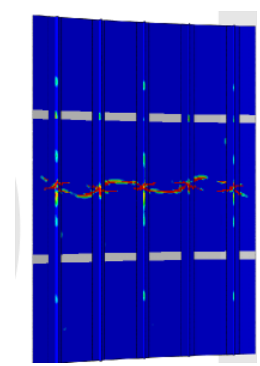
Flight data:
flight recorder, acceleration, etc.







Loads / Stresses



Fatigue evaluation

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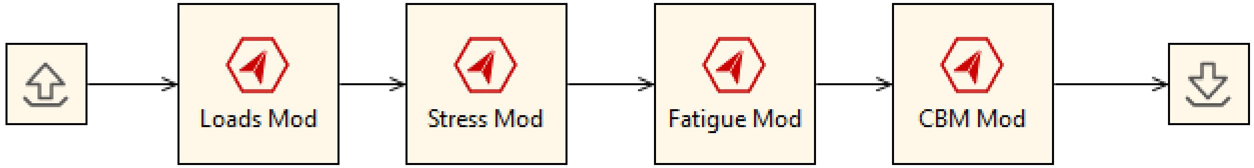
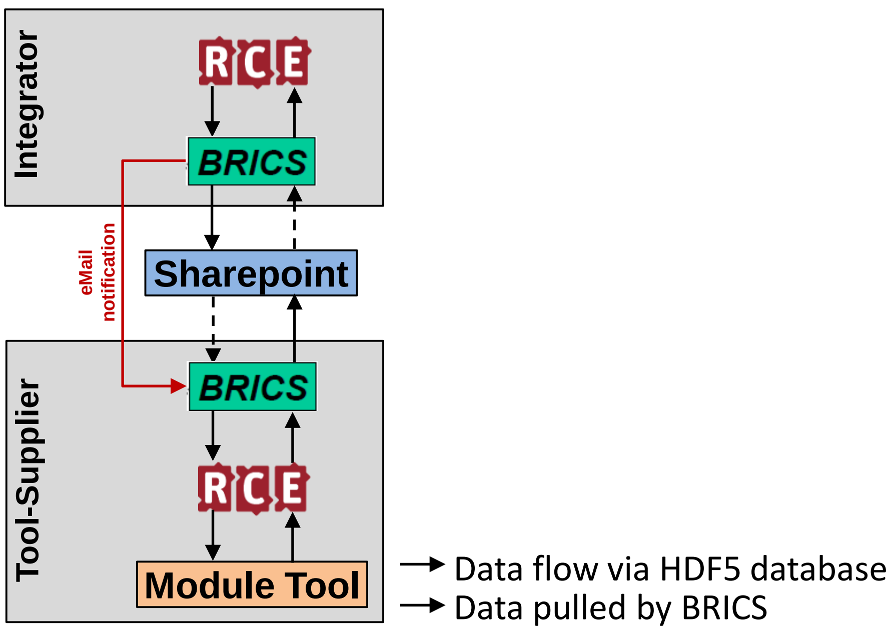
Indirect Monitoring Systems



