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D2.1 Deliverable Appendix - Use Cases analysis for AHT-EP definition

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Abstract

In this document, we provide the information describing the Engineering Process Phases adopted in the 22 Use Cases that have been collected by using WP1-Wp2-WP4 survey.
This information is analysed for extracting a table for each Use Case (UC) that summarise what are the ArrowHead-Tools Engineering Process Phases (AHT-EPP) used in the UC and what are the objectives that each EPP can potentially match during the project.

ECSEL EU project 826452 - Arrowhead Tools
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1. Updated Use Cases summary and AHT-EP analysis

This document contains the information collected from Use Case leaders that have been analysed during the definition of the AHT-EP feature, structure, and components. We provided also a short summary for each Use Case describing the field of application and the main product/service to be developed. A more detailed explanation can be found in WP1 and WP7-8-9 deliverables.
All the information here reported have been extracted from the WP124 Survey [1] documents filled by the Use Cases leaders.

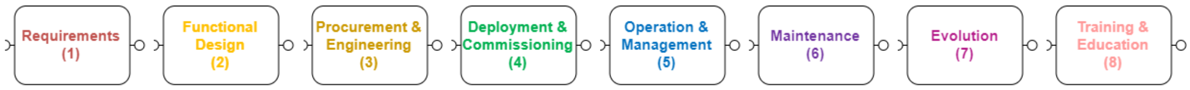


Figure 1 ArrowHead-Tools Engineering Process (AHT-EP)

A table similar to Table 1 is produced for each use case where we report the AHT-EPPs used by the Use Case and the objectives that the UC will potentially match during the project.
In this Table 1 we have the AHT-EPP in the first row. In the second row we have several letters that indicates if the UC have EPPs that match with the AHT-EP. In the following the meaning of each letter adopted in second row:

- **C** indicates that the EPP phase is currently used in the Use Case
- **P** indicates that the EPP is planned to be used during the AHT project
- **N** indicates that the phase is not adopted
- **U** indicates that from the input material is not clear if the phase is used or not

The following six rows (OBJ-AHT) reports if the particular EPP can potentially match one of the ArrowHead-Tools objectives. Whereas, we reported on the last four rows EPPs of the UC that can potentially match the WP2 objectives.
The objective AHT #1 is overlapped to the objective of WP1.
With this notation, we can read the Table 1 as described in the following:
In the UC we use only the Requirements (AHT-EPP1) and Procurement & Engineering (AHT-EPP4) phases. Currently only the Requirement phase is adopted, the AHT-EPP4 will be adopted during the project. The Functional Design phase is not specified in the input material.
For the Requirement phase, we can potentially match the objective #1 of the AHT project and objectives #1 and #3 of that are targeted by the WP2.
Whereas, for the Procurement & Engineering phase we can potentially match objectives #4 and #5 of the project and objective #1 of the WP2.
In the last column, we see that all the UC-EPPs have found a match with one of the AHT-EPP.

Table 1 Example of table that match the UC and the AHT Engineering Processes with focus on the potential objectives that can be matched in each phase.

AHT-EPP	1 (R)	2 (FD)	3 (PE)	4 (DC)	5 (OM)	6 (M)	7 (E)	8 (TE)	Missing ?
UC-EP match	C	U	N	P	N	N	N	N	N
OBJ-AHT #1	x								
OBJ-AHT #2									
OBJ-AHT #3									
OBJ-AHT #4				x					
OBJ-AHT #5				x					

OBJ-AHT #6									
OBJ-WP2 #1	x			x					
OBJ-WP2 #2									
OBJ-WP2 #3	x								
OBJ-WP2 #4									

1.1 Automated Formal Verification (CAMEA)

This Use Case concentrates on one of the phases critical in the development of embedded devices and that is verification. More concretely, the use case primarily aims at systems developed for intelligent traffic surveillance in an SME (CAMEA in particular) that is currently not using latest advanced verification techniques at all. The aim is to improve the situation by allowing the company to use advanced verification techniques. In order to derive verification scenarios for intersection of several roads, a scaled-down (1/10) autonomous car provided by CVUT will be used.
The use case concentrates on verification of systems under development, which can be partly replaced by synthesising some parts of the designs.

