Towards a Unified Predictive Maintenance System - A Use Case in Production Logistics in Aeronautics

Karl Hribernik
BIBA - Bremer Institut für Produktion und Logistik GmbH
7th International Conference on Through-life Engineering Services
Cranfield University, UK, 06.11.18
Agenda

1. Introduction
2. Background & Motivation
3. Requirements Definition
4. Solution Approach
5. UPTIME Components
6. Preliminary Results
7. Next Steps
General Information

- **Topic**: FOF-09-2017
  Novel design and predictive maintenance technologies for increased operating life of product systems

- **Type**: IA

- **Duration**: 36 Months

- **Start**: 01.09.2017

- **End**: 31.08.2020

- **Total costs**: € 6,248,367.50

- **Max grant**: € 4,847,836.25
  (77.59% of total costs)

- **PO**: Ivan Scannapiecoro
A350 Wing Upper Cover
Transportation Jig

- Asset characteristics
  - Mainly *aluminum*, large but light
  - *Sensitive* to vibrations, mishandling, weather conditions, humidity
  - Transported goods *sensitive and valuable*

- Transport conditions
  - *Sea, road and air transport*
  - *Harsh environmental conditions* (snow, salt water, ice, ...)
  - Little to no feedback on effects of transport
  - Sometimes *careless* loading and unloading
Background & Motivation

- **A damaged jig can prohibit transport**
  - Penalties from the customer
  - Damage to the wing cover

- **High effort to ensure operational reliability:**
  - **Airworthiness** ensured by extensive, mandatory pre-flight checks
  - **High effort for** corrective and preventive maintenance
  - **Mishandling** is difficult to detect
  - **No spare jigs available**

- **Unforeseen** maintenance has to be done on-site
  - **Volatile and very short term notification** for maintenance slots
  - Diagnosis and maintenance on-site further delays transport
  - **Unknown asset condition** leads to inefficient maintenance preparation
  - Time and effort to deploy personnel and equipment

- **No feedback** to FFT design team
## Stakeholders in the production logistics processes, their information and decision support needs

<table>
<thead>
<tr>
<th>Stakeholder</th>
<th>Information Needs</th>
<th>Decision Support Needs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jig Designers</td>
<td>▪ Information about recurring problems</td>
<td>▪ Advice on what problem areas to focus on for continuous improvement of jig design</td>
</tr>
<tr>
<td>Jig Manufacturer Maintenance Coordinator</td>
<td>▪ Quick notification about wear and potential damages</td>
<td>▪ Suggestions for preventive maintenance activities</td>
</tr>
<tr>
<td></td>
<td>▪ Analyses of recurring faults and problems</td>
<td>▪ Suggestions for continuous improvement of maintenance procedure</td>
</tr>
<tr>
<td>Jig Manufacturer Maintenance Technician</td>
<td>▪ Information supporting pre-load checks</td>
<td>▪ Support for assessing jig condition during pre-load checks</td>
</tr>
<tr>
<td>OEM Logistics Coordinator</td>
<td>▪ Requires transparency about jig status to efficiently coordinate the logistics chain</td>
<td>▪ Support in planning logistics chain</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ Support for commissioning jigs to transports</td>
</tr>
<tr>
<td>3rd Party Logistics Service Providers</td>
<td>▪ Requires transparency about jig status for logistics operations execution</td>
<td>▪ Support for the execution of logistics operations, such as loading, unloading and transport</td>
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### Critical conditions and potential means of monitoring

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Reason for monitoring/prediction</th>
<th>Potential means of monitoring/prediction</th>
</tr>
</thead>
</table>
| Weather conditions  | ▪ Rain and snow may collect on or in the jig, leading to the creation of dangerous ice in sub-zero temperatures in flight  
▪ Large amounts of snow might put too much weight on the top weather protection | ▪ Humidity and water level sensors  
▪ Maintenance reports                                                                 |
| Transport conditions | ▪ Conditions on the road, in flight or at sea may adversely affect the jig  
▪ Excessive vibrations may damage the frame  
▪ Excessive strains can lead to damage of the main jig frame or top weather protection | ▪ Vibration sensors  
▪ Crack sensors  
▪ Strain gauges                                                                 |
| Mishandling         | ▪ Uncareful loading, unloading or handling may cause damaging impacts to the main jig or top weather protection  
▪ Incorrect loading and/or fixing the top weather protection on the main jig may lead to damages | ▪ Accelerometers  
▪ Pressure sensors monitoring the fixing points between main jig and top weather protection |
Definition of UPTIME unified predictive maintenance concept

