UPTIME
UNIFIED PREDICTIVE MAINTENANCE

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

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7th International Conference on Through-life Engineering Services

Cranfield University, UK, 06.11.18

Horizon 2020
European Union Funding
for Research & Innovation

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

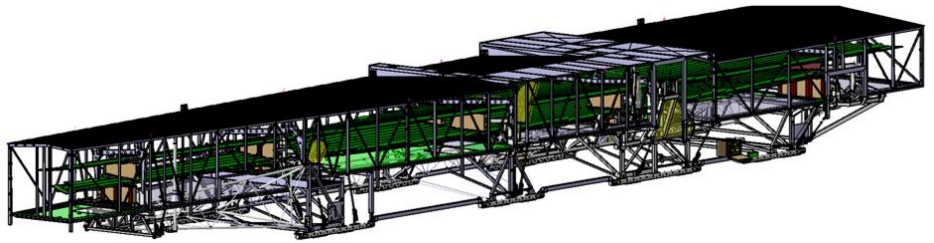
Background & Motivation

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



Requirements Definition

Stakeholders in the production logistics processes, their information and decision support needs

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

Requirements Definition

Critical conditions and potential means of monitoring

Conditions	Reason for monitoring/prediction	Potential means of monitoring/prediction
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

Solution Approach

	Phase I	Phase II	Phase III	Phase IV	Phase V
Predictive Maintenance	Signal Processing	Diagnosis	Prognosis (Failure Mode Analysis)	Decision Making	
Proactive Computing		Detect	Predict	Decide	Act
Industrial Analytics Maturity	Monitor	Diagnose and Control	Manage	Optimise	
MIMOSA OSA-CBM (ISO 13374)	S1 - Data Acquistion S2 - Data Manipulation	S3 - State Detection S4 - Health Assessment	S5 - Prognosis Assessment	S6 - Advisory Generation	
UNIFIED PREDICTIVE MAINTENANCE CONCEPT	VISUALIZE				MAINTENANCE STAKEHOLDERS
	SENSE	DETECT	PREDICT	DECIDE	
	FMECA				
	ANALYZE				