1.1.1 Engineering Process inputs

These activities span across the phases of *functional design* and *engineering* but also *requirements*, *evolution*, and perhaps also *maintenance* (in that if some change in the system is needed due to some malfunction, the changed system should be verified too). Since advanced methods of verification require properly prepared developers, they should be properly *trained* in their usage too.
Deployment and commissioning as well as *operation and management* do not seem to be applicable since they do not imply changes in the implementation of the system that would require further verification.
The planned improvement of the toolchain should speed-up the verification phase and/or make it more reliable. By using synthesis (a correct-by-construction approach) during the development process, it is expected that less problems will be discovered during the testing and verification phase.
It is to be investigated how well current advanced verification technologies and tools are applicable for the kind of systems considered in the use case (mixture of languages used, concurrency and distribution, combinations of hardware and software, dynamic data structures, parameters, data intensive operations, etc.). However, due to advanced verification techniques and tools usually need customisation for the given context, suitable instantiation and optimisation of such technologies and tools seems inevitable. Moreover, many of these technologies and tools are still under very live development in general in order to allow them to deal sufficiently efficiently with various complex features of real-life systems, and so their further development within the use is also to be expected.
The order in which the AHT-EPPs are adopted is similar to the serial order shown in the AHT-EP figure. Fits with that various iterations between the phases are needed.
The scalability level offered by AHT-EP is sufficient for the current production level and complexity of the systems being developed, but there is a need of improving the efficiency of the verification process to cope with the growing production level and the complexity of the considered systems.
Currently, the verification process is not driven by any standard.

The use case has a special focus on the verification of systems under design, which goes across several of the AHT-EPPs.

1.1.2 Engineering Process analysis

Table 2 Matching of the UC and the AHT Engineering Processes & potential Objectives reachable by each EPP.

AHT-EPP	1 (R)	2 (FD)	3 (PE)	4 (DC)	5 (OM)	6 (M)	7 (E)	8 (TE)	Missing ?
UC-EP match	C	C	C	N	N	C	C	C	N
OBJ-AHT #1	X	X	X			X		X	
OBJ-AHT #2		X							
OBJ-AHT #3			X				X		
OBJ-AHT #4									
OBJ-AHT #5									
OBJ-AHT #6		X	X						
OBJ-WP2 #1									
OBJ-WP2 #2			X				X		
OBJ-WP2 #3	X	X	X			X	X		
OBJ-WP2 #4		X	X					X	

1.2 Engineering processes and tool chains for digitalized and networked diagnostic imaging (PHC)

This Use Case aim at automatize the development of an MR-receiver. In an MR-receiver the signal processing is in general performed by hardware for the analog domain and firmware for the digital domain. In its design, Matlab models are used for a number of functional signal processing blocks. From the models, the required parameters for the implementations are derived, as well as the calculation methods for the digital domain. Currently, these models are translated by hand, and the output of the model is compared with the output of the implementation to test the correctness. In addition, necessary adaptations to the calculations in the firmware, e.g. using fixed-point arithmetic vs floating point in the Matlab model, lead to differences between output of the model and the implementation.

1.2.1 Engineering Process inputs

The Engineering process currently adopted is designed by implementing almost any development process as an iterative process; ergo the engineering process contains loops. The basic execution of one (complete) loop is:

- *Requirements* are written down, based on higher-level requirements. This is also valid for Feasibility Models (FeMo's) and Functional Models (FuMo's)
- A global design is made that should be able to fulfil those requirements. The result is described in a design specification.

- This global design is detailed to such a level that the lowest level parts can be produced.
- The parts are assembled into a complete building block, where during this integration step all remarks are written down in a design review report and, where applicable, reported as Defects.
- The building block is tested to show it fulfil its requirements.

If in any of this steps something has been proved to be not realistic, the process loops back to redo a previous step. Frequent reviews ensure that those loops are minimised in throughput-time, costs and quantity.

The methodologies and tools of the UC-EP, used across the lifecycle of the Use Case, are mainly in two phases:

- Requirements: requirements mgt tool (HP ALM PTC Integrity)
- Functional design: Matlab, Matlab Simulink, Vivado

The following AHT-EP phases are not applicable to these UC because the Use Case focuses on the design phase:

- Procurement & Engineering:
- Deployment & Commissioning: not related to UC
- Operation & Management: not related to UC
- Maintenance: not related to UC

Planned improvement of the toolchain potentially impact on two phases of the engineering process:

- Improvement of requirements management: traceability of requirements to lower level requirement and design, as well as to verification better ensure that the released design meets the requirements
- Improvement of functional design tools: by being able to better model the actual implementation, it is expected that less iterations are required

The UC relates to a component that is a small part of a quite complex system. Its requirements are derived from higher-level requirements, and vice-versa, the verification is to be covered by higher-level verifications. Typically, the system - subsystem – component decomposition strategy is used in order to manage the overall design process.