Overall workflow



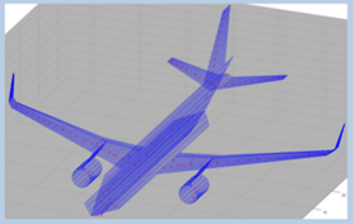
Module workflow

Hdf5 database structure

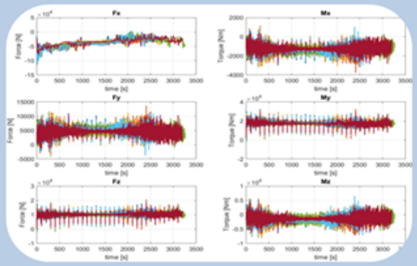
Loads Module

Operational Aircraft Data

Flexible aircraft model + control laws

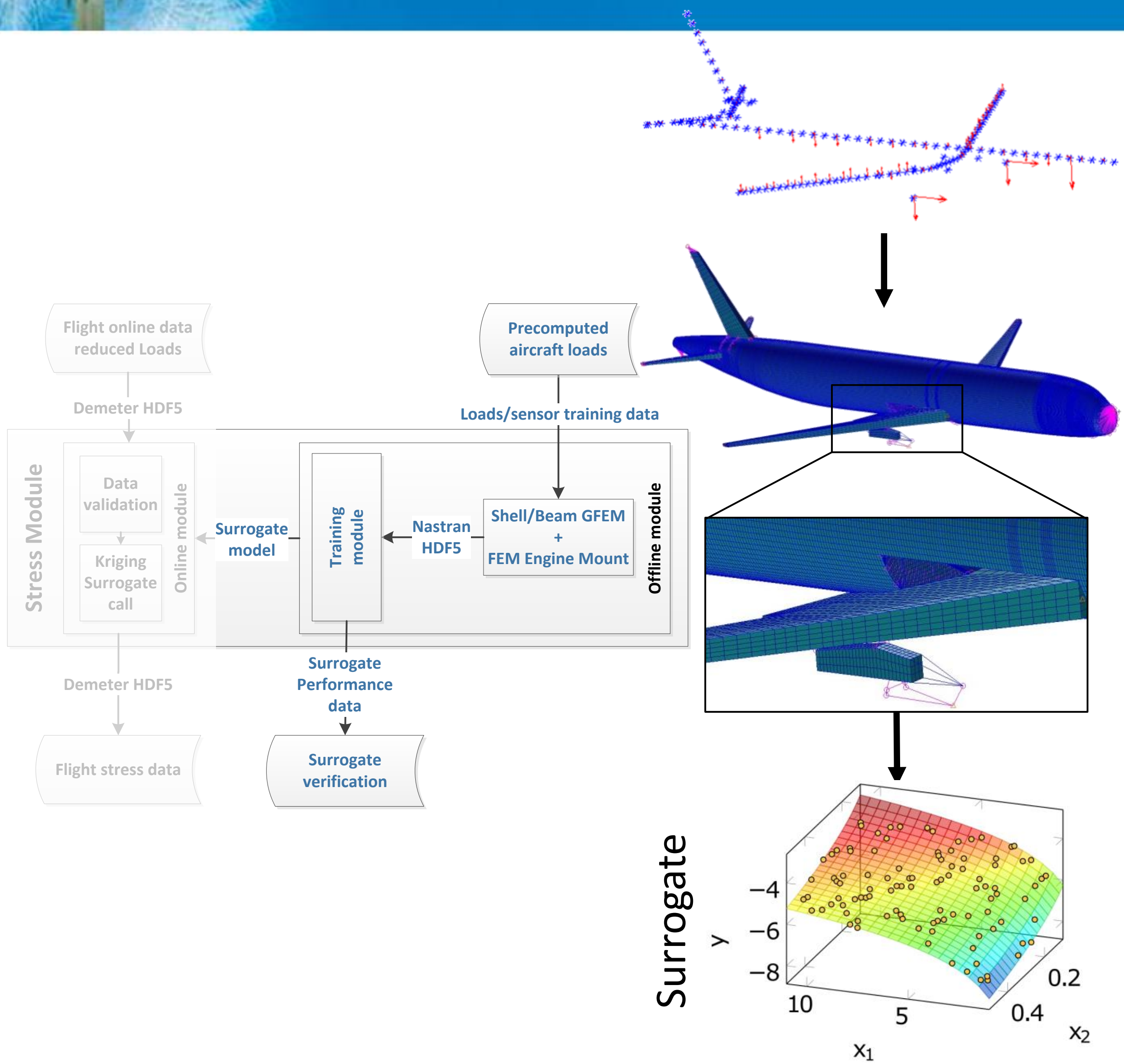


Loads



- Estimation for the loads during flight missions
- Derive loads with a model based approach based on aircraft sensor data
- For the prototype
  - Real aircraft sensor data, is estimated based on trajectory and Mach-Number data of real-life flight missions
  - This data is combined with a physical model based simulation to calculate the loads

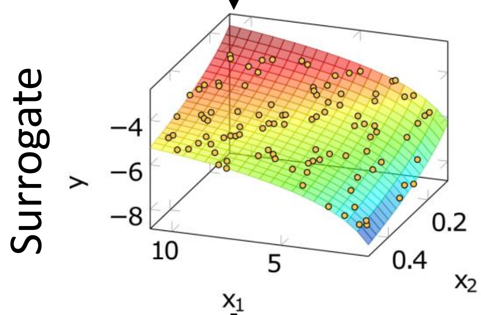
Stress Module - Offline Phase



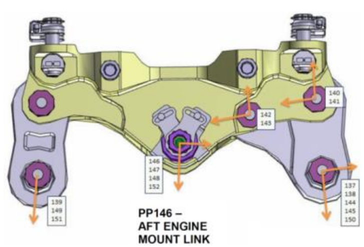
- Apply aircraft loads on a A320-like model
- Extract stresses (and optional sensor data) at engine mount link
- Surrogate input: Loads/sensor data
- Surrogate result: stresses
- Evaluation of surrogate accuracy using crosscorrelation, Kriging MSE