- 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

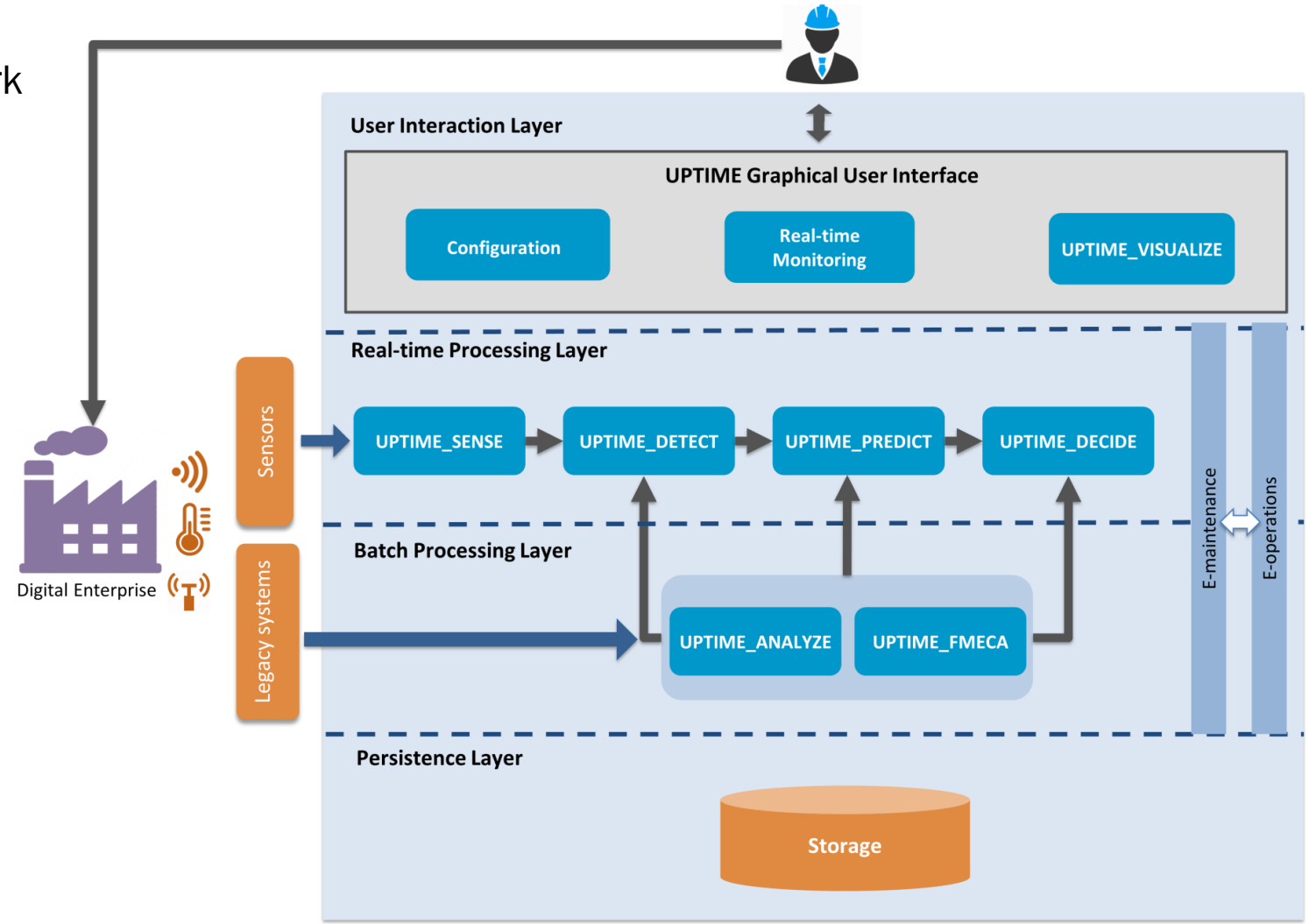
Solution Approach

Functions required by the use case by Unified Predictive Maintenance Approach phase and component

Phase	Component	Function	
I	SENSE	▪ Data acquisition from sensors integrated into the jig ▪ Edge processing, buffering and filtering	▪ Flight mode ▪ Wireless communication with system
II	Detect	▪ Real-time state/behaviour detection ▪ Health assessment of sections and of the entire jig	▪ Edge processing for on-site condition assessment
III	Predict	▪ Prediction of section/jig condition (time-to-failure, RUL, etc.)	
IV	Decide	▪ Decision support for continuous improvement ▪ Suggestions for preventive maintenance activities ▪ Suggestions for continuous improvement of maintenance procedures	▪ Pre-load assessment of jig condition ▪ Logistics chain planning support ▪ Jig commissioning support ▪ Logistics operation support
I-IV	FMECA	▪ Continuous update of FMECA model with critical failure modes	
I-IV	Analyze	▪ Integration and analysis of historical data from maintenance reports and enterprise systems	
I-IV	Visualize	▪ Component UIs with views for different stakeholders ▪ Visualisation of conditions by fleet, jig and section ▪ Visualisation of historical data	▪ Visualisation of warnings, recommendations from decision-support, analyses of all maintenance-related information on different levels of aggregation
V	Stakeholders	▪ Act on the information, analyses and recommendations	

Solution Approach

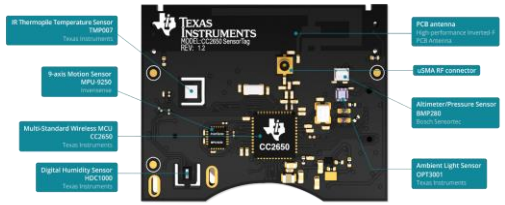
- UPTIME_SENSE serves as a modular data acquisition and integration device framework
  [An extension of BIBA's USG]
- UPTIME_ DETECT and UPTIME_ PREDICT detect and predict the state of a system
  [An extension of BIBA's preIn0]
- UPTIME_ DECIDE proactively recommends maintenance actions and the plans
  [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]

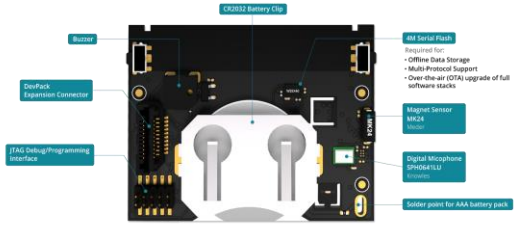


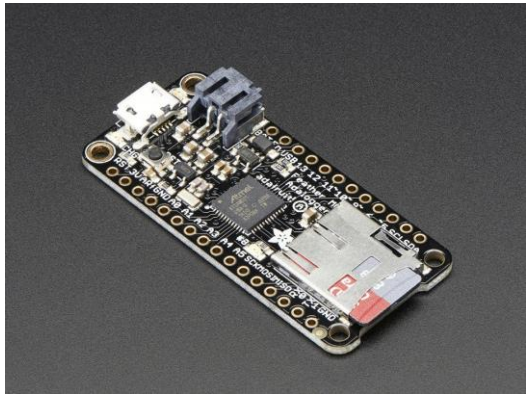
Simplified view of the UPTIME draft architecture