The requirements and verification is compliant with regulatory requirements issued by National Organizations or Standardization bodies, e.g.:

- USA: FDA 21CFR820 (Medical Devices, Quality System Regulation)
- EU: Medical Device Regulation
- IEC60601-1: Medical electrical equipment - Part 1: General requirements for basic safety and essential performance, plus collateral standards
- IEC60601-2-33: Medical electrical equipment - Part 2-33: Particular requirements for the basic safety and essential performance of magnetic resonance equipment for medical diagnosis
- ISO14971: Medical devices — Application of risk management to medical devices
- Plus many others

These standards impact the EP because of the specific requirements and the proof that needs to be delivered.

The engineering process is typically iterative, e.g. between requirements and functional design. In addition a new version typically changes a small part of the design (incremental development), so that the baseline configuration (requirements + design) is relevant.

1.2.2 Engineering Process analysis

Table 3 Matching of the UC and the AHT Engineering Processes & potential Objectives reachable by each EPP.

AHT-EPP	1 (R)	2 (FD)	3 (PE)	4 (DC)	5 (OM)	6 (M)	7 (E)	8 (TE)	Missing ?
UC-EP match	C	C	N	N	N	N	N	N	N
OBJ-AHT #1	X	X							
OBJ-AHT #2	X	X							
OBJ-AHT #3									
OBJ-AHT #4									
OBJ-AHT #5									
OBJ-AHT #6	X	X							
OBJ-WP2 #1									
OBJ-WP2 #2									
OBJ-WP2 #3	X	X							
OBJ-WP2 #4	X	X							

1.3 Integration of electronic design automation tools with product lifecycle tools (ULMA)

This use case is applied to whole development lifecycle of critical systems for IoT and SoS. More specifically, it focuses on the possibility of making a better reuse of physical models covering the abstraction, selection, representation and customization of system artefacts from the whole development lifecycle. Furthermore, in this use case, there is another major objective focusing on the improvement of traceability to be able to keep trace from the very early stage of development to the final release of a complex product. Traceability is a critical activity to ensure that every system artefact exists for a reason.
The main motivation of this use relies then on being able to access and exchange different system artefacts (and tools) enabling a reusability layer based on interoperable standards.

1.3.1 Engineering Process inputs

The engineering process defined for this use case is based on the technical engineering processes of ISO 15288.
Then, different engineering methods and tools are used to implement the use case. More specifically, the mapping between the UC-EP engineering processes and those in the AHT-EP defined lifecycle is shown in the following table:

Table 4 Mapping of UC-EP to AHT-EP processes within UC3.

UC-EP Engineering process	AHT-EP
System Requirements Definition	Requirements
Architecture Definition	Functional Design
Design definition	Functional Design
Implementation	Procurement & engineering, Training & education
Verification & Validation (Measurement process)	Procurement & engineering, Deployment & Commissioning
Information Management	Not available

In general, it is a matter of nomenclature. However, the main difference between UC-EP engineering processes and the AHP-EP is the notion of Information Management that in this use case, it is explicitly defined as a cornerstone to provide reuse capabilities and traceability management. More specifically, this case focuses on the concept of Knowledge-Centric Systems Engineering as a means to guide the engineering process exploiting all the data, information and knowledge that is generated during the development lifecycle and encoded in the system artefacts.

Those AHT-EP phases regarding *Maintenance* and *Evolution* are not explicitly defined in the UC-EP. This is mainly because the system under definition and construction will not be deployed in a production environment but in a relevant scenario (TRL 4-6).

As it has been stated before, the possibility of focusing on the notion of information management and give an implementation to concept of Knowledge Centric Systems Engineering, enables us to define and implement an engineering environment that can take the most of the information and knowledge that is encoded within system artefacts. However, this concept cannot be implemented unless the required data and operations are described in standardised terms.

