UPTIME
UNIFIED PREDICTIVE MAINTENANCE

Project No: 768634

Call: H2020-FoF-2017

Topic: FoF-09-2017

Type of Action: IA

Duration: 01.09.2017 – 31.08.2020

Deliverable 4.1
FFT Business Case, Conceptualization and Evaluation Strategy

Lead Beneficiary	FFT
Type of Deliverable	Report
Dissemination Level	Public
Submission Date	04.07.2018
Version no.	1.0

Versioning and contribution history

Version	Description	Contributions
0.1	Deliverable Table of Contents	Pierluigi Petrali (Whirlpool), Fenareti Lampathaki (SUITE5)
0.2	First draft	Jeroen Versteeg (FFT)
0.3	Second draft – update according to feedbacks and inputs from peer reviewer	Jeroen Versteeg (FFT)
0.4	Review on business case requirements	Moritz von Stietencron, Karl Hribernik (BIBA)
0.5	Update of business case requirements, update risk assessment and mitigation plan	Jeroen Versteeg (FFT)
1.0	Final editing and formatting	Indah Lengkong (BIBA)

Reviewer

Name	Organisation
Alexandros Bousdekis	ICCS

Table of Contents

List of Figures

List of Tables

List of Abbreviations

FMECA	Failure Mode Effect and Criticality Analysis
FFT	FFT Produktionssysteme GmbH & Co. KG
KPI	Key Performance Indicator
MTBF	Mean Time between Failures
MTTR	Mean Time to Repair
OEE	Overall Equipment Effectiveness
OEM	Original Equipment Manufacturer
OOE	Overall Operational Efficiency
PLC	Pre-loading Check
PLC	Programmable Logic Controller
PFC	Pre-flight Check
UPTIME	Unified Predictive Maintenance System
USG	Universal Sensor Gateway
USP	Unique Selling Point
WUCTJ	Wing Upper Cover Transportation Jig
WLCTJ	Wing Lower Cover Transportation Jig

Executive Summary

As one of the three industrial partners in the UPTIME project, FFT aims to improve the maintenance workflow of a large mobile asset, specifically the Wing Upper Cover Transportation Jig, by transforming its maintenance strategy to predictive maintenance. This jig is used by Airbus to transport large components of aircraft wings over land, water and in the air (in the Beluga transport aircraft).

Due to the mobility and complexity of the asset, it is affected by a large number of environmental influences and has many potential failure modes. Any failure delaying the continued usage of the jig according to the plan is potentially costly and can severely impact the production process of the end user. Additionally, since the asset is usually in transit, any maintenance or repair tasks must be carefully planned to be completed in a defined time window on a defined location, in order not to negatively affect the production process.

In the context of FFT's participation in the UPTIME project, the objective is to demonstrate a solution to many of the challenges arising from maintaining the transportation jig by implementing and using the UPTIME framework and information system. Concretely this means that FFT will contribute the following to UPTIME within the consortium: (1) implementing and installing an UPTIME sensor platform on the asset; (2) provide real condition data to UPTIME; (3) contribute to the development of the sensor platform; (4) help optimise the UPTIME feature set by defining requirements from the industrial perspective.

The goal within the use case is to attain comprehensive, continuous and up to date data on the condition of the mobile asset, automatically process this information to obtain actionable information and make it available to the affected stakeholders in different forms to enable them to optimise their workflows. The expected results include:

(1) dramatically increased maintenance efficiency by being able to tailor a maintenance action exactly to the condition of the asset beforehand (including preparing parts and equipment);

(2) by continuous monitoring get valuable insights on environmental stress factors and failure modes, to predict the health of the asset in advance and to conceive design or behavioural solutions to inhibit failure modes;

(3) offer valuable asset condition data on-demand to the end user and possible other stakeholders as a highly useful feature of a maintenance contract.

1 Introduction

This Introduction section introduces purpose and objectives of the Deliverable 4.1 “FFT Business Case, Conceptualisation and Evaluation Strategy”. Moreover, adopted approaches and an overview of the relation to other Work packages or tasks are provided in the following sub-sections. A structure of the deliverable is introduced at the end of this chapter.

1.1 Purpose and Objectives

The Deliverable 4.1 aims to describe in detail FFT’s business case in the UPTIME project. All significant factors, from the choice of the particular project content to the expected benefits to the implementation strategy, are covered in this deliverable.

A detailed description of the as-is situation related to the project is offered, as well as a detailed concept of the envisioned technical result in terms of the UPTIME implementation and deployment in context of the FFT business case. The requirements to be fulfilled to achieve this vision are detailed to enable the consortium partners to design and develop their respective modules such that it can be successfully integrated by FFT, and likewise for the other industrial partners.

Further, this deliverable describes the strategy and methodology used to usefully evaluate the project outcome, and suggestions are made how further development and deployment of UPTIME can benefit the consortium partners, the state of the art of predictive maintenance generally and (potential) UPTIME users in particular.

1.2 Approach

To design and implement the UPTIME platform and to satisfy the respective requirements of the consortium partners and the intended future target audience, the UPTIME consortium has defined the responsible partners for all modules implementing the required functionalities. These requirements are defined in detail in this document for the FFT business case, and in analogue documents for the other business cases and component owners.

To enable a focused and parallel development process, the consortium partners are clustered in work groups, which can initially cover the most crucial aspects of design and prototyping for the respective business cases. In this fashion, each business case can be supported by the component owner providing its most significant functionality while providing the necessary inputs for the definition of the required functionality to be implemented.

Through intensive and continuous communication within the entire consortium, it is ensured that the interfaces and knowledge remain transparent and that frequent knowledge transfer takes place.

For FFT’s business case, a detailed definition of the requirements of the business case is completed. This definition is based on the identification of as-is processes in the business case (while as much as possible taking into account broader applicability) which have improvement potential by application of IT-based approaches. In order to be able to make swift progress, the work has been focussed on the implementation of the USG and its applicability to mobile assets, as well as the processing and presentation (dashboarding) of the data relevant to obtaining maintenance KPI and making maintenance decisions. The implementation of these functionalities is ongoing in working groups consisting of FFT and the respective component owners. This prioritisation is also expected to lead to the earlier availability of representative data sets for the other components, so they can be implemented and tested with diverse data, to ensure generic compatibility and functionality.

1.3 Relation to UPTIME WPs and Tasks

This document describes the business case and related UPTIME conceptualisation for WP4. As such, it defines the vision what UPTIME is expected to provide to satisfy the requirements of the FFT business case and thus serves as an input for the conceptualisation of the work packages responsible for the UPTIME components and their associated tasks and deliverables.

FFT's Business case will be developed and implemented in close cooperation with the other pilots (WP5 and WP6), UPTIME components (WP3) as well as - the UPTIME architecture (WP2 - defined in D2.1a Conceptual Architecture and System Specification).In turn, the tasks in the other WPs define their respective scopes and functionalities, and provide input on the envisioned architecture. Since this is a two-way relationship, integration toward a unified platform is an iterative process.

1.4 Structure of Deliverable

The goal of the Deliverable 4.1 is to define the business case of WP4. First, the top level objectives are introduced. This includes the business objectives, the fulfilment of which is one of the reasons to participate in the UPTIME project, as well as the objectives related to FFT's active contribution to the development of the UPTIME platform.

Chapter 2 describes the context of the business case, the organisational reasons at the basis for the vision (section 2.1), which describes what kind of system would optimally address the identified challenges of the current business process (section 2.3), as well as the detailed scenario or a description of the business processes, the environment and actors (section 2.2).

Chapters 3 and 4 address the requirements resulting from analysis of the business process and vision, and the concept on how UPTIME is envisioned to fulfil these requirements.

Chapter 5 deals with the evaluation of the business case, or rather the evaluation of the performance of the UPTIME platform with respect to fulfilling the requirements of the business case and the achievement of the expected benefits.

The implementation roadmap and project plan with respect to WP4 is presented in chapter 6, and finally the conclusions and outlook in chapter 7.

2 Business Case Context

FFT is a company whose core business is the design and realisation of production systems and test systems in both automotive and aerospace industries, as well as the maintenance of such systems, mainly in aerospace industry. Especially within the aerospace sector, FFT's maintenance activities are growing fast. Typical maintenance projects include both fixed (stationary production equipment, test rigs) and mobile assets (jigs and tools, transportation jigs). Since the production speed using this equipment is relatively low (cycle times range from a few days for aircraft to a few months for test campaigns), traditionally a low degree of automation is implemented on the equipment, both for application and maintenance purposes. Additionally, a lot of equipment used in aircraft assembly lines has not significantly changed over the last decades due to established and certified workflows. Hence, the potential to optimise processes involving this equipment by a higher degree of automation is large.

The drive for efficiency increase and cost reduction which is a general trend in industry, increases the need to "do more with less", which in case of aircraft production is a direct result of increased production rate requirements with a minimum increase of equipment. For most of the mentioned maintenance projects, this translates to "keep the current hardware if possible, but increase availability" (necessary for reduced cycle times). In its role as maintenance service provider, FFT is in a position to optimise maintenance processes and propose relevant modifications to the customer, which can increase maintenance efficiency and effectivity to reach this goal.

FFT's business case in context of the UPTIME project focuses on the maintenance of mobile assets in use by the largest European aircraft OEM.

Inherently the mobile assets under consideration are subjected to a relatively wide range of external influences affecting their condition. The type of asset for the first demo case is a large transportation jig for major aircraft wing shells (Wing Upper Cover Transportation Jig, or WUC Jig), which is used for road, water and air (Beluga) transport. Since the cargo hold of the Beluga transport aircraft is not pressurised or air-conditioned, the transportation jig is subjected to extreme temperatures (-60 to +50 °C) additionally to a multitude of loads, shocks and weather influences.

Due to the fact that both production and logistics schedules can be significantly affected by the availability and plannability for transportation jig deployment, the benefit of having comprehensive condition information about the jig is potentially very high.

Further, the accessibility of asset condition data to all involved stakeholder groups, whereby the specific access permissions and data representation is customised toward the role of the respective stakeholders, is a significant enabler for a highly optimised handling and maintenance workflow, as well as an attractive selling point for comprehensive maintenance contracts.

Summarising, the objective FFT has within the UPTIME context is for the UPTIME platform to deliver a comprehensive awareness of asset condition data by implementing capability to measure, record, aggregate, filter, assess and represent this data within an integrated platform for the purpose of making maintenance operations more efficient and effective.

2.1 Business Vision for Predictive Maintenance

FFT's typical maintenance activities include the turn-key maintenance of assembly lines, test centres (typically containing a collection of mid-sized to large test rigs) and collections of mobile assets, e.g. mobile equipment used in assembly lines. In some cases (such as the subject of this business case), FFT is also the manufacturer of the equipment under maintenance.

Ideally, effective predictive maintenance within the (typical) FFT scope for mobile assets is based on two major features:

1. Continuous availability and accessibility of comprehensive and recent condition data of the assets under maintenance,
2. Reliable post-processed and automatically analysed information that provides actionable results for maintenance operations.

In effect this means on one hand highly automated facilities for data acquisition, and on the other hand the capability to automatically make recommendations for maintenance actions based on configurable rules.

The capability to post-process data intelligently and user-definable, additionally should provide the possibility to present role-dependent views of the asset status. This enables respective stakeholders to get the representation of the asset condition which is optimally suitable to perform their tasks, on-demand, and offers the service provider a possibility to present a role-based selection of data to other stakeholders which may be limited for strategic or confidentiality reasons. Inherently the envisioned data processing and representation capabilities should offer extensive and versatile automatic reporting possibilities, thereby significantly reducing reporting efforts traditionally conducted by project managers and other team members.

From a maintenance point of view this means a potentially drastic increase of efficiency and productivity, because it enables advanced preparation of maintenance teams including pre-ordering of spare parts, thereby reducing downtimes. This is especially crucial for mobile assets which are maintained on geographically dispersed locations, as is the case with many assets under FFT management.