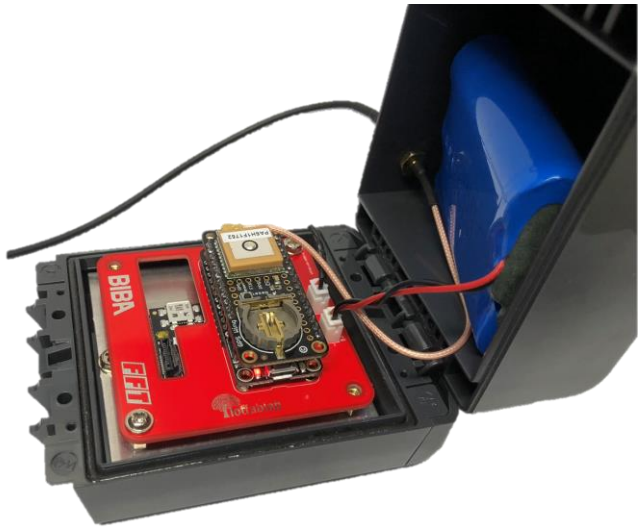
UPTIME COMPONENTS

- 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







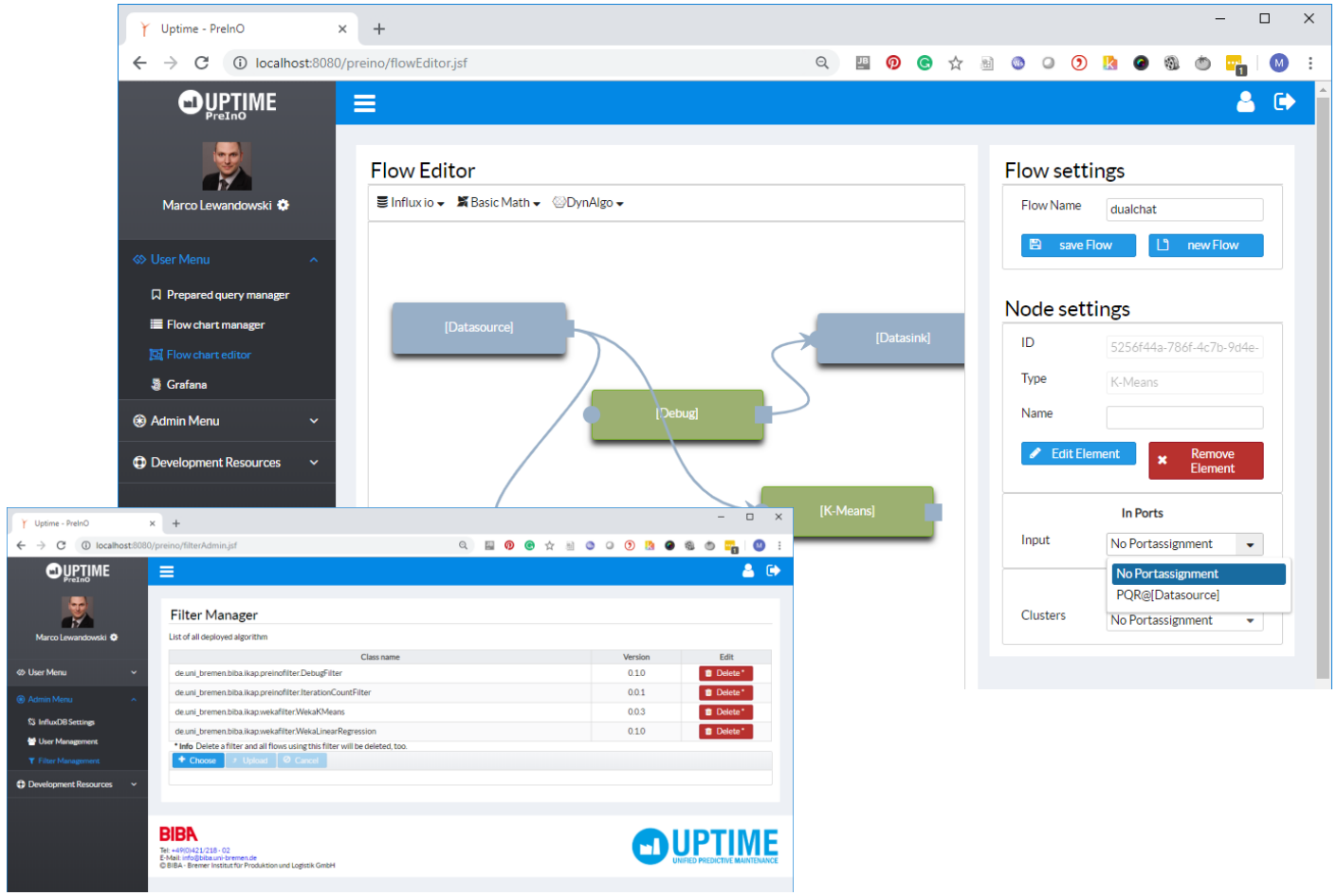


SENSE | DETECT/PREDICT | DECIDE | VISUALISE | FMECA | ANALYSE

UPTIME COMPONENTS

Flexible state detection and prediction engine:

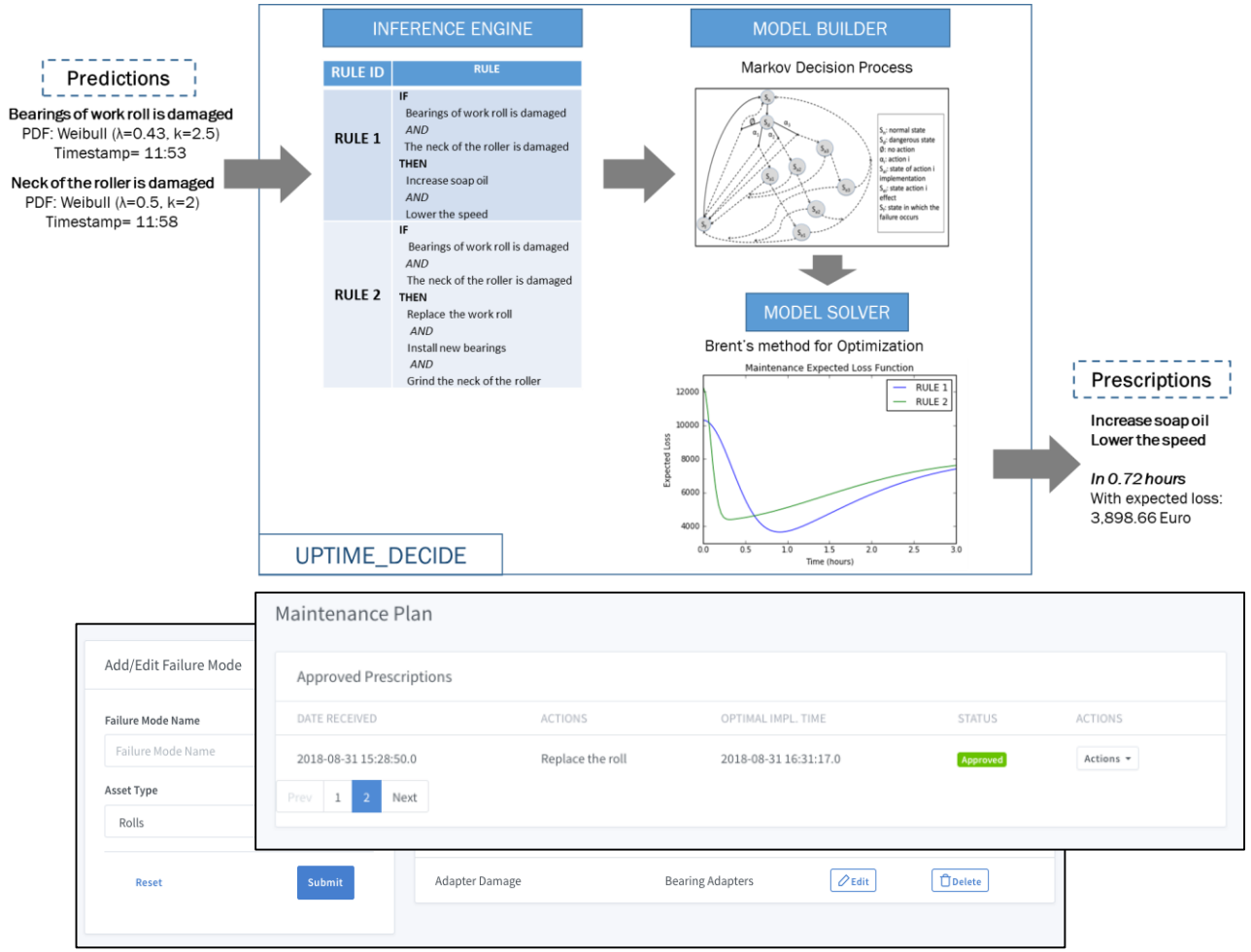
- Graphical flow editor
  - Create custom flows
  - Save and load existing flows
- Extensible algorithm library
  - Plug-in system for algorithms
  - Definition of own algorithms
- Flexible trigger mechanisms
  - Automated recurring flow triggers
  - Event-based triggers
- Output & export analysis results
  - To influx database (UPTIME persistence module)
  - To other UPTIME modules (e.g. DECIDE)



Flow Editor and Filter/Algorithm Management screens in UPTIME_DETECT/PREDICT (M9)