Technology to implement the use case is generally available but not in the frame of Knowledge-Centric Systems Engineering. This means, common data, access and communication models for both data and operations in each of the tools that are part of the toolchain.

As main suggestion, it would be nice to align the AHT-EP to an existing standard such as ISO 15288. There are many technical engineering processes that will be applicable to many use cases. More specifically, those regarding non-functional processes such as quality management, information management or configuration management.

There are two main differences between UC-EP and the AHT-EP:

- Nomenclature. In this use case, the ISO 15288 is used as a framework to describe the UC-EP.
- Information Management. It is an engineering process that has not been considered in the AHT-EP. Likely, it is somehow delegated in tools implementing the different phases.

1.3.2 Engineering Process analysis

Table 5 Matching of the UC and the AHT Engineering Processes & potential Objectives reachable by each EPP.

AHT-EPP	1 (R)	2 (FD)	3 (PE)	4 (DC)	5 (OM)	6 (M)	7 (E)	8 (TE)	Missing ?
UC-EP match	C	C	C	C	U	N	N	C	Information Management
OBJ-AHT #1	X	X	X	X					
OBJ-AHT #2			X						
OBJ-AHT #3		X	X	X					
OBJ-AHT #4			X	X					
OBJ-AHT #5									
OBJ-AHT #6			X					X	
OBJ-WP2 #1			X	X					
OBJ-WP2 #2			X	X					
OBJ-WP2 #3	X	X	X	X					
OBJ-WP2 #4			X					X	

1.4 Interoperability between (modelling) tools for cost-effective lithography process integration (ASML)

ASML is the world's leading provider of complex lithography systems for the semiconductor industry. The design process of these Cyber-Physical Systems of Systems involves multi-disciplinary engineering teams focusing on functional specification and verification of scenarios and mono-disciplinary engineering teams focusing on the realization of these scenarios in a platform composed of mechanical, optical, electrical and software components.
The objective of this use case is to develop a tool chain, mainly focussing on the ***functional design*** phase that establishes seamless interoperability between modelling tools to facilitate multi-disciplinary engineering teams providing functional engineers with an efficient feedback loop to develop and qualify calibration, performance and diagnostic test scenarios.

1.4.1 Engineering Process inputs

In the following the description of the engineering activities currently performed in the phase.

- Matlab is used during the *requirements* / investigation phase (1)
- If the requirements phase is successful, the *functional design* (2) is captured with Word and Visio.
- These unprecise specifications are manually translated to a software specification during the *procurement and engineering* phase (3), and manually implemented in Python software in the same phase using version systems ClearCase.
- The *deployment and commission* (4) use Linux patching to deploy to the field.
- The *operations and management* (5) of the scenarios are captured in field procedures in Word.

- When *maintenance* (6) is needed on the software the scenario is retrieved from ClearCase and updated and newly deployed to the field.
- The *evolutions* in general lead to a new scenario which includes the whole above described phases.
- *Training* (8) of the scenarios is included in the field procedures.

Table 6 UC4-EPP mapped on AHT-EPP

AHT-EP phase	UC-EP tool/methodology groups
Requirements	Matlab, Word documents
Functional design	Word documents & Visio diagrams Matlab Stateflow / LSAT (scenario & platform specification) CIF/SDF3 (scenario synthesis) mCRL2 (formal analysis (model checking))
Procurement & engineering	Python code, ClearCase versioning
Deployment & commissioning	Linux patching
Operations & management	ClearCase / AIR / FCO
Maintenance	ClearCase / AIR
Evolution	ClearCase / AIR
Training	Field procedures documented in Word

All of the AHT-EP phases are applicable to the use case as it encompasses the total software life-cycle of calibration, performance and diagnostics test scenarios.
The AHT-EP toolchain will strongly improve the quality and duration of the CPD development process as manual and error-prone handovers between the phases will be automated. This applies to the functional design and engineering phases, but also the commissioning and maintenance phases.
The executable requirements designed and built in the design phase have to be converted into usable code, and vice versa. This technology is not available and has to be developed.
Additionally the Mathworks tooling is not designed to communicate in real time with a target machine, hence a new component has to be developed to support this.
To reduce manual efforts in scenario modelling, we aim for modular and composable specifications, and use PLE techniques to enable re-use of specifications amongst different product families.
Supervisory controller synthesis suffers from scalability issues. To mitigate this, we use modular and distributed synthesis techniques i.s.o. monolithic synthesis, and attempt to use PLE-techniques to allow for re-use of (partial) synthesis results.
Formal analysis techniques such as model checking suffer from scalability issues due to the state-space explosion problem. To mitigate this, we use compositional model checking techniques next to abstraction techniques.
The creation of the model is checked by a Model Advisor. The off-the-shelves advisor of Mathworks will be extended with specific checks and advices. We will loosely use automotive standards as Modelling Standards for MISRA C:2012.