- **ISO 13374** as implemented by MIMOSA OSA-CBM, RAMI4.0 for compliance with Industry 4.0 standards
- Phases of predictive maintenance and proactive computing
- Phases of industrial analytics maturity
<table>
<thead>
<tr>
<th>Phase</th>
<th>Component</th>
<th>Function</th>
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</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>SENSE</td>
<td>Data acquisition from sensors integrated into the jig</td>
<td>Flight mode</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Edge processing, buffering and filtering</td>
<td>Wireless communication with system</td>
</tr>
<tr>
<td>II</td>
<td>Detect</td>
<td>Real-time state/behaviour detection</td>
<td>Edge processing for on-site condition assessment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Health assessment of sections and of the entire jig</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>Predict</td>
<td>Prediction of section/jig condition (time-to-failure, RUL, etc.)</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>Decide</td>
<td>Decision support for continuous improvement</td>
<td>Pre-load assessment of jig condition</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Suggestions for preventive maintenance activities</td>
<td>Logistics chain planning support</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Suggestions for continuous improvement of maintenance procedures</td>
<td>Jig commissioning support</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Continuous update of FMECA model with critical failure modes</td>
<td>Logistics operation support</td>
</tr>
<tr>
<td>I-IV</td>
<td>FMECA</td>
<td>Integration and analysis of historical data from maintenance reports and enterprise systems</td>
<td></td>
</tr>
<tr>
<td>I-IV</td>
<td>Analyze</td>
<td>Component UIs with views for different stakeholders</td>
<td>Visualisation of warnings, recommendations from decision-support, analyses of all maintenance-related information on different levels of aggregation</td>
</tr>
<tr>
<td>I-IV</td>
<td>Visualize</td>
<td>Visualisation of conditions by fleet, jig and section</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Visualisation of historical data</td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>Stakeholders</td>
<td>Act on the information, analyses and recommendations</td>
<td></td>
</tr>
</tbody>
</table>
Solution Approach

- **UPTIME_SENSE** serves as a modular data acquisition and integration device framework [An extension of BIBA’s USG]
- **UPTIME_DETECT** and **UPTIME_PREDICT** detect and predict the state of a system [An extension of BIBA’s preInO]
- **UPTIME_DECIDE** proactively recommends maintenance actions and the plans [An extension of ICCS’s PANDDA]
- **UPTIME_VISUALISE** aggregates data, analyses and visualizes it [An extension of Pumacy’s SeaBAR]
- **UPTIME_FMECA** identifies failure modes, effects and criticalities based on the data [An extension of RINA’s DRIFT]
- **UPTIME_ANALYZE** ... [A new tool developed by Suite5]
UPTIME COMPONENTS

- **Prototype development platform** for designing and testing dedicated hardware solution
- **Used for test data acquisition** in customer approval process
- **Low-power solution** required for flight approval
- Based on **Texas Instruments SimpleLink CC2650 SensorTag**
  - BLE (Bluetooth low energy)
  - Sensor Controller
  - Micro Controller
  - Environment & motion sensors
  - Adalogger M0 Feather
  - GPS Shield
  - SD Card storage

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Flexible state detection and prediction engine:

- **Graphical flow editor**
  - Create custom flows
  - Save and load existing flows

- **Extensible algorithm library**
  - Plug-in system for algorithms
  - Definition of own algorithms

- **Flexible trigger mechanisms**
  - Automated recurring flow triggers
  - Event-based triggers

- **Output & export analysis results**
  - To influx database (UPTIME persistence module)
  - To other UPTIME modules (e.g. DECIDE)
### DECIDE Prototype
- Generates **actionable maintenance recommendations**
- Incorporates **predictive analytics output**
- Utilizes **artificial intelligence, optimization algorithms and expert systems in a probabilistic context**
- Provides **adaptive, automated, constrained, time-dependent and optimal decisions**
**UPTIME COMPONENTS**

- **UPTIME visualisation dashboard**
  - One-stop-shop for all UPTIME visualisation needs
    - Integration of UPTIME UI widgets into one web-based dashboard
    - Single sign-in
    - Roles and rights management
  - Stakeholder-specific views
    - Deep visualisation and customisation options
    - Intuitive data analysis
  - Prototype visualisation of use case data test campaign
    - Limited amount of test campaign data

**SENSE**
**DETECT/PREDICT**
**DECIDE**
**VISUALISE**
**FMECA**
**ANALYSE**

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Dynamic risk monitoring based on bowtie analysis

Prevention and mitigation measures consider
- DETECT/PREDICT alerts and prognoses
- DECIDE prevention measures

Failure mode probability takes into account
- Historical data analysis (ANALYSE)
- DETECT/PREDICT prognoses

Effect criticality considers
- Maintenance reports from DECIDE
- Analysis of historical data from ANALYSE
Interoperability with and analysis of historical maintenance data

Make historical maintenance data available to other UPTIME components

Semantic uplift to UPTIME data model

Data mining and analytics

Deep and flexible visualisation
Preliminary Results

LEGACY
PERSIST

ANALYSE
DECIDE
VISUALISE

DETECT
PREDICT

SENSE
Next Steps

- Finalisation of SENSE prototype and field tests
- Integration of SENSE with DETECT/PREDICT for health assessment/prognosis
  - Integration of select DETECT/PREDICT functionality into SENSE for edge analysis capabilities
  - Health assessment directly on the jig
- Integration of all components into UPTIME platform
  - VISUALISE GUIs for different stakeholders on different devices
  - Integration into FFT maintenance management system (DECIDE) recommendations
- Test and evaluation
Thank You!

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 768634
Objective: Novel design and predictive maintenance technologies
Topic: FoF-09-2017
Call: H2020-FOF-2017
Lead: BIBA – Bremer Institut für Produktion und Logistik GmbH
Duration: 36 Months
Start: 2017/09

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