UPTIME COMPONENTS

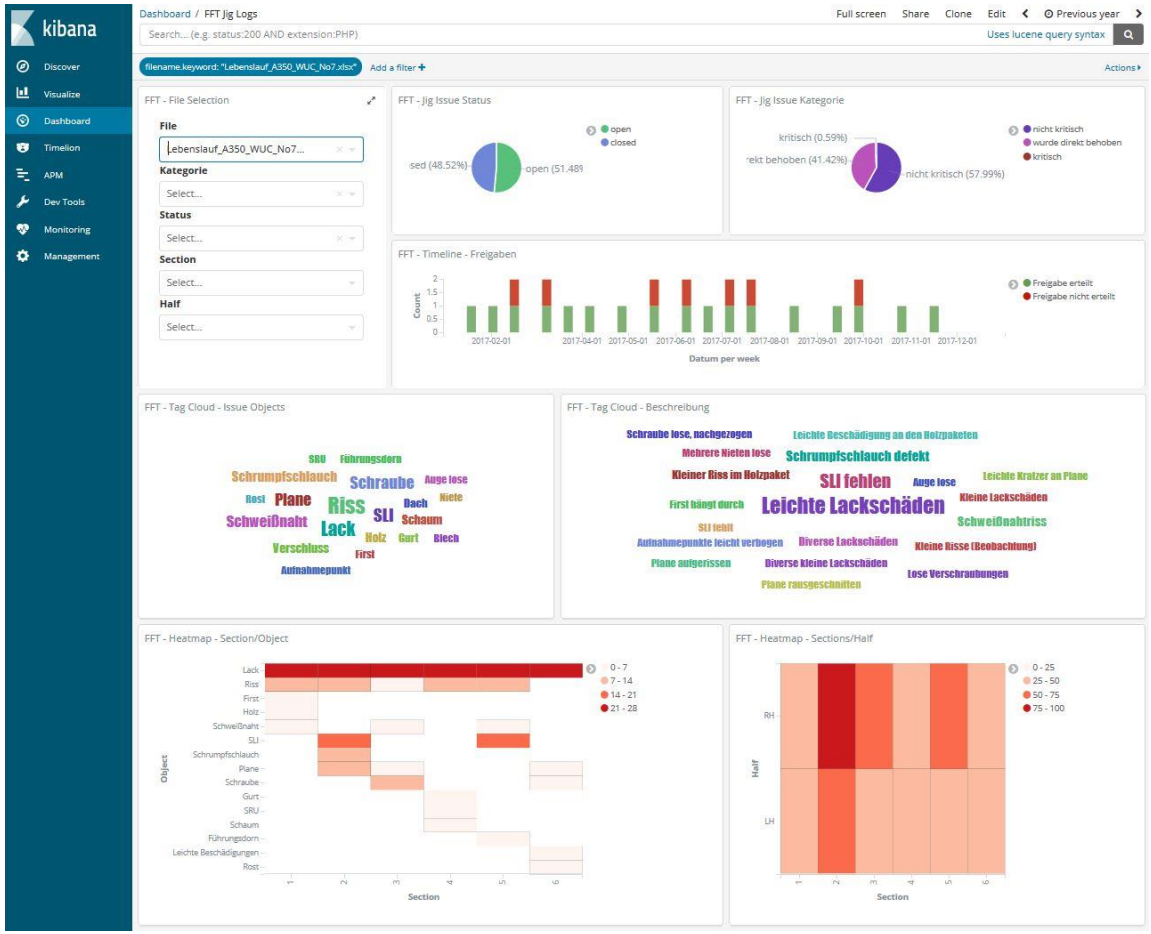
- DECIDE Prototype
  - Generates actionable maintenance recommendations
  - Incorporates predictive analytics output
  - Utilizes artificial intelligence, optimization algorithms and expert systems in a probabilistic context
  - Provides adaptive, automated, constrained, time-dependent and optimal decisions



Failure Modes, Rules and Maintenance Plan screens in UPTIME_DECIDE (M9)

UPTIME COMPONENTS

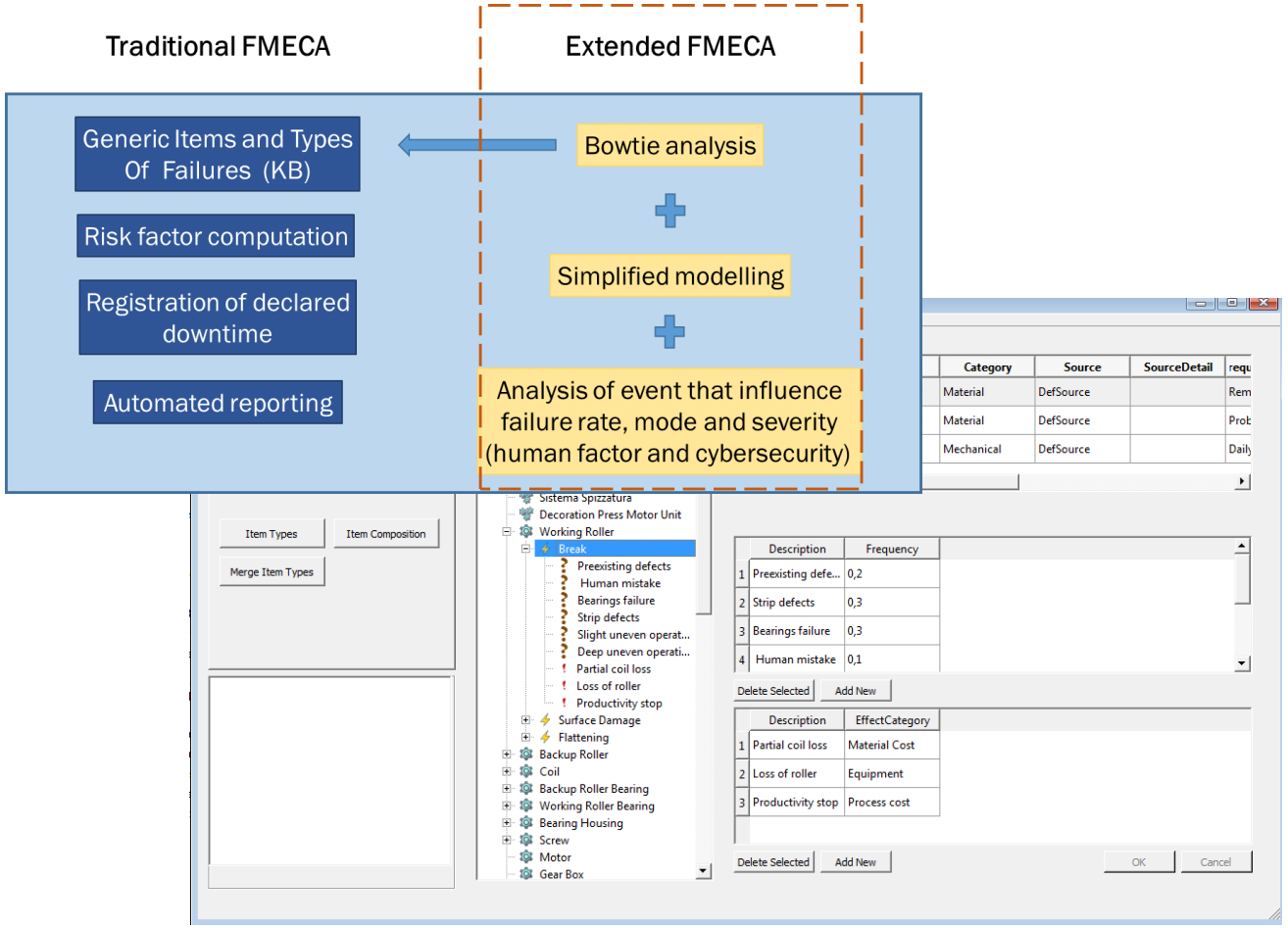
- UPTIME visualisation dashboard
  - One-stop-shop for all UPTIME visualisation needs
    - Integration of UPTIME UI widgets into one web-based dashboard
    - Single sign-in
    - Roles and rights management
  - Stakeholder-specific views
    - Deep visualisation and customisation options
    - Intuitive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



