Process and Methods for E2E Maintenance Architecture


*German Aerospace Center (DLR)
**Netherlands Aerospace Centre (NLR)

*) Advanced Value and Service driven Architectures for Maintenance

• ADVANCEEd Aircraft maintenance

www.cleansky.eu
Process and Methods for E2E Maintenance Architecture development, demonstrations and solutions for technology integration
Indirect Monitoring Systems

Flight data:
flight recorder, acceleration, etc.

Loads / Stresses

Fatigue evaluation
**Indirect Monitoring Systems**

**Overall workflow**

1. **Integrator**
   - Sharepoint
   - BRICS
   - Data flow via HDF5 database

2. **Tool-Supplier**
   - BRICS
   - RCE
   - Data pulled by BRICS

**Module workflow**

- Data flow via HDF5 database
- Data pulled by BRICS

**Hdf5 database structure**
Loads Module

- 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

Surrogate

Local Stresses

Flight online data reduced Loads

Precomputed aircraft loads

Loads/sensor training data

Demeter HDF5

Kriging Surrogate call

Surrogate model

Online module

Nastran

Shell/Beam GFEM + FEM Engine Mount

Offline module

Data validation

Tooting module

Nastran HDF5

Surrogate Performance data

Surrogate verification

Flight stress data

Surrogate Performance data

Flight stress data

CC19

\[ S = \frac{P}{D t} \]

\[ 0.1 \leq \frac{D}{2t} \leq 10 \]

\[ 1.25 \leq \frac{W}{D} \leq 10 \]

\[ 0 \leq \frac{c}{(W-D)} \leq 0.46 \]

\[ a/c \geq 0.1 \]

\[ 0 \leq a/t \leq 0.9 \]
CBM Module

Scheduled Maintenance

Condition Based Maintenance with indirect SHM

RUL Consumption from Fatigue Module → Preprocessing → Monte Carlo Simulation → Simulation Analysis → Execution event → End

RUL Consumption Database → Simulation Parameter → Maintenance Planning Document
Direct Monitoring Systems

Fibre Bragg Input

USG waves input

Global SHM solution
Guided wave - Damage Identification

Wave Propagation

Data Acquisition

Feature Extraction

Pattern Recognition

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
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
Highlights
Up to 5% weight saving is achievable

Highlights
E2E Evaluation

Point to Point
Fleet Size: 104 A/C
Legs/day per A/C
Legs/haul length
Average fleet age: 8.9 yrs

Large Hub & Spoke
Fleet Size: 200 A/C
Legs/day per A/C
Legs/haul length
Average fleet age: 11.3 yrs

Small Hub & Spoke
Fleet Size: 50 A/C
Legs/day per A/C
Legs/haul length
Average fleet age: 12.4 yrs

Clean Sky2
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

1 The shown results are potentials per year that need to be exploited.
Highlights
AAM2019 Dissemination event

- Approximately 60 external visitors came to the conference and market place
- Over 100 people participated on the conference
Steps after Open Guided wave

http://openguidedwaves.de/

Ultrasonic Guided Waves
An Open Access Data Set

TRANSPARENT
Who did what, when and how? Every task tracked.

RELIABLE
Collaborators from different research groups with wide-ranging expertise.

OPEN
Free access for EVERYONE!

IMPROVE YOUR RESEARCH
Rely on Collective Data, Emphasise Your Work!

As importance of ultrasonic guided waves is growing rapidly, new signal evaluation techniques occur almost on a regular basis. Unfortunately, they often lack real data testing or at least comprehensible data acquisition. To enable comparisons of evaluation methods on a mutual basis, this website provides a transparent data set of real wide-range measurements. As it is freely available we explicitly encourage everyone to test their own algorithm with the provided data and include the results in their publications.
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