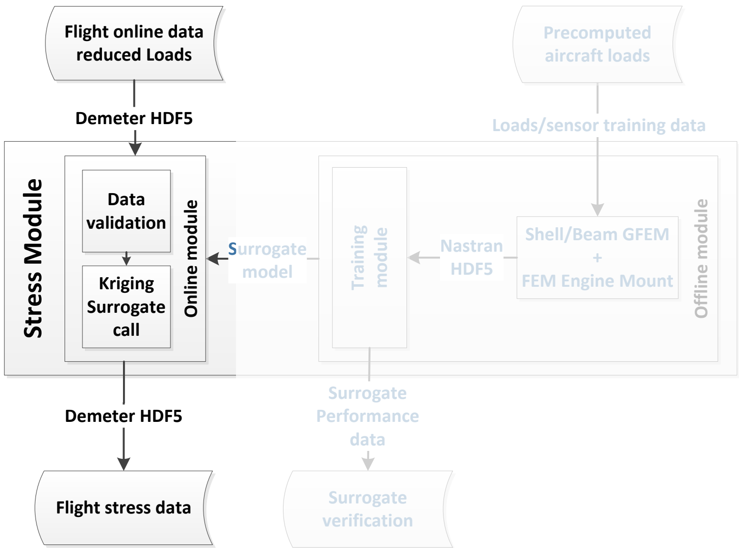
Stress Module - Online Phase

Reduced Loads

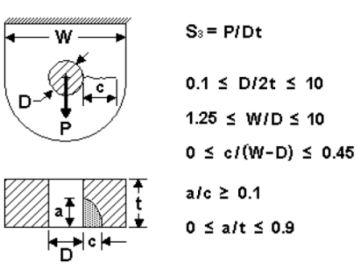


Local Stresses





CC19



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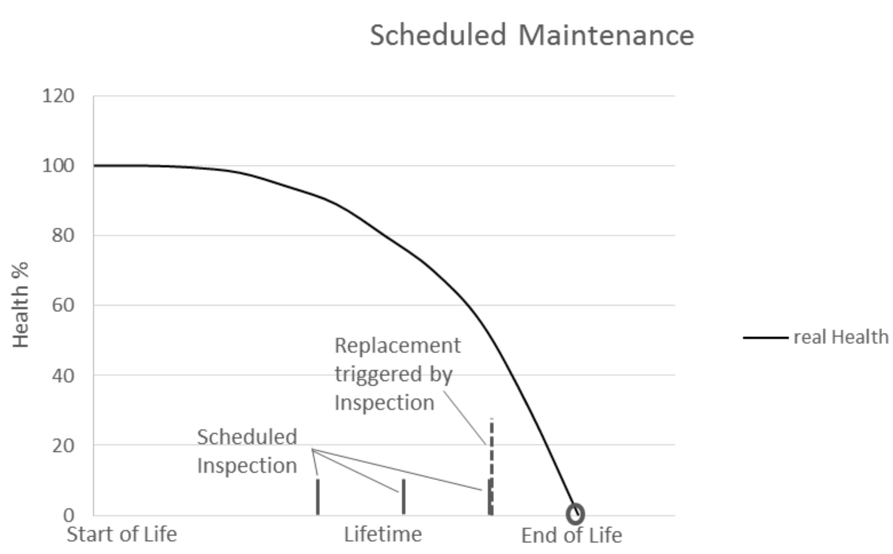
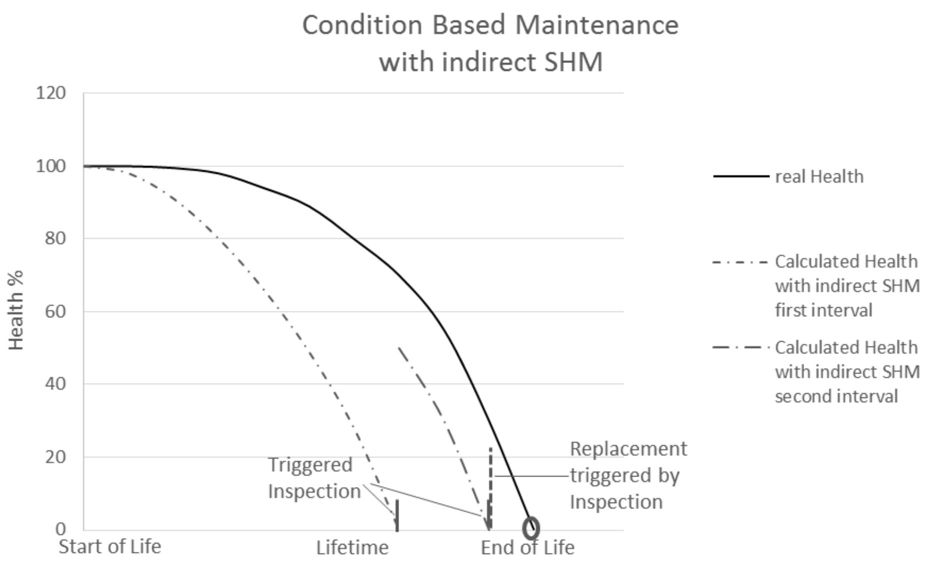
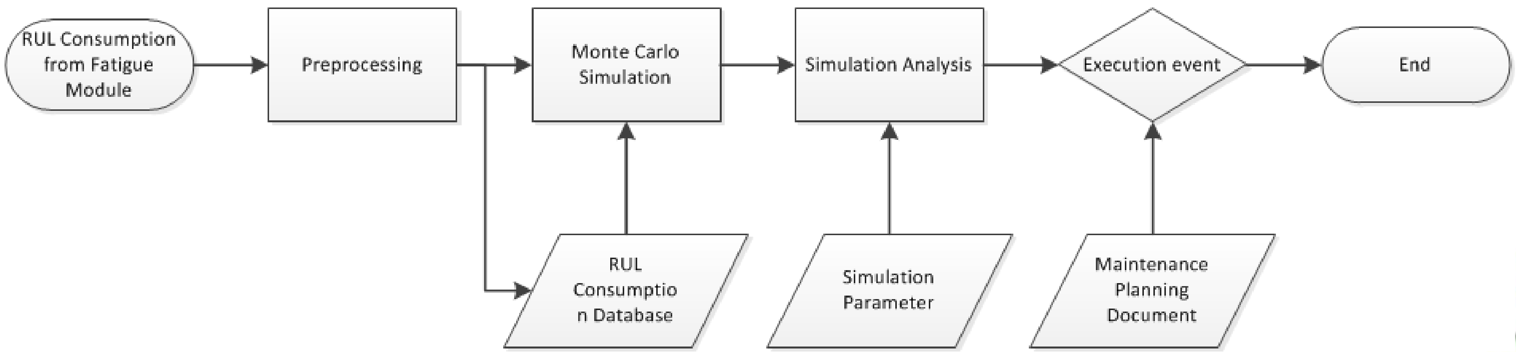
CBM Module



Scheduled Maintenance
120
100
80
60
40
20
0
Health %
Replacement
triggered by
Inspection
Scheduled
Inspection
Start of Life
Lifetime
End of Life
real Health

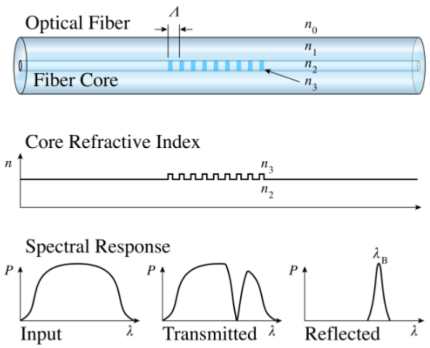


Condition Based Maintenance
with indirect SHM
120
100
80
60
40
20
0
Health %
Triggered
Inspection
Replacement
triggered by
Inspection
Start of Life
Lifetime
End of Life
real Health
Calculated Health
with indirect SHM
first interval
Calculated Health
with indirect SHM
second interval

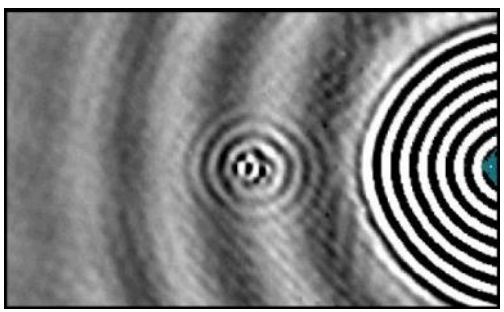


RUL Consumption
from Fatigue
Module
Preprocessing
Monte Carlo
Simulation
Simulation Analysis
Execution event
End
RUL
Consumptio
n Database
Simulation
Parameter
Maintenance
Planning
Document