UPTIME_VISUALISE dashboard prototype (M9)

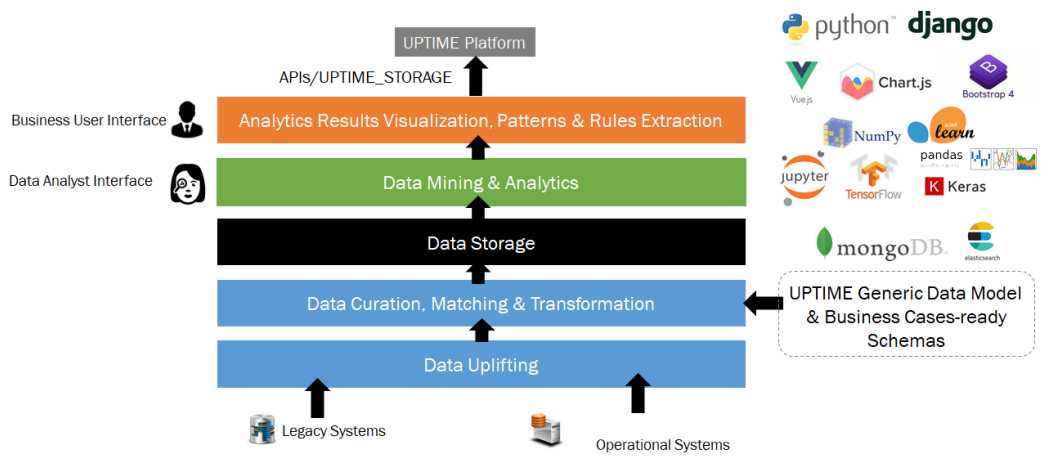
UPTIME COMPONENTS

- 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

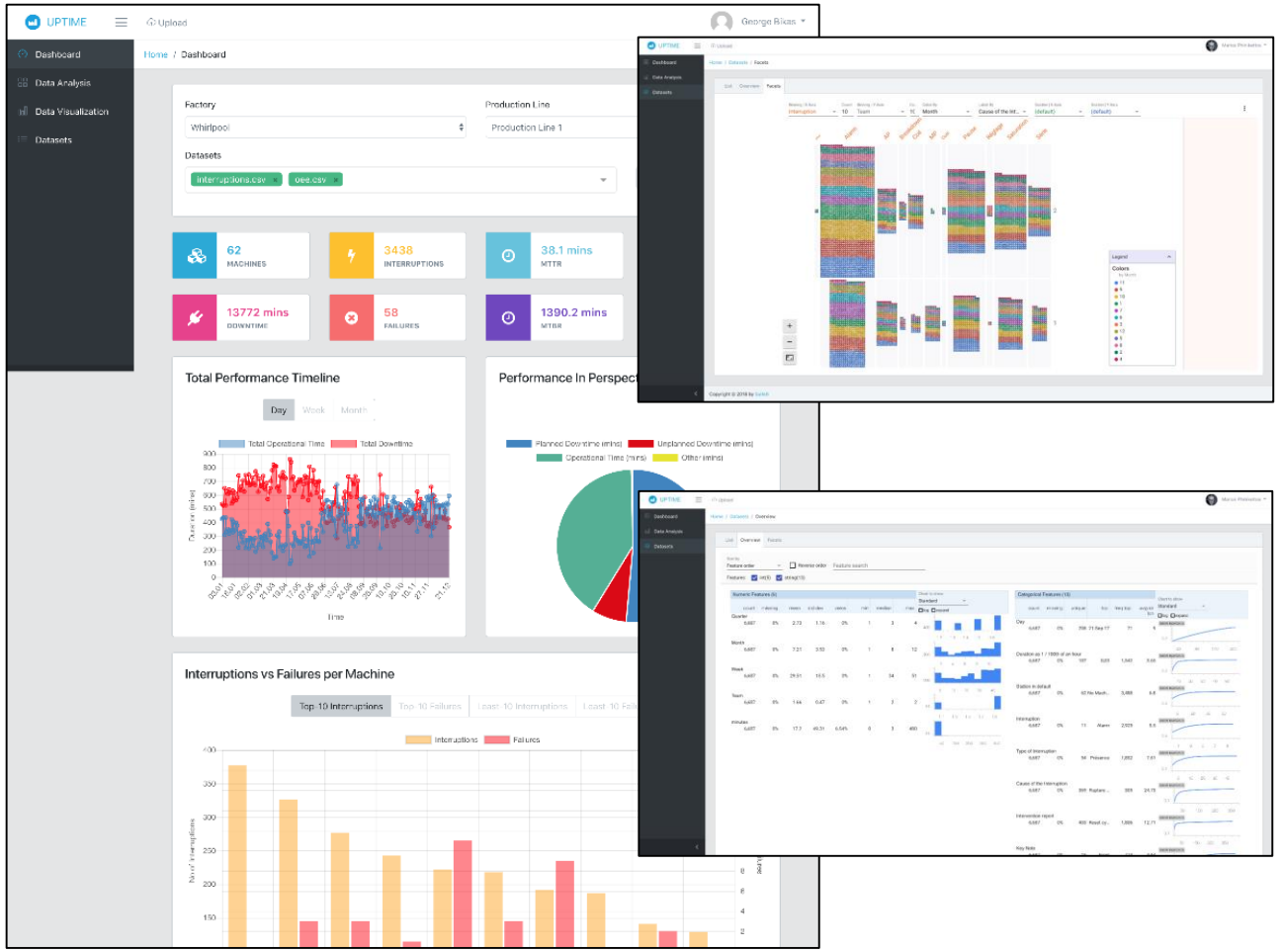


Extended FMECA concept/Prototype UPTIME_FMECA component (M12)

UPTIME COMPONENTS