A top-level topology to be able to fulfil the mode of operation according to this vision is illustrated in Figure 2-1.

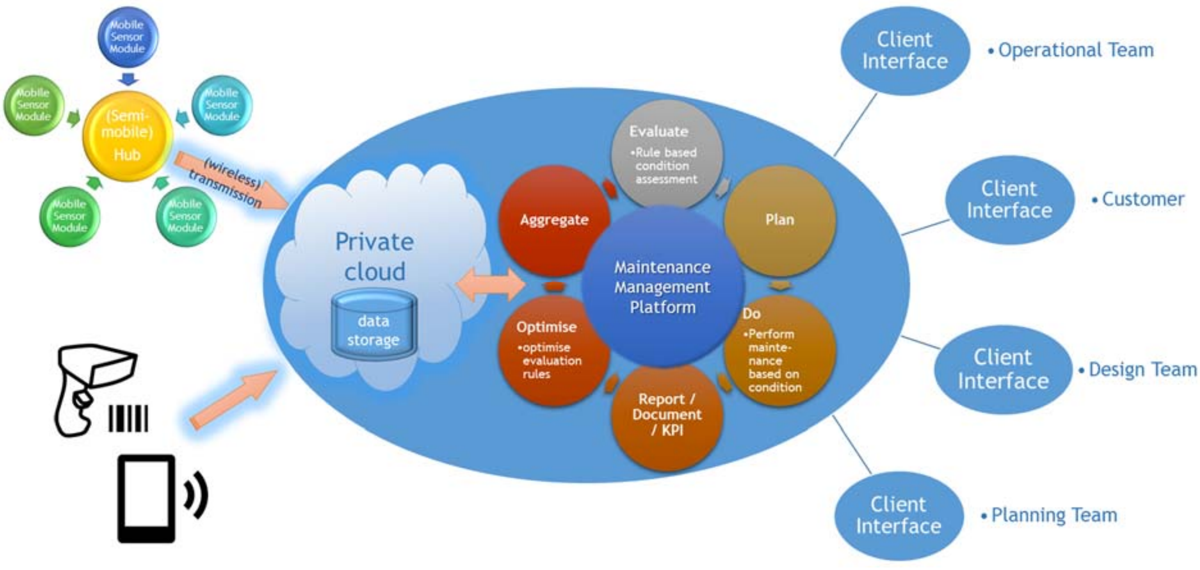

Figure 2-1: Top-level system topology example covering the required functionality

This topology represents a qualitative conceptual structure to identify the top level functions and improved workflows envisioned to be provided by UPTIME.

The basic topics to be addressed (as depicted in Figure 2-1 from left to right) are:

1. Automatic recording of physical quantities representing environmental conditions or damages;
2. Mobile capabilities of the sensor based data acquisition functionality (top left);
3. Semi-automated input (bar code scanning, user input in forms, e.g. on tablet) of assessments or activities on the asset;
4. Collection and central storage of all asset data;
5. Capability to programmatically (through a “Maintenance Management Platform”) support the main processes:
    a. Aggregate and filter pluriform data to enable useful status assessments
    b. Offer (semi-)automatic (rules-based) evaluation of available data to provide clear (health) status information
    c. Provide an HMI to support planning based on the data evaluation and to store planning data in the database
    d. Generate dashboards and reports to assess the performance of all processes
    e. Offer a way to continuously optimise the processes based on the results. For automatic functionalities such as rules based data evaluation this means a user interface to configure the evaluation rules and process.
6. Capability to offer role-based user interfaces to interact with the Maintenance System containing the data and processes. This means based on the role of the user, he will be presented with a different interface containing the information suitable or authorised for his work scope. Potential users include all stakeholders, e.g. customer manager, maintenance manager, maintenance operators, equipment design engineers, maintenance provider

management, customer's procurement managers (to monitor contract fulfilment), etc. The roles depicted in Figure 2-1 are examples and not exhaustive.

7. The "Maintenance Management Platform" as described here is also thought to include FFT's in-house asset management and maintenance platform "FFT Maintain". It is envisioned, that FFT Maintain is used for asset inventory, maintenance planning and dashboarding (i.e. planning, logistics and project overview/KPIs), and UPTIME for all individual asset related topics. The relevant interfacing is significant to consider and to cover within the UPTIME project realisation.

It is the expectation that UPTIME will provide a unified system offering these functionalities.

2.2 Business Scenario - Transportation Assets

FFT's business scenario will focus on large transportation jigs (cf. Figure 2-2), consisting of a steel structure (the so-called main jig) and an associated light-weight roof component (Top Weather Protection) made from aluminium profiles. The asset is 40m long with an empty weight of around 2350 kg and was designed to transport wing covers of a commercial aircraft between plants of a transnational manufacturer in Germany and the United Kingdom. During its journey, the asset is moved by different means of transportation on land, water, and air. All these environments impose different kinds of stress on the asset.

Concerning their specific environments each of these transportation modes comes along with individual requirements and impacts with respect to health monitoring of the asset. While live monitoring through mobile connectivity is possible on land and water, any transmissions functions must be disabled when the asset is aboard the cargo plane to comply with airworthiness regulations. Other issues to be considered during operation of the transportation asset (or transportation jig) covers the loading/unloading of aircraft parts as well as the assembly/disassembly of the asset after loading or prior of unloading of aircraft parts (attaching/detaching the top weather protection on the main jig). Furthermore, load/unload procedures between the different legs of the journey should be observed with respect to potential damages of the asset.

Figure 2-2: Transportation asset (WUCTJ) with inserted payload (green)

Indeed, there are many situations where damages can occur – often such damages will remain undetected and have to be addressed by urgent repair activities in order to keep the transportation in operation – particularly with respect to its airworthiness. Unfortunately, FFT as the manufacturer of the transportation asset, who is in this case also responsible for its maintenance, will see the assets only at the beginning as well as end of a transportation cycle on the German site and can neither anticipate the needed measures to prepare the asset for the next cycle nor are any information available which indicates any kind of damages – such as mishandling of the asset during the loading and unloading between different transportation modes.

2.2.1 UPTIME support for the aviation use case

Although the maintenance approach foresees a number of maintenance activities which are done either regularly after each transportation cycle or periodically, there are many unplanned repair activities which have to be done on short notice. Particularly such unplanned activities are targeted by the analysis of data which have been measured before and uploaded to the UPTIME system. Data of interest for the analysis are provided by sensors directly attached to the asset - such as strain gauges, location sensing devices, noise detectors, and shock detectors as well as sensors for temperature and humidity.

These data will then be used to get information about special events during the multiple transport and loading processes (truck, ship and airplane). Lots of maintenance efforts are assumed to be caused by such events. Except for obvious damages during loading/unloading processes, it is difficult to detect and exactly refer to the source of damage later. Particularly cracks in the lightweight structure of the transport asset can lead to non-availability of the asset due to strict regulations concerning the airworthiness of a transportation jig. Consequently, this will cause product delivery delays and airplane assembly delays and thus affects a complete value chain.

The most relevant events affecting the jigs fitness for operation are briefly described in the following:

- Weather conditions like rain and snowfall: Water may collect on either the payload or the tarpaulin covering the asset. It must be removed before loading the asset into the aircraft: as the cargo hold is neither pressurised nor air-conditioned, it would freeze and become a threat for flight safety.
- Road and flight conditions like potholes or air turbulences may cause vibrations and impacts which lead to deformations and cracks of the asset's light-weight frame construction.
- Mishandling, like unintended touching of the asset or its components with the surrounding environment during transportation or loading unloading causing structural deformations. Such situations may arise during attachment/detachment of the top weather protection if a wrong or not properly adjusted hoisting tool is used. Another reason is accidents which may happen while manoeuvring the assets in a narrow space. Such situations are not always reported which induces tremendous efforts to restore their operational readiness.

It is the objective, that the occurrence of these events can be identified and their effects measured by using the appropriate sensor technology. A list of planned sensors is presented in Table 2-1 (p. 19).

Due to the cyclic and mobile nature of usage of the transportation jig, continuous monitoring possibilities are limited (also due to the flight-mode and power-saving requirements which require suspension of data transmission), but can be valuable to avoid a situation where further usage should be avoided due to damages occurring between maintenance/assessment points. In such a case immediate repair or extra cautious handling may be necessary, and this information has to reach relevant parties somehow. In other words, it would be beneficial if the UPTIME system would make limited health assessments either offline or as soon as flight-mode is turned off or based on certain events, and inform the central UPTIME system and/or provide local feedback (on the jig) through physical indicators.

2.2.2 Stakeholders in the transport chain

In addition to the constant data monitoring and analysis, the system also has to consider and address the individual information needs of the different stakeholders in the value chain. To provide usable results for the different use cases each end user's business case has been carefully analysed during the first phase of the project. In general, three groups of stakeholders have been identified:

- The manufacturer of the transportation assets who is also responsible for their maintenance.
- The customer who is shipping aircraft parts between its European plants using the asset.
- Additional service providers who are involved e.g. in the road transportation phase of the asset's journey.

Related to these stakeholder groups several roles have been identified to be the most relevant users of the UPTIME system:

- The manufacturer's **designers** are very much interested in identifying problem hot-spots to derive design modifications for the current fleet as well as the design of future assets.
- The manufacturer's **maintenance coordinator** plans and coordinates scheduled as well as unscheduled maintenance events, and is also responsible for spare part logistics and communication with the customer. This role is interested in getting information about possible damages as soon as possible. Furthermore, the coordinator gathers information about damages and repairs which occurs frequently e.g. in order to propose continuous improvements which are usually expected by the customer as part of the maintenance contracts.
- The manufacturer's **maintenance technician** is responsible for the actual inspection and on-time repair measures. When the asset has returned from a cycle, the technician will carry out a so-called pre-load check. All issues found during this inspection are recorded and fixed immediately – if possible, before the asset is flagged as "ready for flight" again. If a repair of an issue affecting airworthiness is not possible, the asset has to be grounded until the repair is completed and accepted.
- The **customer's coordinators** take care of the logistics planning and all loading/unloading processes of the assets during a transportation cycle. They are also coordinating the logistic chain including the costly scheduling of the cargo flights between Germany and the United Kingdom. While doing this the coordinators need reliable information about the availability of transportation jigs.
- Several logistics processes are performed by external **logistic services providers** which are responsible for road as well as water transportation during the cycle from the manufacturing site in Germany to the production site in UK and back again to Germany.

2.3 AS-IS Business Processes

The current (i.e. pre-UPTIME) business and operating processes associated with the maintenance of the WUCTJ is laid out in the following paragraphs.

In general the operation of the WUCTJ is based on transport cycles, in between which maintenance and repair is done. An example is shown in Figure 2-3.