1.4.2 Engineering Process analysis

Table 7 Matching of the UC and the AHT Engineering Processes & potential Objectives reachable by each EPP.

AHT-EPP	1 (R)	2 (FD)	3 (PE)	4 (DC)	5 (OM)	6 (M)	7 (E)	8 (TE)	Missing ?

UC-EP match	C	C	C	C	C	C	C	C	N
OBJ-AHT #1	X	X	X	X	X	X	X		
OBJ-AHT #2									
OBJ-AHT #3					X				
OBJ-AHT #4				X	X	X	X		
OBJ-AHT #5									
OBJ-AHT #6								X	
OBJ-WP2 #1									
OBJ-WP2 #2			X	X	X				
OBJ-WP2 #3	X	X	X	X	X	X	X		
OBJ-WP2 #4								X	

1.5 Support quick and reliable decision making in the semiconductor industry (KAI)

To support quick and reliable decision making in the semiconductor industry, three tools will be improved and implemented in the course of the project. They are TePEx, WHF and DR.

- TePEx: (Test pattern extraction): An algorithm which is able to detect test patterns, which are related to malfunctioning testing equipment.
- For the TePEx algorithm, wafer test data are used, which are electrical tests, taken per device.
- WHF (Wafer health factor): An algorithm which is able to detect process patterns, which are related to deviations during production.

DR (Digital Reference): During the engineering phase, integration of added goods and services is a key step for the engineering phase. Thus, interconnectivity and interoperability should be guaranteed. The proposed Semantic Web representation of the Supply Chain, namely Digital Reference is a lingua franca understandable by machines as well as humans. Semantic Web implementation can guarantee interoperability as it creates an abstraction layer that defines concepts and relationships between heterogeneous data sources. Digital Reference allows the interconnectivity between different physical or virtual systems, machines and users.

1.5.1 Engineering Process inputs

In the Figure 2 the current coverage of the UC-EP phases.

Figure 2 UC-EPP

In the Figure 3 the methodology and tools of the UC-EP mapped on the AHT-EP.