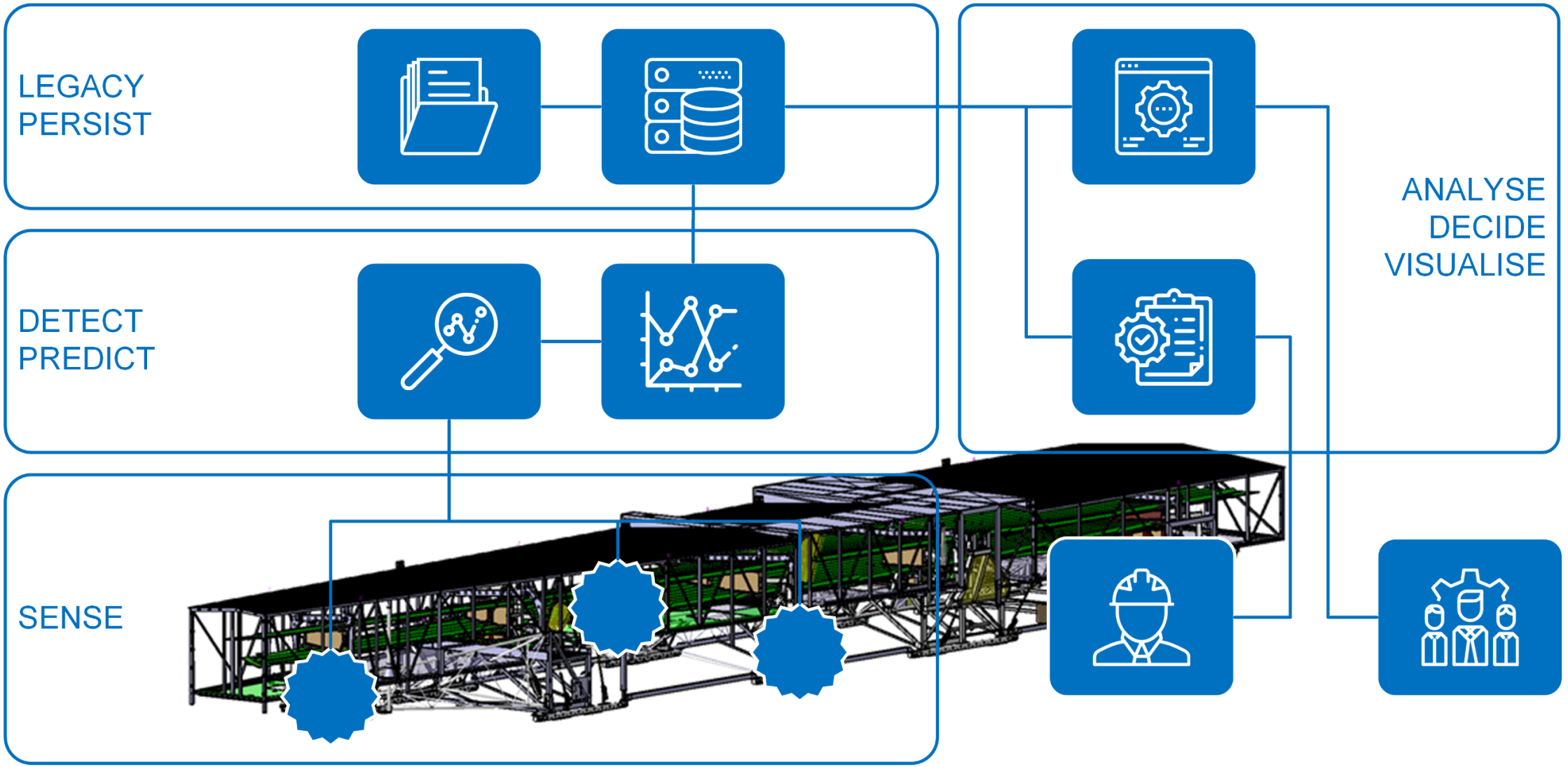
- Interoperability with and analysis of historical maintenance data
- Make historical maintenance data available to other UPTIME components
- Semantic uplift to UPTIME data model
- Data mining and analytics
- Deep and flexible visualisation