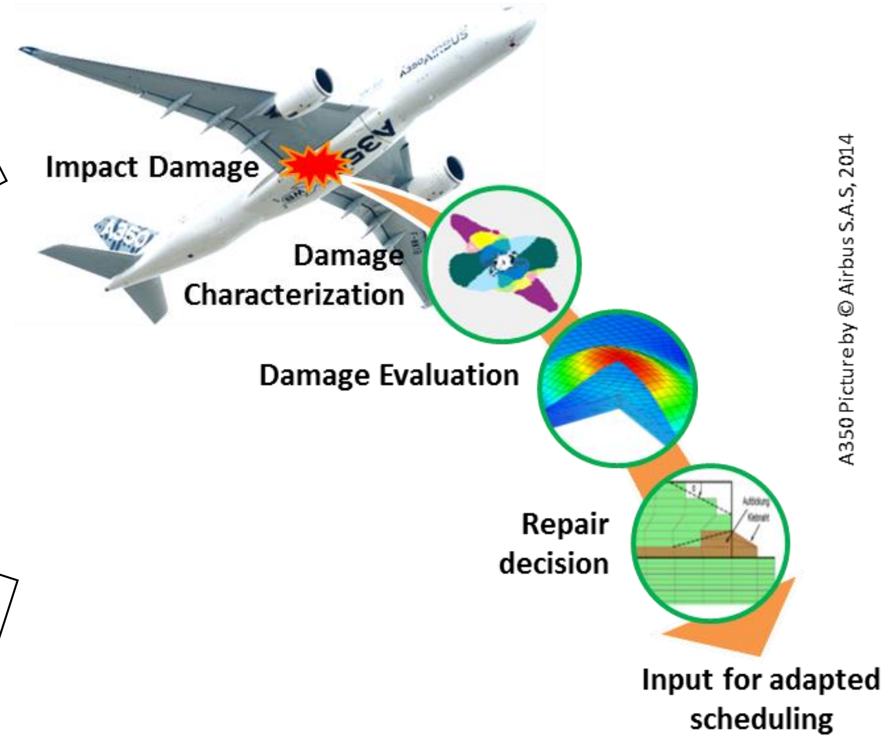
Direct Monitoring Systems



Fibre Bragg Input



USG waves input



Global SHM solution

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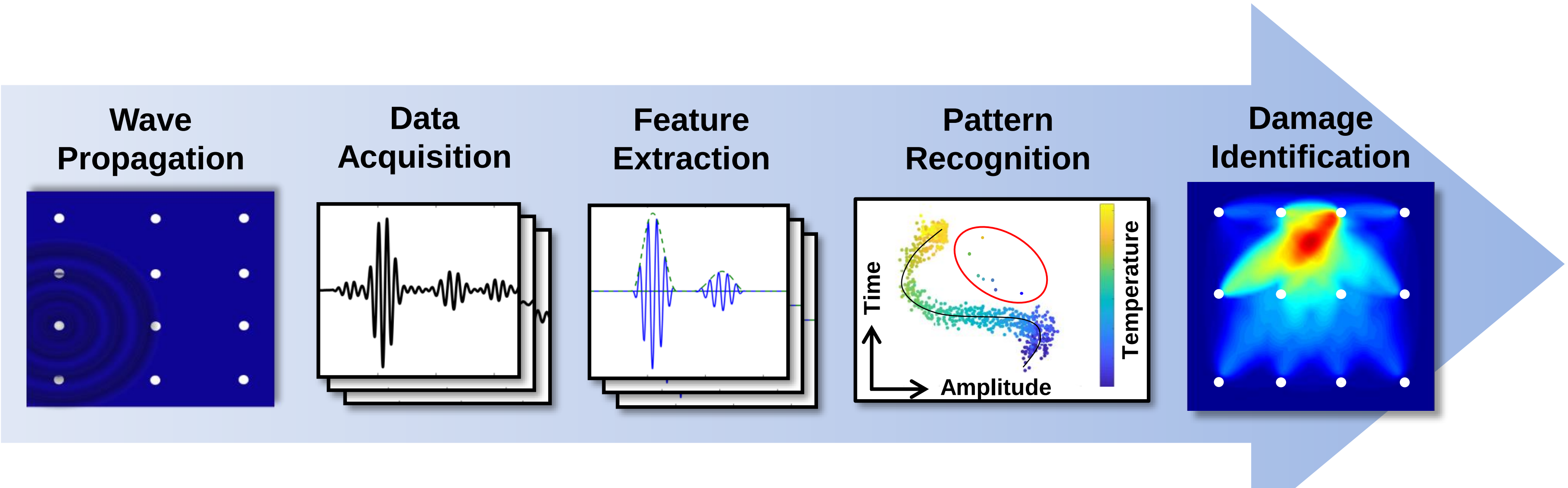
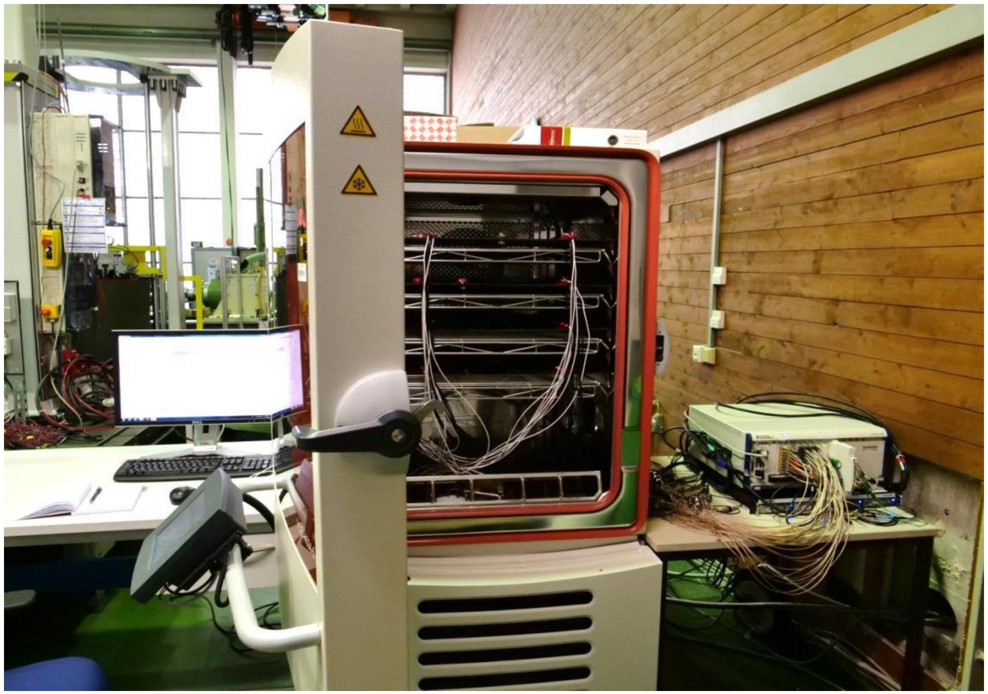
Guided wave - Damage Identification



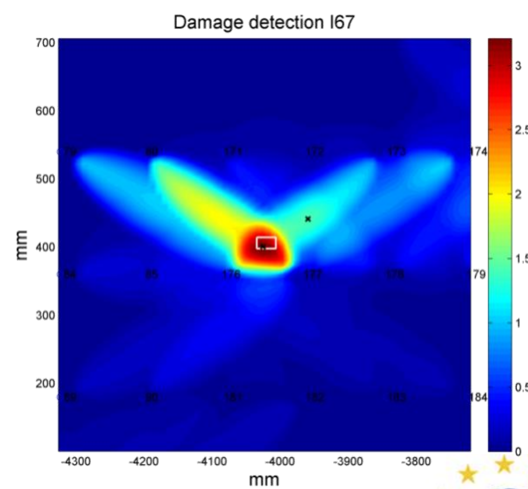
- Stiffened coupons
- Temperature tests
- Matching Pursuit
- Gaussian Mixture Model
- Damage Effects Results

Guided wave - Validation



Test control through GUI (left), climate chamber (center) and data acquisition equipment (right)