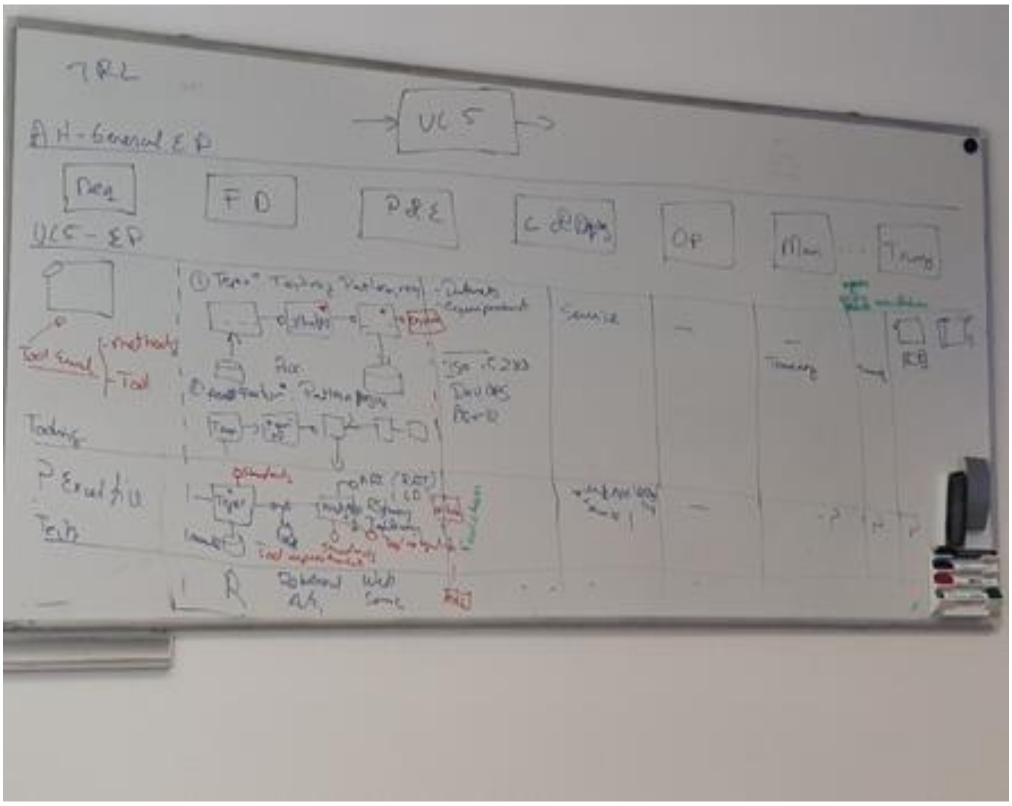


Figure 3 UC-EPP mapping on AHT-EPP

The planned improvement of the toolchain potentially impact on the engineering process by improving the API based on standards and by providing new version of tools.
In the following the order in which the AHT-EP phases are adopted in the use case domain;

Figure 4 UC-EPP sequence

TePEx and WHF will be verified for a huge product palette.
The ontologies fit for different domains, TePEx and WHF can also be used on other company sites and for different equipment and products.
Standards for AI/ML techniques and for writing code will be investigated in the course of the project.

1.5.2 Engineering Process analysis

Table 8 Matching of the UC and the AHT Engineering Processes & potential Objectives reachable by each EPP

AHT-EPP	1 (R)	2 (FD)	3 (PE)	4 (DC)	5 (OM)	6 (M)	7 (E)	8 (TE)	**Missing ?**
UC-EP match	C	C	C	C	C	C	P	C	N
OBJ-AHT #1	X	X	X						
OBJ-AHT #2									
OBJ-AHT #3									

OBJ-AHT #4			X	X	X	X			
OBJ-AHT #5									
OBJ-AHT #6						X		X	
OBJ-WP2 #1									
OBJ-WP2 #2			X	X					
OBJ-WP2 #3	X	X	X	X	X	X	X	X	
OBJ-WP2 #4						X		X	

1.6 Production preparation tool chain integration (LIND)

In this use case, there are three parties. Lindbäcks Bygg AB (Lindbäcks), Lundqvist Trävaru AB (Lundqvist) and PodComp AB (PodComp).
Lindbäcks has an engineering process from architect drawing to the automated wood house factory. The technology used in the engineering process originates from the 1980s, it consumes a lot of engineering time, since it creates deviations a lot of manual verification is needed and sometimes errors slip in to production that causes downtime and delays in the production. To be able to keep the pace in the factory Lindbäcks buys completed bathroom pods from PodComp, these are lifted in place into the wooden modules that Lindbäcks produce in their factory.
Today Lindbäcks sends pdf drawings to PodComp, at PodComp the pdf drawings are manually transfer into a drawing system connected to their production system, here machine files are created and verified in a simulator before they are put into their production line.
Lundqvist Trävaru AB has a system where their customers configure desired products in a 3D configurator. The 3D configurator has the engineering logic and transfers the information to drawings and bill of materials that is the basis for purchasing and production. However, the system is not scalable, and it is getting harder to update and enhance it with new systems. This in turn is an obstacle for growth and further digitalization in the production process.
PodComp has a good production and manufacturing line. However, a lot of their information flow from order to machine is handled manually. This is limiting PodComp to be to extend their footprint on the market towards smaller companies or even end users (i.e. more and smaller orders)
The three companies can, within the Arrowhead Tools project, collaborate to streamline the process from architectural drawing, via a 3D configurator to created machine files. By utilizing the Arrowhead Tool framework, they can implement and verify a more automated yet secure way of transferring data in the information flow.

1.6.1 Engineering Process inputs

In the following, the current status of the UC-EP is declared:

- Vertex implementation is on going
- Requirements have been defined and function design is ongoing, this will cover the engineering process at Lindbäcks.

- The architecture of a new 3D configurator is being finalized at Lundqvist
- Next step is to start development.