UPTIME_ANALYSE dashboard, dataset facets and dataset navigator screens (M9)

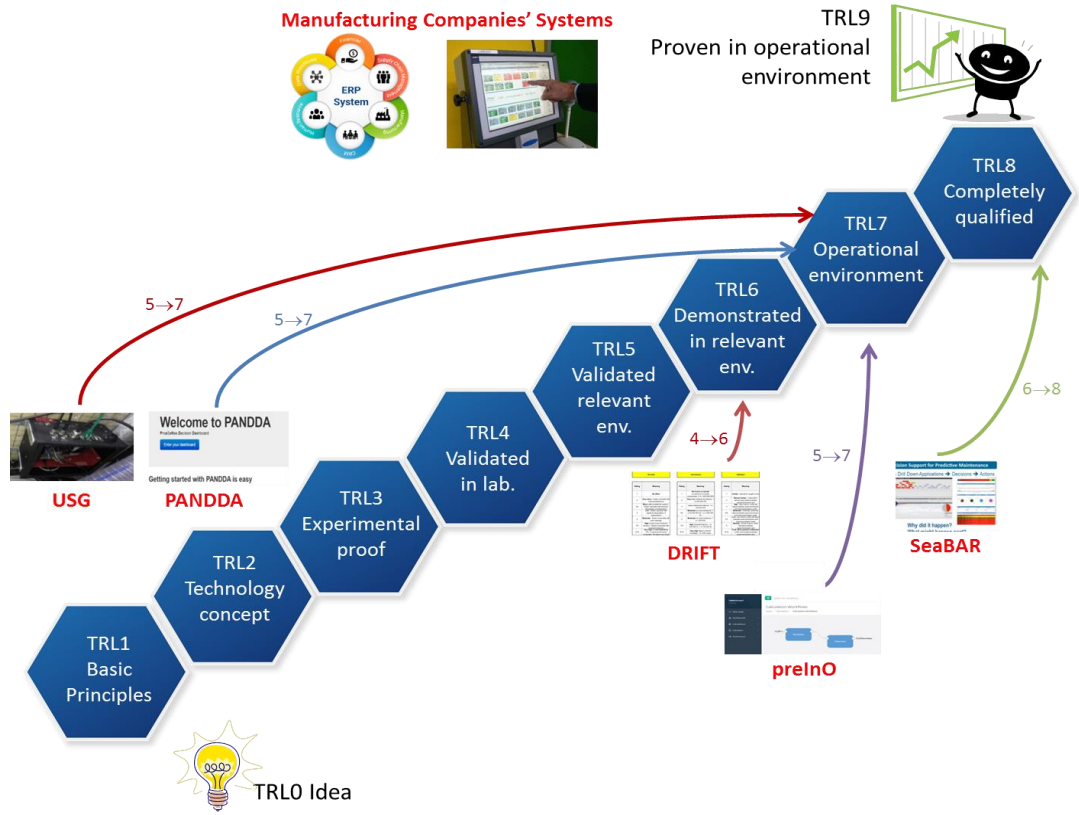
SENSE | DETECT/PREDICT | DECIDE | VISUALISE | FMECA | ANALYSE

Preliminary Results



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*

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- **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