Dummy damage under the stringer head



Damage detection and localization

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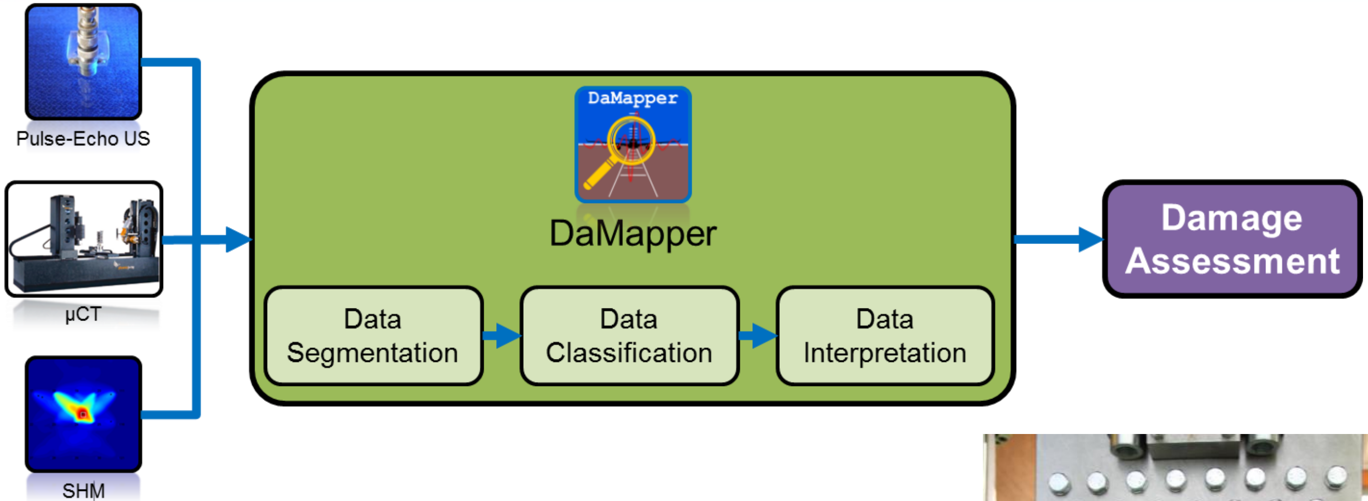
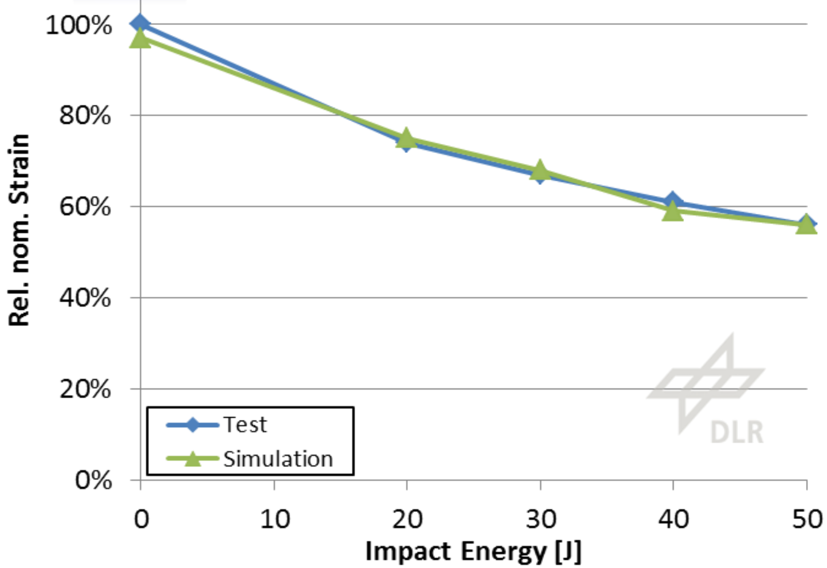
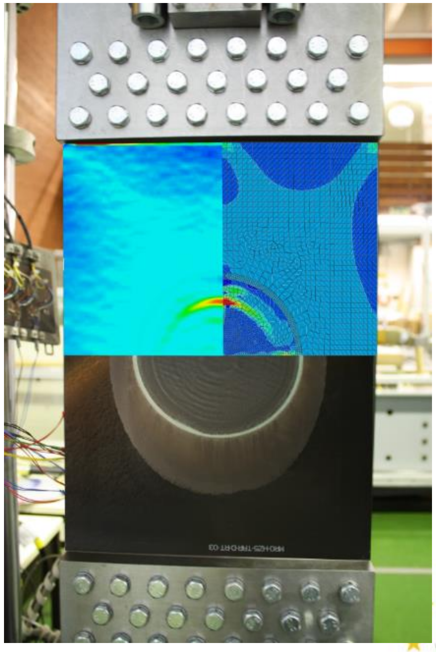
Damage Assessment