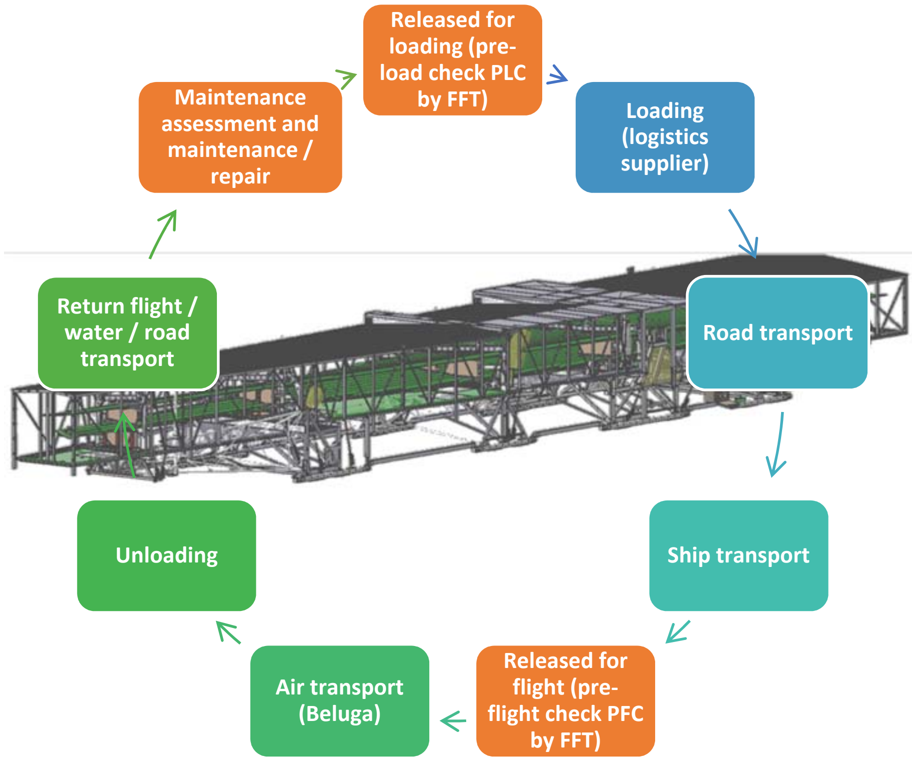

Figure 2-3: Typical WUCTJ operation cycle

The focus of actions to be performed within the scope of maintenance is shown in the orange blocks, the remaining activities is the actual usage of the asset in which damage may occur. Significantly, any damage which occurs during a transport step bears a risk for the equipment and payload as well. This risk could be mitigated if a real-time warning indication were available. The potentially long time between any assessments (days to weeks), depicted as all process steps between the assessment and approval steps marked in orange in Figure 2-3, has a high potential to not only be lost time that could be used to prepare maintenance and repair, but also increases the technical and safety risks due to the potentially long time the jig is operated while damaged.

Figure 2-4 shows an overview of the current process. This process relies heavily on personal communication, and in principle has no possibility of "on-demand" status information. Since most process steps are bound to specific locations, can mainly only be executed sequentially and need a certain preparation time, the flexibility is low and the impact of unexpected situations increases inefficiency in the best case and may impact customer schedules and cause financial losses or even damage in worse case.

It should be considered that due to the required airworthiness and multiple transport modes any issues may have a larger impact than for stationary production equipment:

1. mechanical failure is potentially fatal
2. assets subject to extreme temperature variations
3. prompt discovery of severe issues not always possible during transit
4. immediate corrective action if necessary often not possible during transit

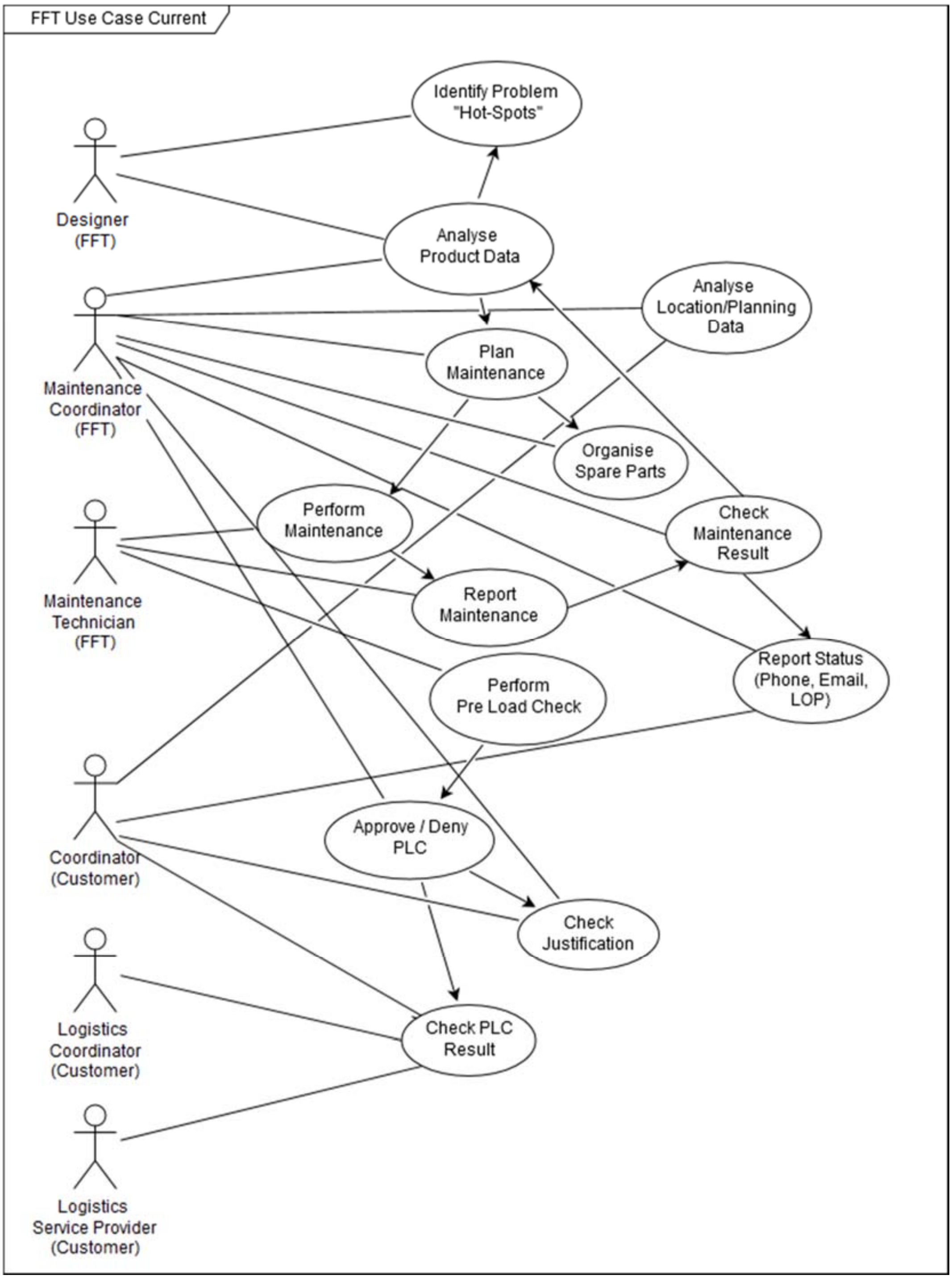

Figure 2-4: UML overview current process

In detail, the relevant maintenance processes can be illustrated using a usage cycle of the WUCTJ, under the assumption some exemplary events take place.

1. The jig is loaded with payload (two wing upper covers) using a hoisting device. Potential problems:
    a. handling errors of loading operator (end-user) resulting in wrong position of jig parts leading to collision and related damage
    b. discovery of previously unidentified damage (e.g. to A/C part interfaces on the jig) leading to loading abort and immediate repair demand

c. application of too much force by loading operator during securing of the payload

2. The top weather protection (roof) is applied. Potential problems:
    a. handling errors of loading operator (end-user) resulting in wrong position of jig parts leading to collision and related damage
    b. previously unidentified deformation leading to collision and damages
3. Road transport. Potential problems:
    a. stronger than expected vibrations due to bad road conditions or driver behaviour
    b. wind or rain damage (ripped cover, undrained water)
    c. unnoticed manoeuvring collisions leading to damages/deformations
4. Ship transport. Potential problems:
    a. stronger than expected vibrations/collisions due to ship loading/unloading
    b. wind or rain damage (ripped cover, undrained water)
5. Before loading into the Beluga, an FFT maintenance team executes a pre-flight check (PFC). Potential problems:
    a. identification of a flight-blocking fault (damage) leading to flight delay
    b. any significant issue can lead to a costly delay exacerbated by possible unavailability of parts and/or manpower for repair
6. Flight transport per Beluga. Possible problems:
    a. stronger than expected vibrations/collisions due to A/C loading/unloading
    b. Freezing of unidentified (hidden) volumes of water leading to deformations/cracks
    c. unexpected vibrations and/or G-loads (unlikely to be a significant problem due to conservative design envelope)
7. Unload payload. Possible problems:
    a. see (1) loading
8. Maintenance assessment/repairs. Potential problems:
    a. unexpected damages requiring ordering of unavailable experts or parts
9. Pre-loading check. Potential problems:
    a. delayed due to (8) taking too long
    b. identification of previously unnoticed faults.

A very significant factor in this operating cycle is the necessary communication between the stakeholders, which costs a lot of effort. This can be seen in Figure 2-4 as the large number of arrows between the stakeholders and the activities.

2.4 Data Availability

The availability of data for the early development phase of UPTIME is relevant for the exact definition of interface requirements. While the exact format of the data supplied to the UPTIME data store by the UPTIME USG cannot be frozen yet at this (early development) stage, it can serve for reference during development of the all UPTIME components dealing with sensor data (see also [1], Table 2-1). In this respect, the availability and applicability versus the development status can be illustrated as seen in Figure 2-5.

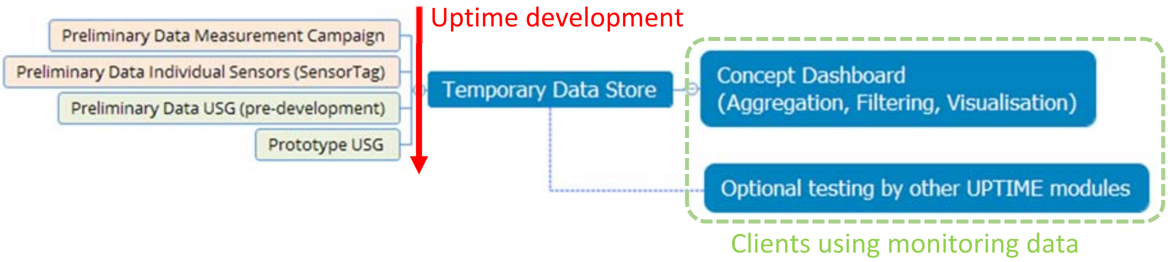

Figure 2-5: Preliminary Data Availability and Usage

This means that relatively independent of the implementation status of USG, it is beneficial to have data available which is relatively representative of the data format to be delivered by USG. This makes it possible to develop and test modules which process this data, including the time series storage backend, in parallel to the development of the USG itself.

To make data available which is representative enough to be able to start developing the required data processing concepts, FFT has conducted an elaborate measurement campaign (see Figure 2-6). This campaign has produced sensor data (strain gauges, acceleration and video data) of a particular road transport of a WLCTJ (which is a Wing Lower Cover Transportation Jig, an asset which is very similar to the WUCTJ which is the subject of the UPTIME demo implementation). The main purpose of this data in the UPTIME context is to use it for the development of the first stage of the data processing chain.

This is useful, since the general format of the data (in terms of physical quantities, sample rate) is representative, or can be made representative through filtering, to the data expected from the USG.

During the first development stage, additional data will become available from first measurement campaigns based on early sensor application (SensorTags applied to the WUCTJ), while at the same time offering the possibility to experiment with state-dependent measuring modes on that platform.