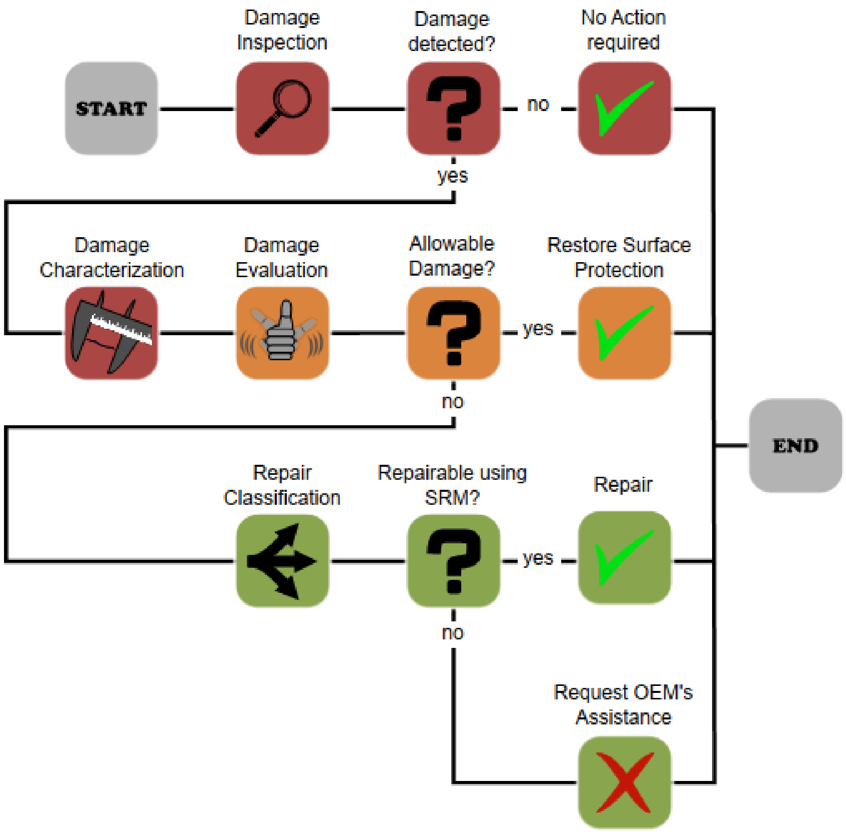




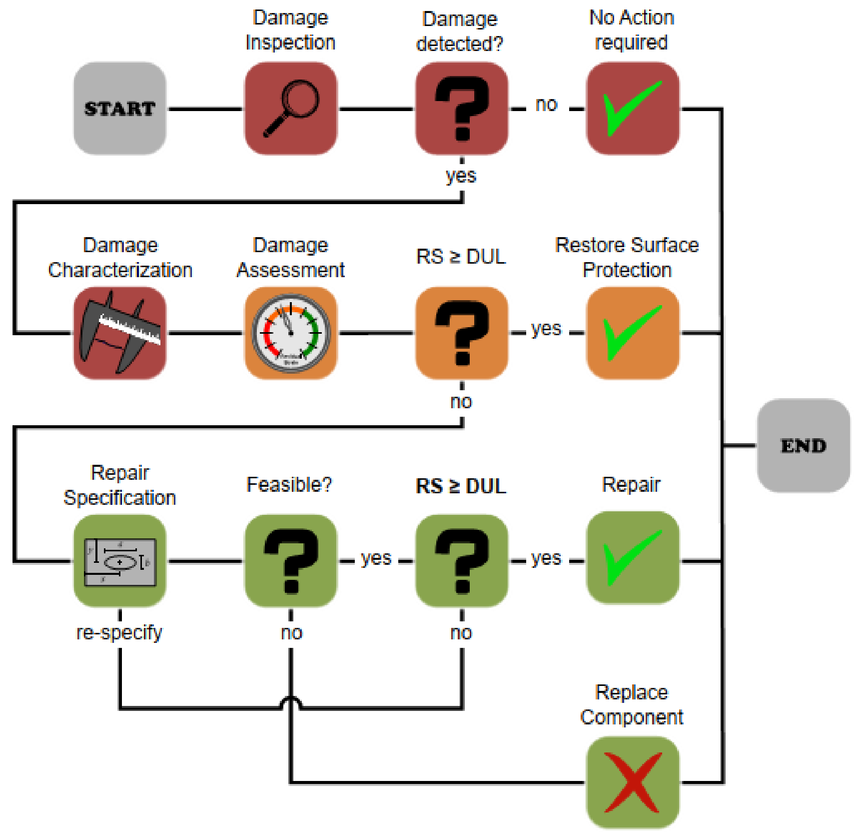


Comparison of experimental and simulation results. Excellent residual strength prediction.

Damage Assessment

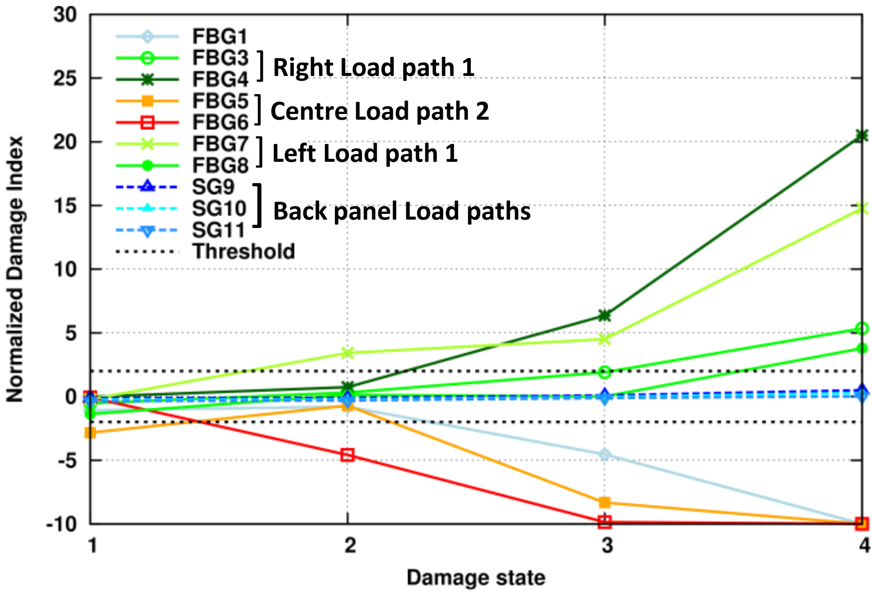


Current Decision-Making Process



Modified Decision-Making Process

Highlights
Damage detection multiple load path failure



- Experiments performed by NLR

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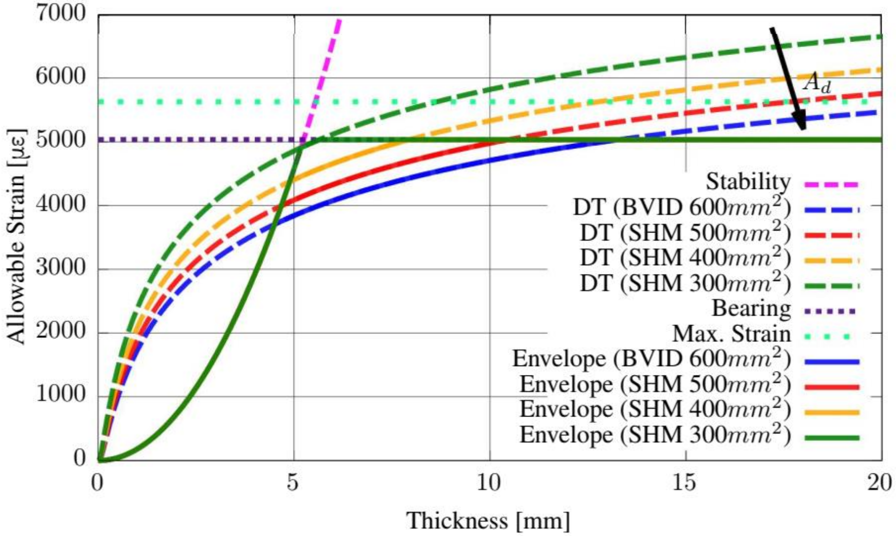
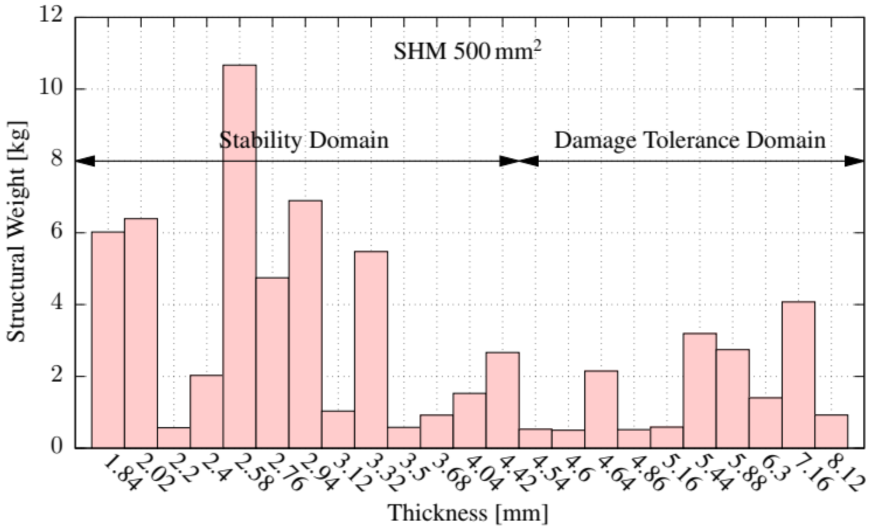
Highlights
Up to 5% weight saving is achievable