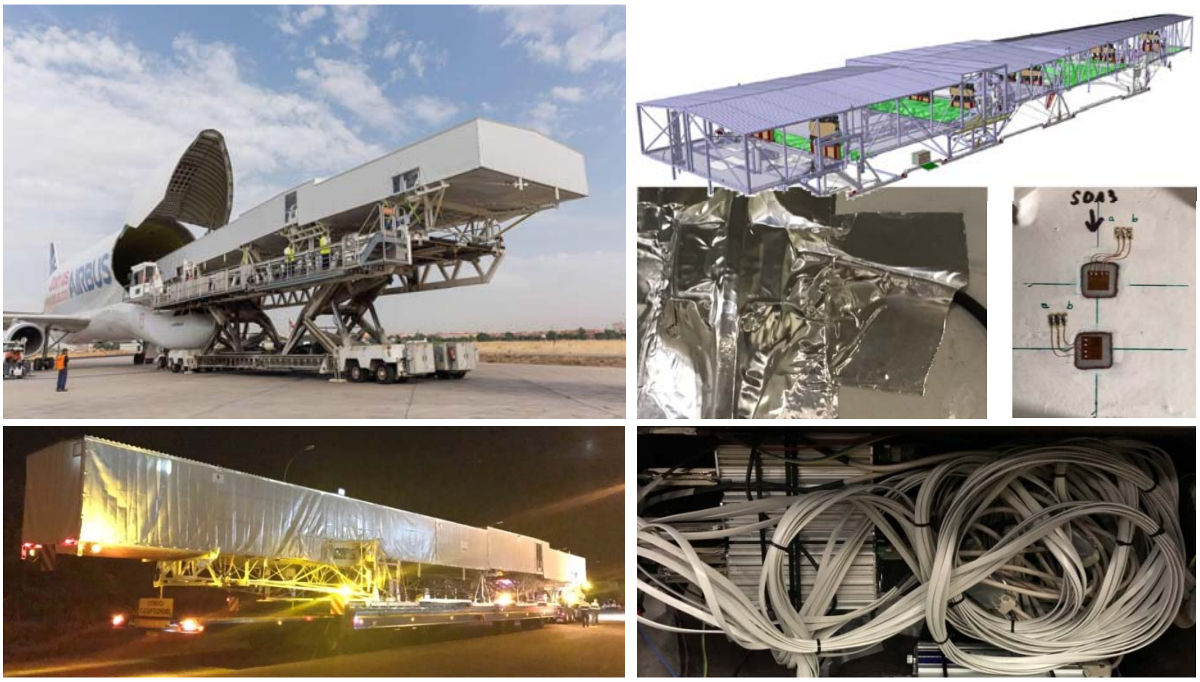

Figure 2-6: Measurement campaign with WLCTJ

A list of data and its formats (as far as available) which will be primarily acquired from the WUCTJ in the context of uptime is specified in Table 2-1. The acquisition of this data is scope of the instrumentation (sensor installation), USG and more generally UPTIME_SENSE.

Table 2-1: Physical quantities / sensor types to be used for data acquisition

Pos	Sensor type	Functional quantity	Sample rate	Remark
1	Temperature	Temperature	1 /min	
2	Pressure (gas)	Air pressure	1 /min	
3	Humidity	Air humidity	1 /min	
4	Light intensity	Ambient light	1 /min	(Optional?)
5	Microphone	Sound	TBD	Possibly for impact noise and/or state detection
6	GPS	Position	1 /min	
7	Water level	Liquid water	0.1 /min or interrupt/threshold	
8	Accelerometer	Shock / vibration	1 /s – 500 /s (state dependent)	
9	Strain gauges	Strain / deformation	0.1 /min – 1 /s (?) and/or interrupt/threshold	Possibly also record large magnitude/low frequency structural vibrations (resonance), most effective strategy TBD.

As can be seen in this list on Table 2-1, for some quantities a certain flexibility is required for the acquisition rate to cover both low-power or transmission-less modes and higher resolution modes, where necessary.

2.5 Relevant IT Systems

Location and Hosting

For the application of the UPTIME system in the FFT Business Case, it is foreseen to use an on-premises (either at FFT or at FFT's customer) hosted database for all asset and measurement data. It is likely that the UPTIME front end (user interface) will be hosted in the same network or the same location.

FFT Maintain

In FFT's use case a significant role is also envisioned for the FFT Maintain platform (Figure 2-7), which is a web based asset maintenance management platform developed by FFT. FFT Maintain focuses on the management of collections of assets related to projects. This means that within e.g. a maintenance project, it contains a database of all assets under maintenance in which for each asset all relevant properties are stored, as well as links to any relevant documentation. For each asset group (asset with a unique product number) maintenance workflows consisting of maintenance steps (e.g. goods in, first assessment, maintenance/repair, load test, etc.) can be defined as well as their status or whether any periodical inspections are due. Other status information such as current storage location and transfer dates are also recorded and can be evaluated to determine historical lead times, deliveries etc. and associated KPIs, with the possibility to show relevant performance and status data in dashboards.

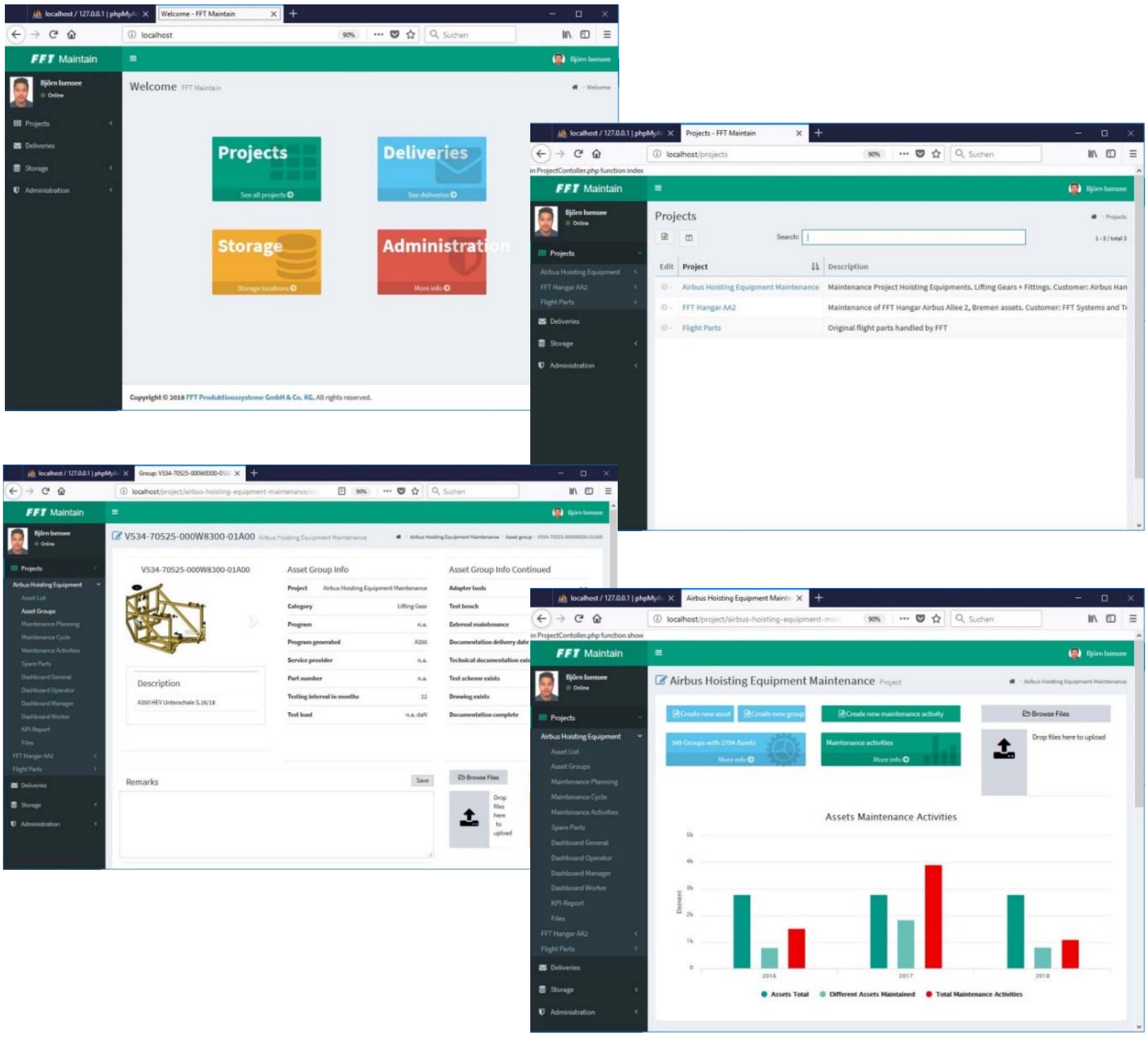

Figure 2-7: FFT Maintain

It is anticipated, that good synergies between UPTIME and FFT Maintain can be achieved, since FFT Maintain offers a comprehensive asset handling information system while UPTIME will cover extensive per-asset condition monitoring and assessments. For optimum integration, it is important, to consider the interfaces between UPTIME and FFT Maintain.

3 Business Case Requirements for UPTIME

In section 3, the system and technical requirements of the FFT Business Case are analysed and documented. The stakeholder groups with their different roles, as identified in section 2.2.2, are depicted in the following sub-sections as users of the UPTIME system.

3.1 FFT Business Case

The UPTIME based processes for the considered use case can be described in terms of the current processes (cf. Figure 2-4) updated with the automated and optimised functions the UPTIME platform provides. This is not limited to making existing processes more efficient, but also offers a significant opportunity for changes to the operating paradigm. Chief example of this is the reduced effort necessary in reporting due to the availability of on-demand customer dashboards.

More comprehensive information and UML graphs can be found in [1], Chapter 8.

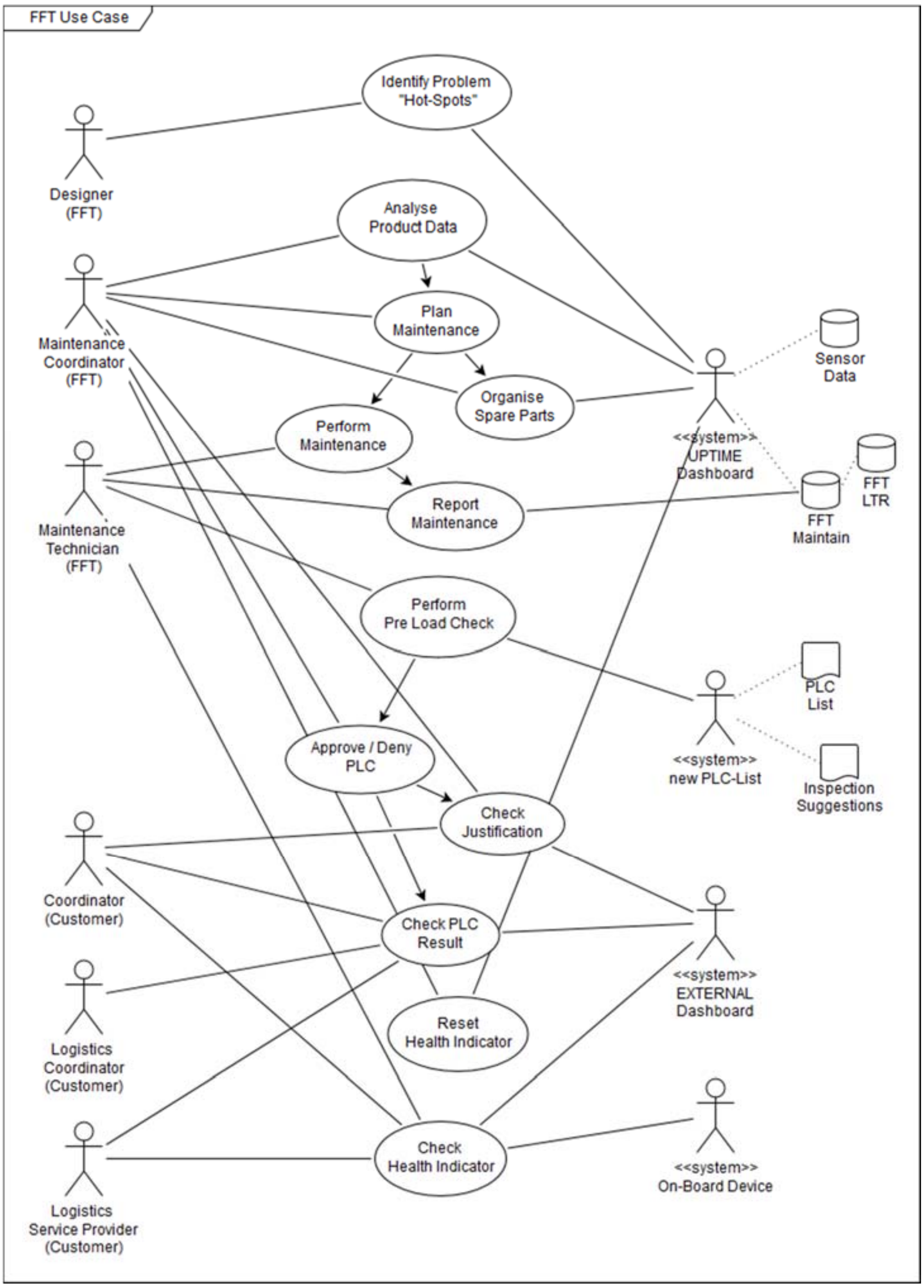

Figure 3-1: UML overview of FFT Use Case in the UPTIME Context

The scenario for this business case with its actors, processes and actions and functionalities analysed in the UPTIME context yields their respective allocation to the UPTIME phases and modules, as presented in [1], Table 8-1.