Dienel, C. P., Meyer, H., Werwer, M., & Willberg, C. (2019). Estimation of airframe weight reduction by integration of piezoelectric and guided wave–based structural health monitoring. *Structural Health Monitoring*, *18*(5–6), 1778–1788. https://doi.org/10.1177/1475921718813279

Highlights
E2E Evaluation

Point to Point

Fleet Size: 104 A/C

Legs/day per A/C

Legs/haul length

7-8/day

2/day

Average fleet age: 8,9 yrs

Large Hub & Spoke

Fleet Size: 200 A/C

Legs/day per A/C

Legs/haul length

5-6/day

2/day

Average fleet age: 11,3 yrs

Small Hub & Spoke

Fleet Size: 50 A/C

Legs/day per A/C

Legs/haul length

6/day

2/day

Average fleet age: 12,4 yrs

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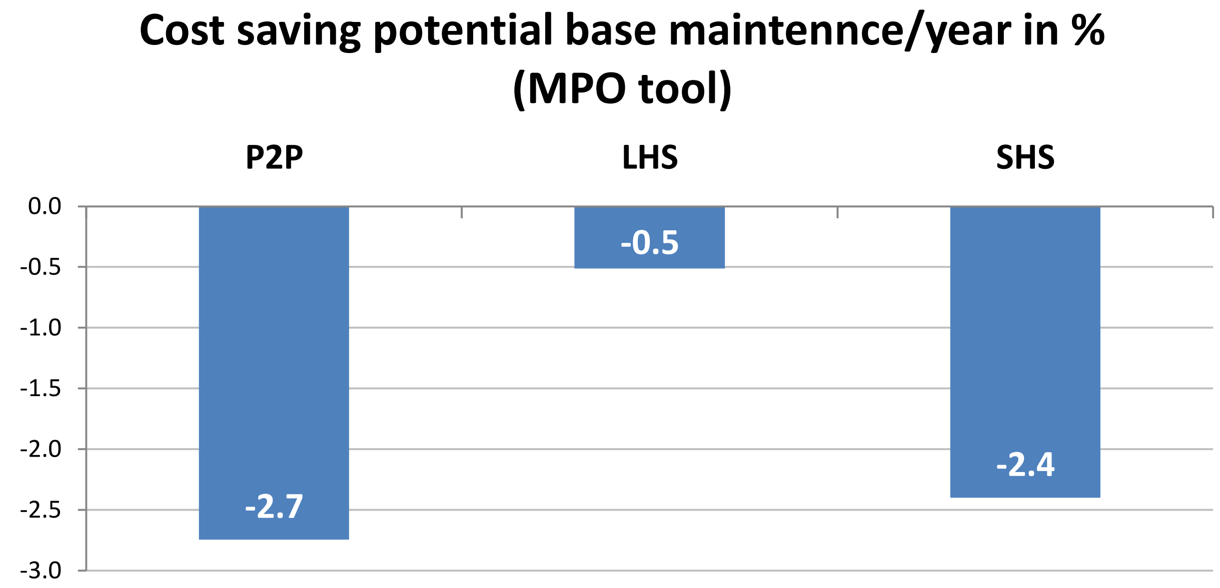
Highlights
E2E Evaluation

Assumptions:

- The results from the MPO tool are valid for each airline cluster
- The available aircraft performs additional flights
- The age of the fleet of the airline is equally distributed with the average given by the analysis



- **Significant potential for decrease of base maintenance cost by using the MPO tool**
- MPO tool **developed especially for SHS carriers**.
- **Higher aircraft utilization leads to increasing revenue**, especially for P2P carriers
- Aircraft utilization and fleet age are additional factors for good results at SHS and P2P airlines

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[1] The shown results are potentials per year that need to be exploited.

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Highlights
AAM2019 Dissemination event

- Approximately 60 external visitors came to the conference and market place
- Over 100 people participated on the conference