In more detail, it can be seen by comparison of Figure 2-4 and Figure 3-1, that for most stakeholders the number of arrows linking to actions and information sources is reduced by using UPTIME, which represents a simpler communication structure. Additionally, it is envisioned that most interactions will be either on-demand (check status when info is needed) or system-initiated (this can be thought of as an alarm message or, more passively, an indicator showing intervention is needed). This means that stakeholders can go about their daily business and their attention is only required when they are required to take action to go forward. This is expected to bring significant efficiency improvements.

A further significant improvement is that the condition status is automatically measured continuously, meaning that warnings requiring intervention can be generated as soon as damage occurs, which may be days earlier than would have been the case in the as-is-situation, where typically damages are first (and usually only) noticed during dedicated checks (the orange blocks in Figure 2-3). This has the potential to not only increase efficiency, but also to increase quality (the asset is less likely to be operated while damaged) and reduce risks.

3.2 FFT Business Case Requirements

The system and technical requirements relevant to the implementation of the FFT Business Case in the UPTIME context are listed in this section. Some requirements will need additional clarification and specification, which will be done progressively during the early design phase.

According to the requirement engineering methodology introduced in the Deliverable 2.1 [1], the UPTIME requirements have been grouped in three categories:

1. Stakeholder Requirements
2. System Requirements
3. Technical Requirements

These requirements, their description and dependencies with other type of requirements are listed in Table 3-1.

It needs to be noted that for traceability purposes, these requirements have a unique ID that follows a specific pattern:

- G_STHR_I_number, where G indicates global stakeholder requirements, which are applicable for all three business cases; STHR stands for stakeholder requirement; I (or II) represents the release it was defined; and and number is the number of the defined requirement.
- BC1_STHR_I_number, where BC1_STHR stands for stakeholder requirement of the BC1
- BC1_SR_I_number, where BC1 indicates Business Case 1 by FFT; SR stands for system requirement.
- BC1_TR_I_number, where TR stands for technical requirement.

Table 3-1: Stakeholder, System and Technical Requirements for Business Case 1 (FFT)

ID	Title	Description	Requirement Type	Priority	derives from
G_STHR_I_1	The system shall contribute to increasing the Overall Equipment Effectiveness	Indicates how effectively a manufacturing operation is utilized and points to the gap between the actual and the ideal performance. {(Operational Availability)*(Performance)*(Quality)}	stakeholderRequirement	1	G_STHR_I_6
G_STHR_I_2	The system shall contribute to increasing the Operational Availability	How long a system has been available to be used when compared with how long it should have been available to be used. {Tup/(Tup+Tdown)}	stakeholderRequirement	1	G_STHR_I_1
G_STHR_I_5	The system shall decrease the Maintenance Cost	The costs associated with keeping the manufactured goods in good condition by regularly checking it and repairing it. {Σ(all costs)/(Man-hours for maintenance)}	stakeholderRequirement	1	G_STHR_I_6, G_STHR_I_22
G_STHR_I_6	The system shall contribute to decreasing all costs	Those include: spare parts, consumable unit cost, packaging, storage, handling, transportation, training cost for mainenance, disposal cost.	stakeholderRequirement	1	G_STHR_I_5
G_STHR_I_7	The system shall decrease the man-hours for Maintenance	The accumulated duration of the individual maintenance times used by all maintenance personnel for a given type of maintenance action or over a given time interval.	stakeholderRequirement	1	G_STHR_I_5, G_STHR_I_22
G_STHR_I_8	The system shall increase the Percentage of the Predictive Maintenance Execution	Number of maintenance actions avioding failures/Number of total failures	stakeholderRequirement	2	
G_STHR_I_9	The system shall increase the Number of the Maintenance Actions Avoiding Failures		stakeholderRequirement	1	G_STHR_I_8

ID	Title	Description	Requirement Type	Priority	derives from
G_STHR_I_10	The system shall decrease the Number of Total Failures		stakeholderRequirement	1	G_STHR_I_8
G_STHR_I_14	The system shall contribute to preventing injuries due to failures		stakeholderRequirement	1	
G_STHR_I_15	The plant shall increase the mean time between failures (MTBF)	1/λ; The predicted elapsed time between inherent failures of a system, during normal system operation.	stakeholderRequirement	1	G_STHR_I_10
G_STHR_I_16	The plant shall decrease the total failure rate of the equipment	λ; The frequency of failure for a unit of time.	stakeholderRequirement	1	G_STHR_I_10
G_STHR_I_18	The plant shall decrease the Total Critical Failure Rate of the Equipment	λc; The frequency of critical failure for a unit of time. Critical Failure: A failure or combination of failures that prevents an item from performing a specified mission and as a result there is a loss of the required functions and causing the loss of the equipment mission.	stakeholderRequirement	1	G_STHR_I_16
G_STHR_I_19	The plant shall contribute to decreasing the mean time to repair (MTTR)	Σ(corrective maintenance times)/Number of failures	stakeholderRequirement	1	
G_STHR_I_20	The plant shall decrease the sum of the corrective maintenance times		stakeholderRequirement	1	G_STHR_I_19
G_STHR_I_21	The plant shall decrease the number of failures		stakeholderRequirement	1	G_STHR_I_19, G_STHR_I_8, G_STHR_I_1

ID	Title	Description	Requirement Type	Priority	derives from
G_STHR_I_22	The system shall provide recommendations for scheduling the predictive maintenance activities to legacy systems (e.g. SAP-PM)		stakeholderRequirement	1	G_STHR_I_26
G_STHR_I_23	The system shall receive historical machine failures from legacy systems (e.g. SAP-PM)		stakeholderRequirement	1	
G_STHR_I_24	The system shall receive energy consumption data streams from legacy systems (e.g. Whr EMS)		stakeholderRequirement	2	
G_STHR_I_25	The user should have a clear indication about the current health status of the machine under monitoring		stakeholderRequirement	1	G_STHR_I_23, G_STHR_I_24, G_STHR_I_27
G_STHR_I_26	The system shall provide a clear prognosis indication about the machine health status in the near future		stakeholderRequirement	1	G_STHR_I_23, G_STHR_I_24, G_STHR_I_27
G_STHR_I_27	The system shall inherit all the maintenance-related static information (e.g. equipment Ledger, failure classifications, etc) from legacy systems (i.e. SAP PM DB)		stakeholderRequirement	1	
BC1_STHR_I_1	The system shall increase the planning quality	The actual availability of the asset shall be reliably known in advance and its condition stable.	stakeholderRequirement	1	G_STHR_I_22, G_STHR_I_26

ID	Title	Description	Requirement Type	Priority	derives from
BC1_STHR_I_2	The system shall increase the asset's component life		stakeholderRequirement	2	G_STHR_I_9, G_STHR_I_10, G_STHR_I_13
BC1_STHR_I_3	The system shall be easily deployable on mobile assets	The data acquisition capability must be suitable for mobile application in both on- and off-line mode.	stakeholderRequirement	1	
BC1_STHR_I_4	The system shall be capable of measuring mechanical loads, liquid water, and other physical quantities representing the condition and environment of the asset.		stakeholderRequirement	1	
BC1_STHR_I_5	The system shall be based on COTS components where possible	To limit cost and enable quick development of proof-of-concept for hardware modules and parallel development of the software components, appropriate standard hardware should be chosen where possible.	stakeholderRequirement	1	G_STHR_I_6
BC1_STHR_I_6	The system shall be based on open standards, free software / Open Source where feasible / appropriate	To limit cost, enable flexible deployment (less dependencies on licenses) and increase accessibility and extensibility, open standards and open software (modules, libraries, applications) shall be chosen if feasible from a development effort and functionality perspective.	stakeholderRequirement	1	G_STHR_I_6
BC1_STHR_I_7	The system shall be suitable to operate mobile over land, water, air (air transport in un-pressurised, un-climatised cargo hold), independently		stakeholderRequirement	1	

ID	Title	Description	Requirement Type	Priority	derives from
BC1_STHR_I_8	The system shall offer means of local (on-asset) status indication	There must be means other than through the (web-based) management interface to indicate certain status information locally on the asset.	stakeholderRequirement	2	G_STHR_I_25
BC1_SR_I_1	The system shall provide adequate and current status information		systemRequirement	1	BC1_STHR_I_1, G_STHR_I_25, G_STHR_I_26,
BC1_SR_I_2	The presentation of project information shall be visually appealing		systemRequirement	2	G_STHR_I_26
BC1_SR_I_3	The UI shall be easy to use and easy to learn	The UI is intuitive in comparison to similar interfaces for similar target groups.	systemRequirement	1	G_STHR_I_6
BC1_SR_I_4	It shall be easy to deploy the system	For a typical usage scenario, it shall be easy to install and configure the UPTIME system for a person with general knowledge of server applications and monitoring hardware and software.	systemRequirement	1	G_STHR_I_6
BC1_SR_I_5	It shall be easy to manage the system	Management and maintenance of the system shall be easy for system administrators with relevant knowledge.	systemRequirement	1	G_STHR_I_6
BC1_SR_I_6	The system shall be scalable.	The system shall be designed with scalability in mind.	systemRequirement	1	G_STHR_I_6
BC1_SR_I_7	Interoperability shall be high	Through the use of open and well-adopted standards, it shall be easy to interface the platform with other systems.	systemRequirement	1	G_STHR_I_6, BC1_SR_I_4, BC1_SR_I_5
BC1_SR_I_8	Security and privacy shall be adequately enforced.	The system architecture shall incorporate state-of-the-art security standards and mechanisms.	systemRequirement	1	G_STHR_I_6

ID	Title	Description	Requirement Type	Priority	derives from
BC1_SR_I_9	The system shall be easily and automatically configurable for each asset (-type/class)	Automatic configurability also refers to condition based operating modes.	systemRequirement	1	G_STHR_I_6, BC1_STHR_I_3
BC1_SR_I_10	Data Storage on-premises or private cloud supported		systemRequirement	1	BC1_STHR_I_6
BC1_SR_I_11	Data Storage platform (database manager) free/public license		systemRequirement	2	G_STHR_I_6, BC1_STHR_I_6
BC1_SR_I_12	Power efficient hardware components		systemRequirement	1	BC1_STHR_I_3, BC1_STHR_I_7
BC1_SR_I_13	Intelligent power management		systemRequirement	1	BC1_STHR_I_3, BC1_STHR_I_7
BC1_SR_I_14	Long-lasting power supply (min 4 weeks, preferably > 6 months) concept through accumulators		systemRequirement	1	BC1_STHR_I_3, BC1_STHR_I_7
BC1_SR_I_15	A good balance between central structure (easy exchange of battery pack during maintenance) and decentral structure (for more independent sensor modules) shall be focus		systemRequirement	1	BC1_STHR_I_3, BC1_STHR_I_7
BC1_SR_I_16	Suitable energy harvesting solutions available to increase lifetime of battery packs?		systemRequirement	3	BC1_STHR_I_3, BC1_STHR_I_7
BC1_SR_I_17	Situational awareness of infrastructure (state detection)		systemRequirement	1	BC1_STHR_I_3, BC1_STHR_I_7

ID	Title	Description	Requirement Type	Priority	derives from
BC1_SR_I_18	The system shall offer configurable state detection	It shall be possible to configure the rules for mode selection based on the detected state by communicating (wirelessly) with the gateway.	systemRequirement	1	BC1_STHR_I_3, BC1_STHR_I_7, BC1_SR_I_1
BC1_SR_I_19	Hardware components for in-door and out-door operation	The hardware should be able to operate long-term in harsh environmental conditions	systemRequirement	1	
BC1_SR_I_20	Temperature range +55°C to -55°C		systemRequirement	1	BC1_SR_I_19
BC1_SR_I_21	The mobile part of the system shall be water resistant (rain, sea transport), humidity, shock and dust resistant		systemRequirement	1	BC1_SR_I_19
BC1_SR_I_22	The system shall offer self-indication of damages or failures and required repair/maintenance (including battery exchange notification etc.)		systemRequirement	1	BC1_STHR_I_8, BC1_SR_I_1
BC1_SR_I_23	The system have the capability to visualise a large number of views/aggregations of monitoring data, both over time and over assets	The UI, Dashboarding components in particular, shall have advanced data representation capabilities.	systemRequirement	1	BC1_STHR_I_8, BC1_SR_I_1
BC1_SR_I_24	The system shall support role based reporting views (based on stakeholder roles/login)		systemRequirement	1	G_STHR_I_6, BC1_SR_I_1

ID	Title	Description	Requirement Type	Priority	derives from
BC1_SR_I_25	Capability to configure dashboard views		systemRequirement	2	G_STHR_I_6, BC1_SR_I_1, BC1_SR_I_5, BC1_SR_I_3
BC1_SR_I_26	Capability to configure rules for all predictive and analysis modules through the user interface		systemRequirement	2	G_STHR_I_6, BC1_SR_I_1, BC1_SR_I_5, BC1_SR_I_3
BC1_SR_I_27	Capability to interface with FFT Maintain asset handling database		systemRequirement	1	G_STHR_I_6, BC1_SR_I_5, BC1_SR_I_7
BC1_TR_I_1	Mobile data concentrator/pre-processor (in gateway), central per mobile asset	Independent and mobile data concentrator to collect all acquired data on the asset	technicalRequirement	1	BC1_STHR_I_7, BC1_STHR_I_3
BC1_TR_I_2	Sensors for the physical quantities: temperature, air pressure, humidity, liquid water detection, shock/acceleration, strain gauges, acoustic, ambient light, GPS		technicalRequirement	1	BC1_STHR_I_4, BC1_STHR_I_7
BC1_TR_I_3	Gateway must be capable of forwarding control/config information to programmable sensors (e.g. to set operation mode)		technicalRequirement	1	BC1_SR_I_5, BC1_SR_I_9
BC1_TR_I_4	The gateway shall have capability to interface with TI SensorTag	The SensorTag platform has been chosen for one type of sensor node, due to its suitable properties (low power, multi-sensor, standardised)	technicalRequirement	1	BC1_STHR_I_5, G_STHR_I_6

ID	Title	Description	Requirement Type	Priority	derives from
BC1_TR_I_5	Capability of flight mode (all transmission functionality suspended)	Flight mode shall be activated based on automatic situational awarenes, to guarantee that the mobile system is in flight mode when air transport is being conducted.	technicalRequirement	1	BC1_STHR_I_7
BC1_TR_I_6	On-asset physical indicator of asset condition	An on-asset (mobile) status indication feature shall be implemented. At minimum a binary indicator (e.g. "fit for operation: yes/no" or traffic light status) is required.	technicalRequirement	2	BC1_STHR_I_8, BC1_SR_I_1
BC1_TR_I_7	Communication via GSM/LTE (data transmission to data servers)		technicalRequirement	2	BC1_TR_I_3, BC1_STHR_I_3
BC1_TR_I_8	Bluetooth Low Energy (BLE) for wireless short range communication („talking“ to maintenance crew / mobile devices)		technicalRequirement	1	BC1_STHR_I_3, BC1_STHR_I_7 BC1_TR_I_1, BC1_TR_I_3
BC1_TR_I_9	Capable of feedback to embedded system (e.g. configuration or indicator control)		technicalRequirement	1	BC1_STHR_I_3, BC1_STHR_I_7 BC1_TR_I_1, BC1_TR_I_3

ID	Title	Description	Requirement Type	Priority	derives from
BC1_TR_I_10	It shall be possible to initiating wake-up or make USG/sensors sleep both automatically (based on detected state) and manually (by sending a command over BLE)		technicalRequirement	1	BC1_STHR_I_3, BC1_STHR_I_7, BC1_SR_I_1
BC1_TR_I_11	Recognition of entering an aircraft (e.g. deactivate sensor platform during taxiing and when being in flight)		technicalRequirement	2	BC1_STHR_I_3, BC1_STHR_I_7, BC1_SR_I_1
BC1_TR_I_12	Offline damage assessment based on measurement data (sensors) shall be implemented	The USG shall have the capability to make (limited) assessments that represent significant condition information affecting the operational readiness of the asset (e.g. damages) offline, i.e. without communicating with the specific UPTIME assessment modules (which are server/cloud based)	technicalRequirement	1	BC1_STHR_I_3, BC1_STHR_I_7, BC1_SR_I_1

4 Business Case Conceptualization

In section 4, the overall business case architecture is defined in terms of what components will be involved and how they are going to interact with each other to fulfil the specific business case needs. The overall business case architecture along with the adaptation of the e-Maintenance model is described. Furthermore, the infrastructure to support the architectural definition will be presented.

4.1 Adaptation of the UPTIME e-Maintenance Model

The e-Maintenance model of UPTIME is described in more detail in [1]. The participation of the industrial partners in the UPTIME project has the objective to be able to develop a unified system which is at the same time generic enough to satisfy diverse application requirements. The high level conceptual architecture of UPTIME is shown in Figure 4-1

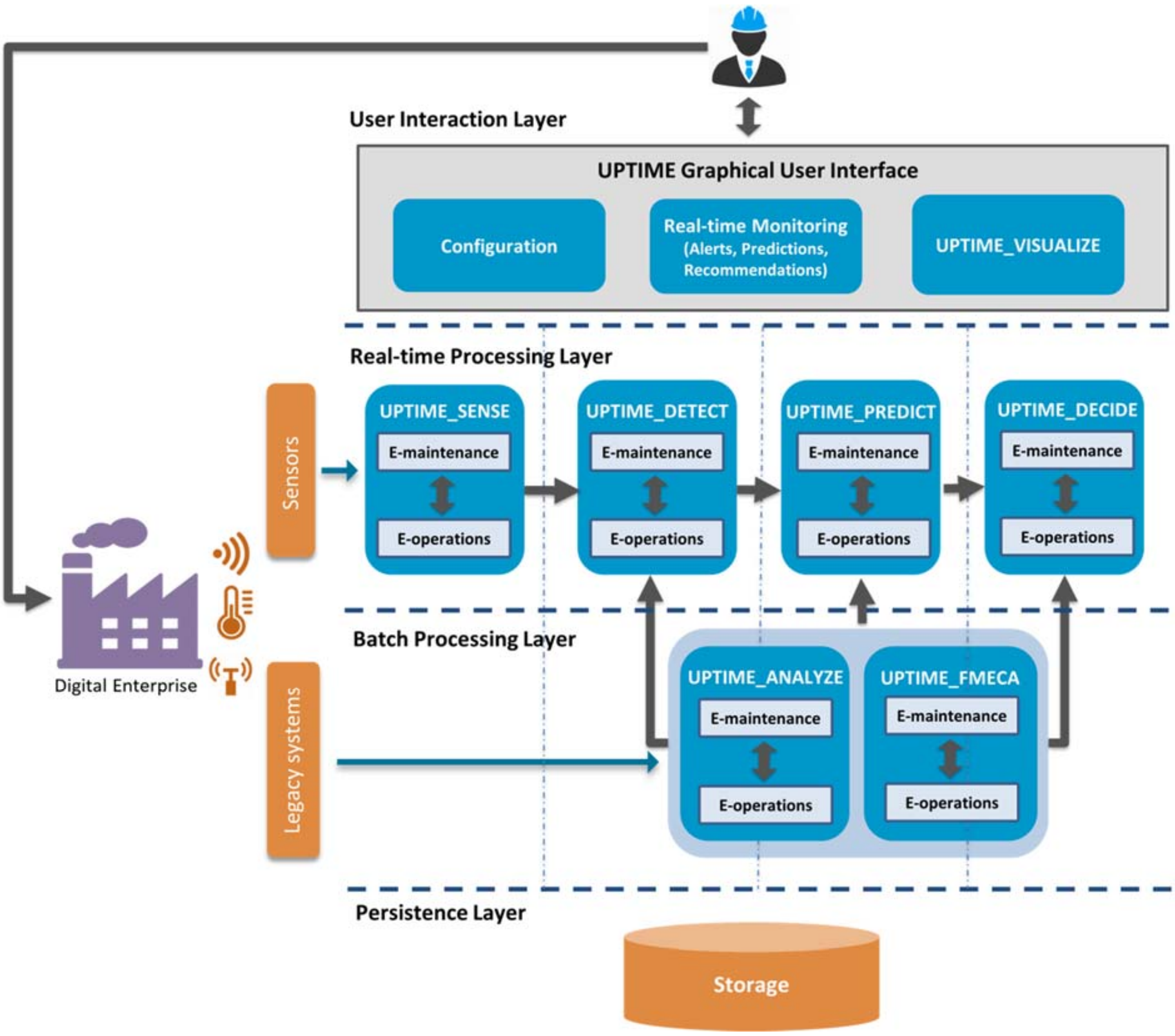

Figure 4-1: The Functional/ High Level View of the UPTIME Conceptual Architecture [1]

In FFT's case, the sensor platform is not planned to be real time in the traditional sense, therefore the handling of data from sensors and legacy systems will not need to be much different. This is due to the

[1] Source: [1], Figure 7.3

fact that the sensors are installed on a mobile asset that underlies communication restrictions, which will likely result in batch wise or limited data rate transmissions. The general functionality shown in Figure 4-1 is entirely applicable to the FFT business case; indeed the functional requirements to the handling and processing of data are in generic terms not much different from other production systems. It should be noted, that FFT requires configurable role based user views in the GUI / data representation functionality, a feature which has not been explicitly defined before in the “UPTIME Graphical User Interface” context.

In the FFT business case context, FFT primarily focuses on the agreed functionality/modules, which provide the largest benefit, as is illustrated in Figure 4-2, p. 37. The mapping of the functionality is presented in [1], section 8.1 and Table 8-1.

An additional consideration is the interfacing between UPTIME and FFT Maintain, which is FFT’s maintenance and asset management system.

4.2 Business Case Architecture

The architecture for the FFT business case in the UPTIME context can be thought of as the most effective mapping of functionality required by the UPTIME-powered FFT business processes and the functionality in the UPTIME platform, which is organised in modules. A detailed mapping is provided in [1], section 8.1.

In Figure 4-2 the modules which provide functionality of primary relevance to the FFT business case are indicated, as well as modules responsible for providing interfacing functionality to FFT Maintain.