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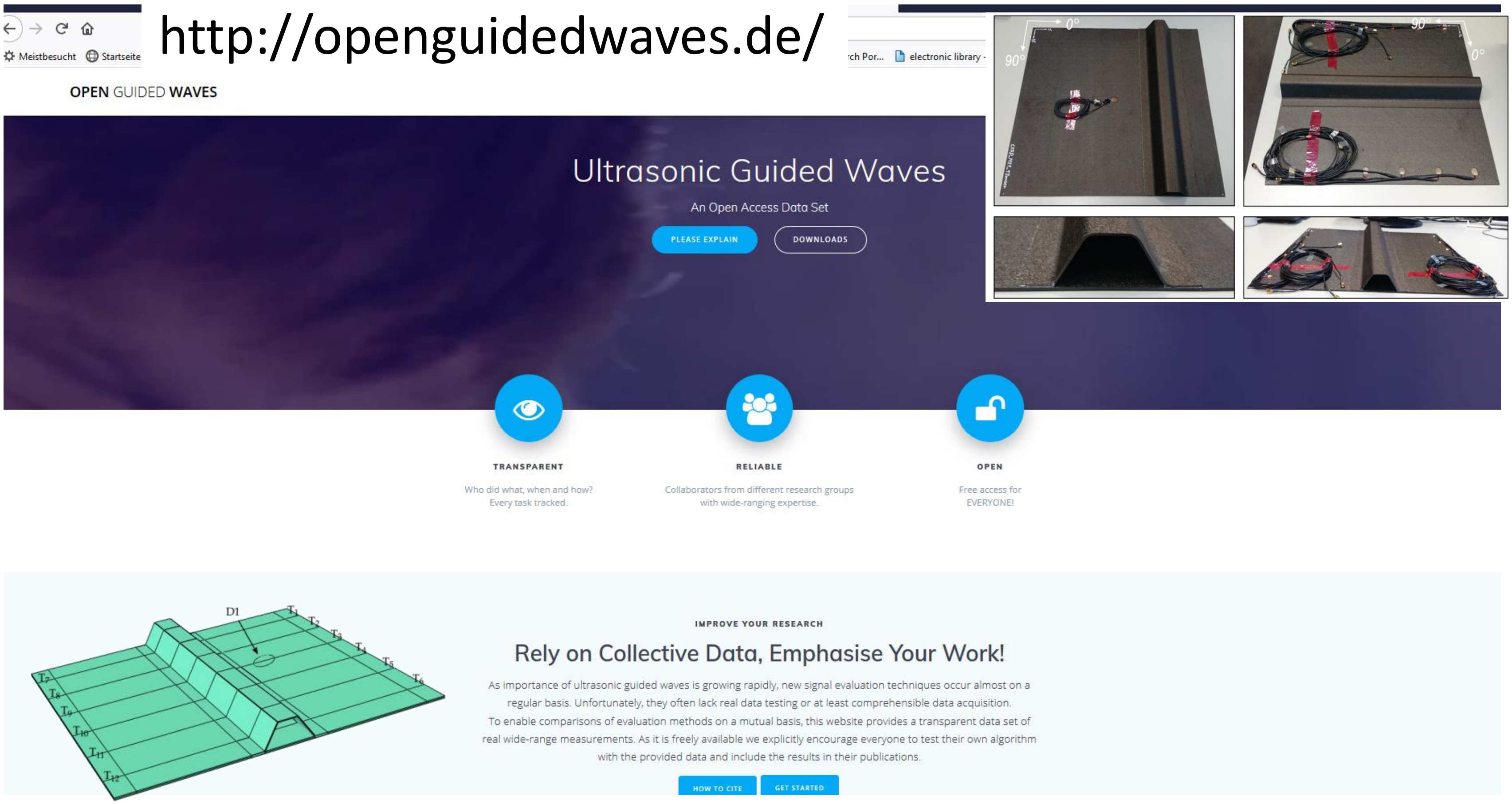
Steps after
Open Guided wave

http://openguidedwaves.de/



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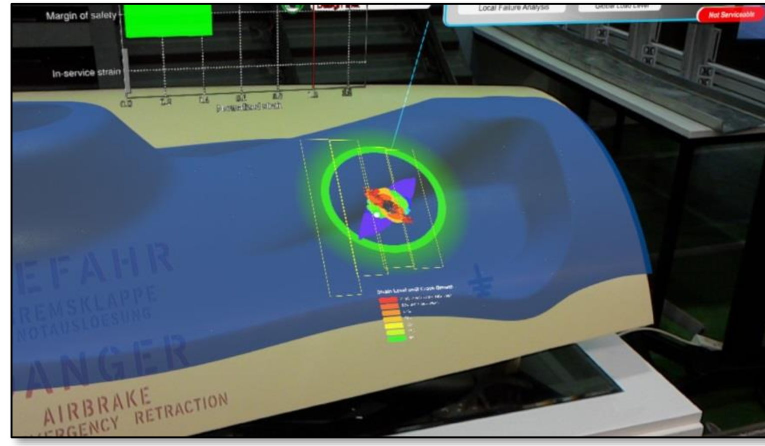
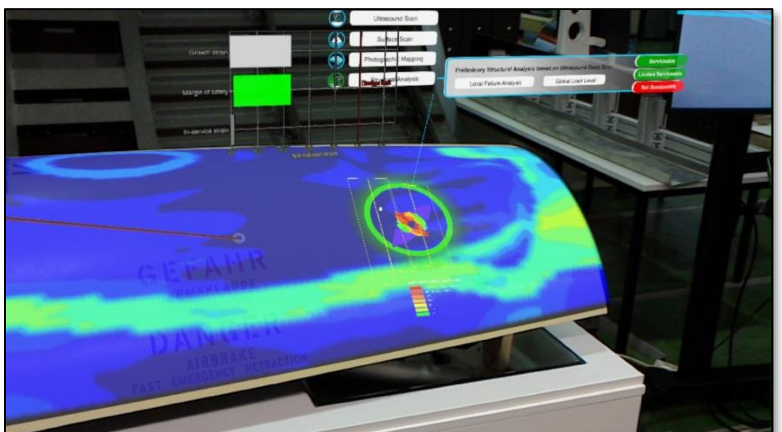
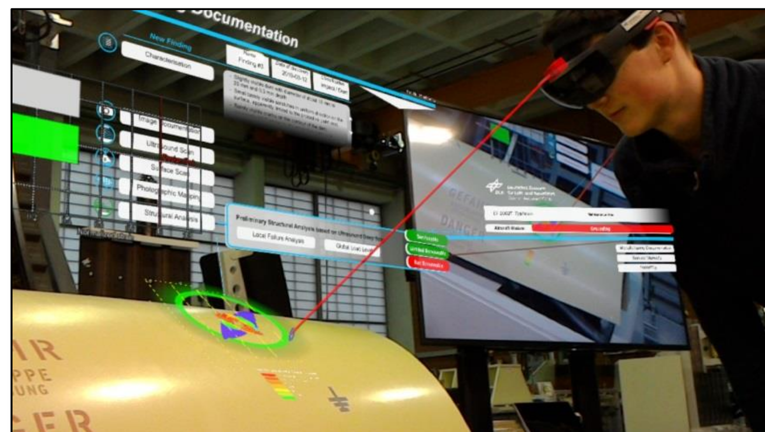
Steps after SHM Demonstrator

- Maintenance → Does the delamination grow?
- Assistance of the technician in finding the damage







JEC Composites, Paris 2019

Lessons learned

- Data availability (for exchange) must be clarified in advance of the project
- Demonstrator case selection should be done and fixed early in the project
- More resources for the core partner
- Multi project work can be a success

Useful infos and acknowledgements

- German Aerospace Center/DLR
  Hyperlink: www.dlr.de
- Christian Willberg
  christian.willberg@dlr.de
- Netherlands Aerospace Centre/NLR
  Hyperlink: www.nlr.org

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 685704