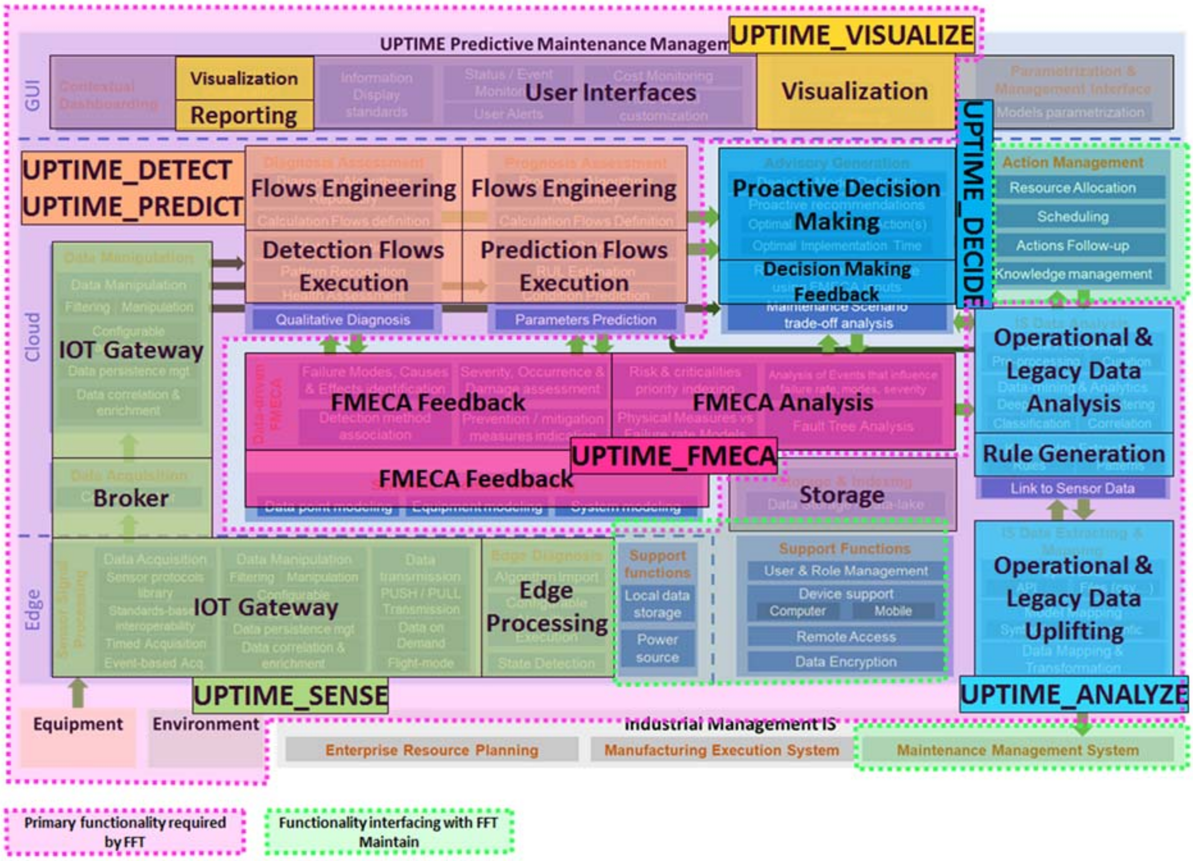

Figure 4-2: Main functionality allocation FFT use case (Draft Version)

As shown, most functions are expected to be usefully deployed by FFT, but “FMECA” and “Proactive Decision Making” are excluded from the primary focus. That is not to say it cannot or will not be adopted by FFT’s UPTIME deployment, but to indicate that the other functionalities will be prioritised in case the configuration of these modules to produce useful results takes too much effort. It is expected that significant results are already achievable using the preInO and Contextual Dashboarding functionalities if properly configured, see also Figure 4-3.

Figure 4-3 depicts the functionality provided by each UPTIME module, to provide an overview how the UPTIME consortium envisions achieving the top level functions.

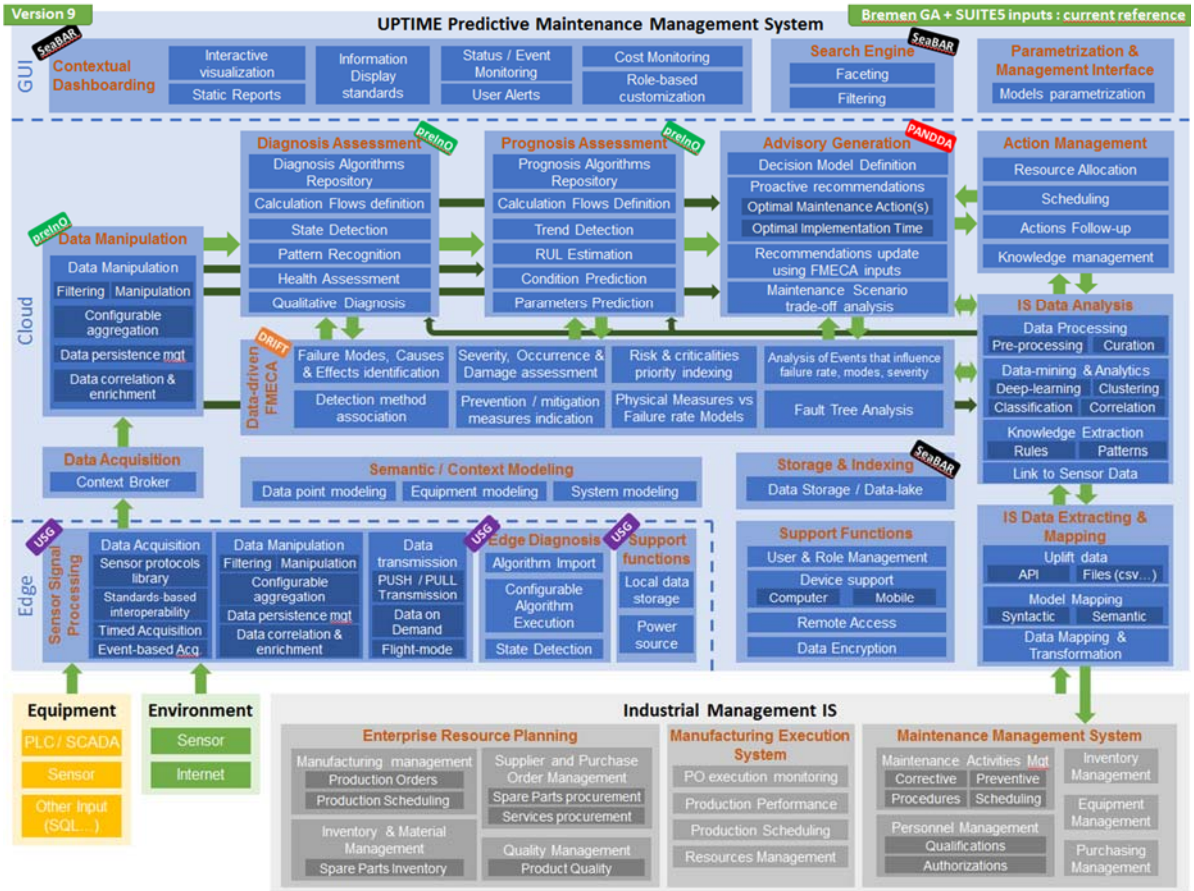

Figure 4-3: Detailed functionality of UPTIME modules (Draft Version)

4.3 Existing Business Case Infrastructure

The infrastructure supporting the current business processes for the use case (cf. section 2.3) is briefly described in this section.

Since the WUCTJ assets are small in number (less than 10 in operation) and the start of production is relatively recent, most processes rely on manual planning and execution, and the infrastructure is coordinated mainly on an as-needed basis. Referring to the main action windows of FFT depicted in orange in Figure 2-3 (p. 15), operations are planned by the project coordinator in cooperation with the site-manager (which can be the same role, depending on the location).

Relevant infrastructure is for analysis purposes divided in four categories:

1. Assets under Maintenance
2. Customer facilities (includes storage areas and external means of transportation)
3. FFT tools, equipment and means of deployment (all physical means used by the Maintenance Ops team)
4. Information and communication infrastructure

As focus of the Business Case demo in UPTIME context, in more detail this can be listed as:

1. WUCTJ Jigs (in principle the focus is on one prototype for instrumentation, but for practical and scheduling reasons the possibility exists to work with several assets in parallel)
2. Customer facilities consist of:
    a. open air storage areas and transit areas
    b. transport trucks
    c. transport ships
    d. transport aircraft (Beluga)
    e. means for loading and unloading
    f. storage racks (large fixed frames on which the jigs are positioned for loading and unloading from the truck, same level as cargo floor of trailer)
3. FFT infrastructure applicable to this case consists of:
    a. Mobile Maintenance Ops unit, small truck with maintenance tools and equipment
    b. Repair equipment (welding equipment etc.)
    c. Local on-call supplier infrastructure for high speed delivery of parts and services
    d. Engineering back-office
    e. Corporate back-office (procurement, project management, etc.)
4. Information and communication is currently mainly done manually and traditionally:
    a. E-mail / phone (coordination of multiple stakeholders)
    b. Text- and paper-based reporting
    c. Manual recording and storage of physical asset information, damages and repairs (apart from the single measurement test campaign, see also section 2.4, currently the WUCTJ do not have any sensors installed, all assessments are done by manual inspection).

It is evident, that (4) directly stands to benefit significantly from UPTIME, while the efficiency and effectiveness of coordination and planning for (2) and (3) can be increased dramatically. Direct automatic health assessment and monitoring of the assets (1) will not only give a tremendous advantage because the assessment can be done independent of the on-location presence of an inspection team, but will also ensure that the deployment of Maintenance Ops teams can be planned in advance potentially leading to dramatic time savings (not only related to team deployment but also due to the possibility to equip the team with necessary tools and spare parts in advance).

5 Business Case Evaluation

In section 5, the methodology to evaluate the FFT business case, including expected improvements and business implication by implementation of UPTIME are introduced.

5.1 Methodology

The implementation results for the FFT Business Case in the UPTIME context will be evaluated against three main criteria:

1. optimisation of the business processes, i.e. the increase of efficiency and effectivity of the workflows related to the maintenance and handling of the demo case asset by using UPTIME
2. the level of compatibility of UPTIME platform functionality with the defined business case requirements and FFT business processes
3. the level of generalisation of the implemented functionality (can the UPTIME functionality be used well for all three business cases with limited adaptation effort?)

The first criterion can be comprehensively and quantitatively evaluated by the KPIs listed in section 5.2. The latter two are less easy to measure quantitatively, though the reduction of maintenance costs can be used partly, since the level of success in these categories will reduce coordination costs and effort. The performance of the qualitative criteria will further be assessed based on the reported usability and deployment success of UPTIME in the three industrial use cases. This could be broken down according to the processes defined in [1], section 8.1.

The methodology to assess the qualitative performance of UPTIME and the predictive maintenance processes in which it is used, will include the following:

- Experts review of the UPTIME system's implementation in the FFT use case (and its comparison to the other use cases), assessing effectivity of the implementation for the given situation
- Short user stories (narratives), reflecting the perceived usability, functionality, effectivity and efficiency of the actors using the system, and the perceived improvement compared to the situation before UPTIME. It is expected that all significant stakeholders will have the opportunity to experience the necessary interaction with the prototype implementation.

To measure the quantitative performance of the UPTIME implementation, the defined KPIs from before UPTIME deployment (as-is situation) will be calculated from historical data. To achieve this, it is proposed to input the relevant data (which is currently paper-based) in the UPTIME database retroactively, in order to be able to use the evaluating and dashboarding functionality of UPTIME expected to be available when the business case evaluation is done. The same corresponding KPIs after the implementation of UPTIME will then be determined in the same way and a comparison will be made. The result of this comparison is then assessed against the target KPI improvement (section 5.2) and the level of fulfilment is trivially established.

5.2 Benefits and Impact

As has been shown in the analysis of the as-is business processes compared to the UPTIME-powered processes, for most core activities the quality and efficiency can be significantly increased by deployment of UPTIME, while effort and time (both reaction time for reactive maintenance and the lead time for all types of maintenance) can be dramatically decreased.

The main KPIs considered for the impact of the application of UPTIME in FFT's business case are:

- 5% improvement of OEE
- 20% reduction of MTTR,
- 20% improvement of MTBF,
- 20% reduction of unplanned plant/production system outages,
- 15% extension of component life,
- 20% reduction of total maintenance costs.

Among others, the following aspects are expected to drive these improvements:

- Flexible process planning and integration: Through the availability of information related to the condition of assets, planning can be improved considerably e.g. be ensuring the availability of resources (equipment, spare parts, materials etc.).
- Continuous Information Management: Relevant information of the transportation assets can be shared among all stakeholders. All maintenance activities can be documented at a centralized knowledge base. Thus, configuration management becomes much more integrated.
- Continuous Improvement: Smart analytics of condition information helps to indicate weaknesses (such as potential sources of damages) and to propose improvements to the customer.

Due to the generalised implementation and unified premise of UPTIME, the effort to extend deployment of the system to many other assets under maintenance is expected to be modest. As a result, the identified benefits from analysis of the processes and evidence from the demo case are expected to impact the majority of maintenance projects at FFT. Initially this may focus on the maintenance of mobile assets, but (in reference to the other two industrial business cases in the UPTIME project) expansion to e.g. production lines is highly attractive as well, dependent on the customer.

5.3 Business Implications, and Future Trends

The ready availability of the UPTIME platform will not only provide a huge opportunity to increase the efficiency, effectivity and quality of maintenance processes for producing industrial organisations, but also be a USP for organisations offering maintenance as a service. Application in products (investment goods, production equipment) could also open new markets, where these could be marketed with integrated monitoring facilities and sold in combination with a maintenance management framework.

In light of the current "Industry 4.0" trend which is expected to continue (since real world applications still have significant improvement potential), it is expected that deployment of the UPTIME concept can find highly attractive application in potentially many variations for decades to come.

6 Implementation Roadmap

The demonstration of the FFT Business Case will be held in two iterations, following an agile methodology. In the following sections, the list of tasks and activities to be performed and the goal of each iteration is described.

6.1 Planning of 1st Iteration

The overall top level schedule for the FFT business case in UPTIME context is shown in Figure 6-1.

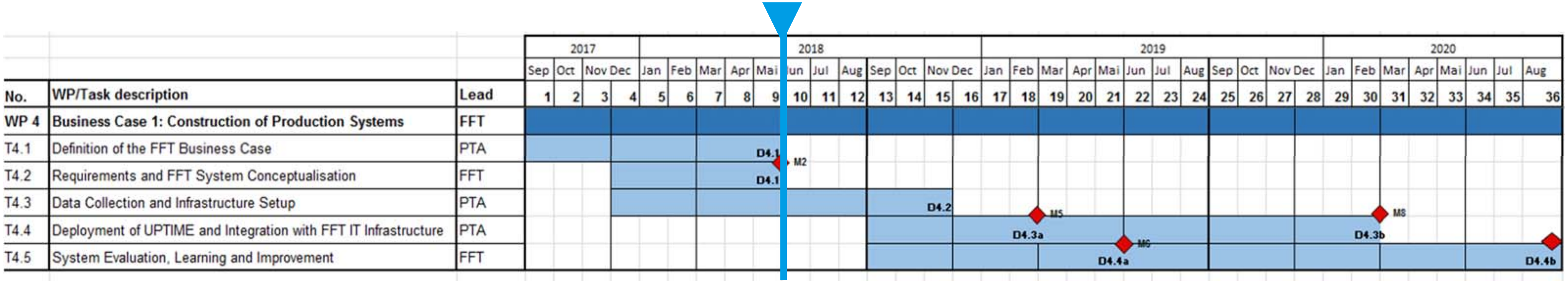

Figure 6-1: Overall schedule of WP4 tasks

The results of tasks 4.1 and 4.2 are provided in Deliverable 4.1, this document.

The goal of the first iteration is a functional proof of concept, for the business case. At the time of writing the business case definition and the concept definition of UPTIME for application in the FFT business case has been concluded. Sub-tasks that will be done in this context are listed below and depicted in Figure 6-2. Activities covering the first iteration include:

- Store (transfer) the test data available from the early measurement campaign of the WLCTJ in a time series database (BIBA/PTA)
- Continuously develop dashboarding / UPTIME UI functionality and use any (temporarily) available data to experiment and test this functionality (PTA, UBITECH)

- Implement a partial sensor solution based on TI Sensor Tag hardware in combination with an MCU platform (Arduino) as temporary sensor gateway or intermediate storage to incrementally develop the capability to make mobile measurements and acquire data (FFT, BIBA, PTA)
- Install sensor and gateway platform on a WUCTJ and perform mobile measurements (FFT)
- Incrementally expand the sensor platform on the demo asset (WUCTJ) with further measurement capabilities, e.g. strain gauges (FFT)
- Continuously conduct mobile measurements and update the available data in the time series database with the installed sensors (FFT)
- Develop and implement USG
- Deploy a first integrated UPTIME version as test/pilot installation (including transfer of historical data into the UPTIME database)
- Implement the interface between UPTIME and FFT Maintain
- Commission ANALYSE and PREDICT modules with FFT data. This includes the configuration of these modules and provides a first feedback about their usability and ergonomics as well.
- Conduct and summarise first phase system evaluation and identify improvement potential.

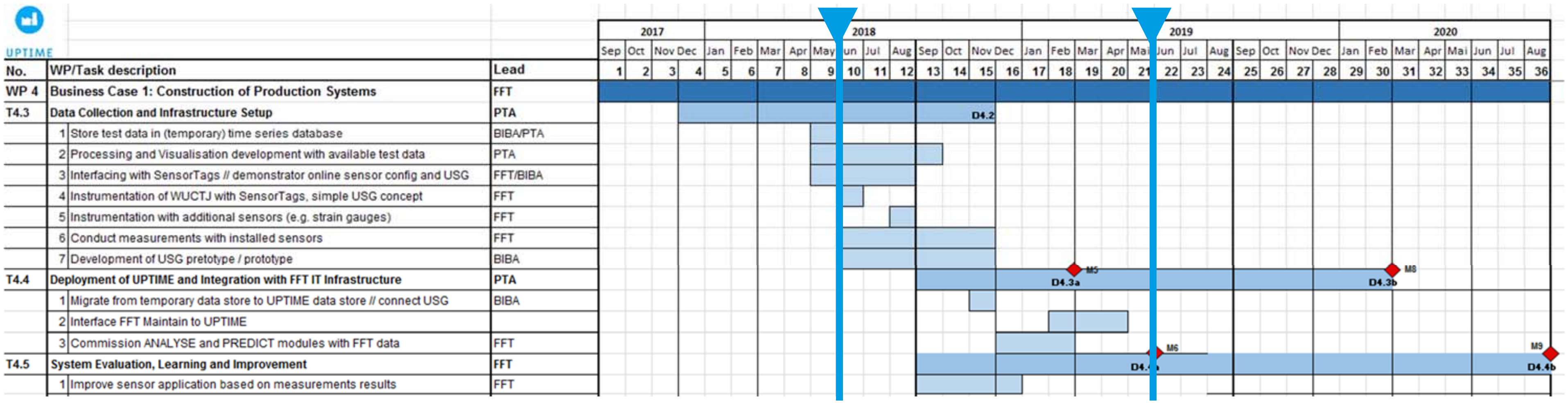

Figure 6-2: Tasks and subtasks for WP4 in first iteration (Evaluation on M21)

The main implementation period for Iteration 1 is M10 – M21.

6.2 Planning of 2nd Iteration

In the second iteration focus will be on improvement of the system. This will be a more continuous and iterative process where lacking features, bugs, improvement requests, etc. will be addressed in the UPTIME consortium. Since most issues will only become visible during actual usage of the system, it is of importance that a functional deployment is in place at the start of this phase. Significant tasks for this phase are depicted in Figure 6-3.

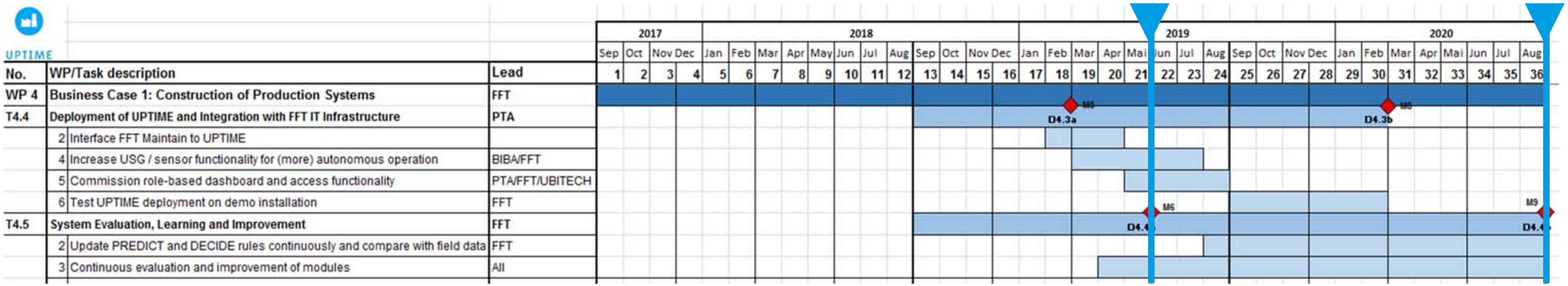

Figure 6-3: Tasks and subtasks relevant to WP4 in the second iteration (Evaluation on M36)

Activities covering the second iteration include:

- Finalise interfacing of UPTIME and FFT Maintain
- Increase USG / sensor functionality for more autonomous operation
- Commission role-based dashboard and access functionality in production mode
- Test UPTIME deployment on demo installation (prototype) under production conditions
- Update PREDICT and DECIDE rules configuration and compare with field data
- Continuous evaluation and improvement of modules

The main implementation period for Iteration 2 is M22 – M36.

6.3 Experimentation Boundaries and Constraints

The selected use case for WP4 within the UPTIME project offers many opportunities for the application and testing of UPTIME functionality. There are, however, some limitations inherent to the asset and its operating mode:

1. Due to safety constraints, some failure modes are to be avoided at all cost, so there will be no experimental data on these.
2. The mandatory flight mode during air transport will impose some limitations on data resolution, batch size or real-time availability (the latter is less significant, since for this use case batched data availability is sufficient for most measured quantities).
3. Most data acquisition will inherently take place in transit, where it is impossible to deploy people who can provide human assistance or intervention. The operation envelope of the system is therefore defined by the achievable degree of autonomous operation within acceptable safety constraints.

Also, there are risks associated with the proposed implementation. The identified risks and the respective contingency plans are presented in Table 6-1.

Table 6-1: Risk assessment for FFT Business Case

Risk ID	Risk Description	Mitigation Plan
R1	Unexpected delay in delivering UPTIME modules crucial to developing/testing FFT scope.	Simultaneous Engineering approach with early proof-of-concept implementations that offer part of the necessary functionality.
R2	Unexpected challenges with interfacing/integration of UPTIME functions/modules.	Continuous communication within working group and all consortium partners. Early experiments with mock-ups and proof-of-concept implementations. Adherence to open standards and early definition of communication interfaces.
R3	Data quality issues due to technical challenges with sensor platform implementation.	Get early performance data from early prototypes; enable early adaptation of data handling modules for appropriate data-conditioning.
R4	Limited acceptance by end-users	Early and continuous communication of the project development plan to get buy-in from the stakeholders; limit the absolute reliance on certain functionalities / consider flexibility in the design.
R5	Metrology concepts are inadequate to measure all necessary physical parameters	Early prototypes deliver early data; flexible implementation leaves room for retrofit or plugin alternatives
R6	Limited availability of mobile asset / industrial pilot platform	Consider parallel deployment on multiple assets if this issue occurs.
R7	Performance issues with chosen COTS components leading to inadequate data quality.	Application of open standards increases possibility to use drop-in replacements. Early testing of proof-of-concept implementations enhances experience and enables early recognition of potential problems.

7 Conclusion and Outlook

Based on a unified platform supporting predictive maintenance by providing tailored views supporting all stakeholders of a given value chain as well as new innovative service offers current challenges in the manufacturing sector are addressed. Automatic anomaly detection for anticipation of needed maintenance activities, monitoring of asset's condition and health or the provision of interactive dashboards for fault analysis are just view examples out of many on how maintenance - as an important aspect in the manufacturing value chain - can be improved to ensure competitiveness of European manufacturing industry. The given use case provides much room for such improvements. Thus, the stakeholders of the use case described in this document pursue the results of UPTIME with the highest interest.

References

[1] ICCS, "UPTIME Deliverable D2.1a - Conceptual Architecture and System Specification," ICCS, Athens, 2018.