The planned improvement of the toolchain potentially impact on the engineering process since it will require less rework in the engineering process as well as that the change of project in the production line will run smoother with less waste and down time. The quality of the output will also improve due to less manual work and risk for human errors.
No technology for how to transfer output from Vertex or the 3D configurator to machine file have been identified. Plan is to build it within the project.
The engineering process at Lindbacks is not scalable at the moment due to that the drawing tool used is so customized that it is now hard to get it to handle new requirements without a losing other functionionality or introducing bugs.
The 3D configurator at Lundqvist can not longer support the more complex products that Lundqvist would like to sell.
The engineering and order handling at PodComp is so manual that it is not scalable at all and restrict PodComp from reaching other market segments.
All of the engineering steps has to apply to the laws and regulations set by the Swedish authorities and by that is creating standards:

- PBL – Plan och Bygg lagen
- BBR – Boverkets Byggregler

The goal with the use case is to get a data exchange process within and between the companies connected to the use case from requirements to operations. Maintenance, Evolution and Training & Education will be considered in the use case but not the focus areas.

1.6.2 Engineering Process analysis

Table 9 Matching of the UC and the AHT Engineering Processes & potential Objectives reachable by each EPP

AHT-EPP	1 (R)	2 (FD)	3 (PE)	4 (DC)	5 (OM)	6 (M)	7 (E)	8 (TE)	Missing ?
UC-EP match	C	C	C	P	C	P	P	P	N
OBJ-AHT #1	X	X	X	X	X	X	X		
OBJ-AHT #2									
OBJ-AHT #3	X	X	X	X	X	X			
OBJ-AHT #4		X		X					
OBJ-AHT #5									
OBJ-AHT #6		X						X	
OBJ-WP2 #1					X	X	X		
OBJ-WP2 #2	X	X	X	X	X				
OBJ-WP2 #3	X	X	X	X	X	X			
OBJ-WP2 #4		X						X	

1.7 CNC machine automation (FAUT)

Customers of Fagor Automation usually spend one or two days parameterising and tuning the machine axes. Customising HMI is done with a proprietary tool based on legacy technologies on a computer.
Tuning tools are both located at the CNC or with a computer connected with DCOM protocols. Version tracking and adaptation between CNC and tools is usually a source of problems. The new tools should reduce by 50% the time needed by our customers. The new tools will follow the evergreen approach to cope with the versioning problem.
The current tools are mostly integrated in the CNC and as such are difficult to update (need to update the full code). The new tools will follow a modular approach and rely on open source standards for version managing if necessary. Moreover, for better interoperability, the tools will use semantics from standards, as OPC-UA and, more importantly, related companion standards like the already published by VDW for machine tools. This will improve integration with third party tools.
There is currently a CNC simulator for Fagor Automation's CNC. The system is very good for CNC programming training, but can not be used easily with customising and tuning tools. This simulator will be modified up to some extent with control algorithms as a platform where both intended tools of the project will be demonstrated. In the related Work Package at least a lathe and a milling machine will be shown with a small tutorial for tuning.

1.7.1 Engineering Process inputs

All the tools used in this UC are Fagor Automation proprietary toolchains. The actual architecture assumes tight integration of the different parts and DCOM use for HMI. Individual evolution of the components is aggregated in full product versions.

Procurement:

-Canned Cycles and OEM-specific know-how integration

Deployment:

-Topology detection, bus configuration, drive and IOs parameter…

-Identity handler, option management.

Commissioning:

-PLC programming

-CNC & Drives tuning

-CNC Customizing

Operation & Management

-CNC programming applications

-CNC customizing tools

-Identity, rol and security handler

Maintenance

-Data gathering of operational data

-Diagnostics tools

Evolution

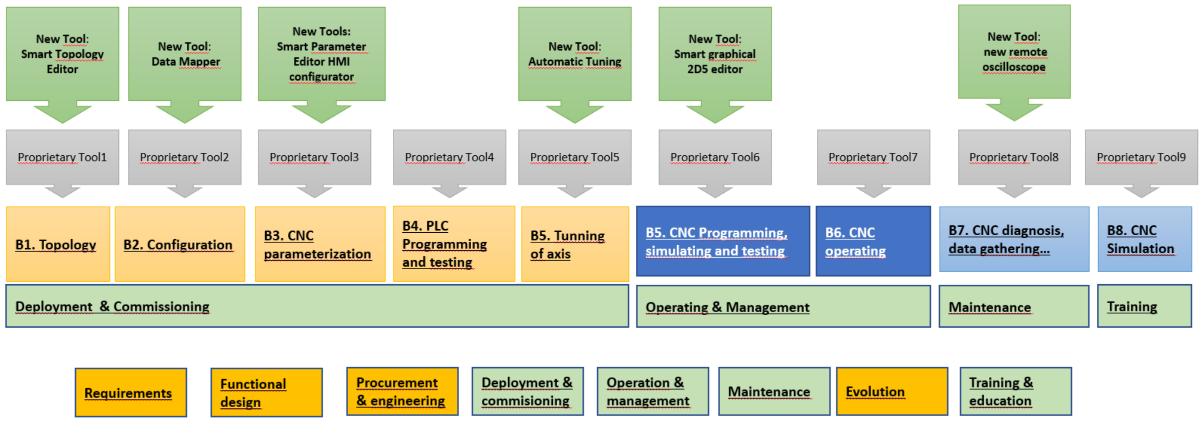
-Version maintenance

-Upgrading (options managing)

Training

-CNC simulator with 3D graphics and realistic display of final parts.

In the following the mapping between the UC-EP and the AHT-EP



The following Engineering phases are not applicable in our use case:

- Requirements:
- Functional design:
- Procurement & engineering

It's important to remember that the use case identifies the integration and use of a CNC in a Machine tool. We don't look at the machine design and construction (in the machine tool builder case) nor the part piece design (in the machine tool user case). Under such assumptions, no requirements, functional design or procurement phases are applicable.

Maintenance for the Machine Tool is out of scope, whilst the CNC gathers information and provides tools for diagnose and these tools have been already covered.

The improvement will impact mainly two engineering phases in specific tools.

First, the parameterizing-configuration-tuning phase can be shortened by up to a 50% with the appropriate support and automation.

Second, the advanced programming tool, combined with the simulation tool, will reduce the translation from drawing to part program by a large amount, but will depend on the complexity of the piece. Between 20% and more than 60% of time can be spared with adequate tooling for somewhat complex parts in 2D5 dimensions.

Additionally, improvements in this suite of tools will impact both maintenance and training. This last would benefit of an extended simulation platform where the deployment and commissioning could be simulated very much like in a real machine. Configuration and tuning tools will be used in maintenance phase for diagnosis.

Available Technologies seem to be enough for the phases addressed in this use case.

The order in which the AHT-EP phases are adopted is the one specified but it must be pointed out that, regarding this use case, some phases would be done by the machine tool builder and are not applicable here. Deployment and engineering is done both by the machine tool builder and the end user and the remaining are mixed between these 3 subjects (MT builder, CNC builder, MT user).

The HMI customization tool is used both by the OEM and by the final user. There is a brand customization possible (OEM) and individual Machine tool customization (End User).

Tuning is done at machine level usually, but in some cases a fine tuning for specific parts is done for a part program.

We have recently adopted OPC-UA for data acquisition related to maintenance and operation & management. Companion standards for machine tool are still in early phases or immature. We actively follow this track.

1.7.2 Engineering Process analysis

Table 10 Matching of the UC and the AHT Engineering Processes & potential Objectives reachable by each EPP

AHT-EPP	1 (R)	2 (FD)	3 (PE)	4 (DC)	5 (OM)	6 (M)	7 (E)	8 (TE)	Missing ?
UC-EP match	N	N	N	C	C	C	P	C	N
OBJ-AHT #1				X	X	X	X		
OBJ-AHT #2				X	X	X			
OBJ-AHT #3				X	X	X			
OBJ-AHT #4				X	X	X	X		
OBJ-AHT #5				X	X	X	X	X	
OBJ-AHT #6				X		X		X	
OBJ-WP2 #1						X	X		
OBJ-WP2 #2									
OBJ-WP2 #3				X	X	X	X	X	
OBJ-WP2 #4				X		X		X	

1.8 SoS engineering of IoT edge devices (ST-I)

1.8.1 SoS engineering of IoT edge devices: Smart City - Env. Monitoring (REPLY)

This use case will propose a highly pervasive sensing infrastructure must provide chemical, PM 2.5-10, noise, temperature, weather data at sampling times of less than 1 minute and potentially with a spatial granularity of less than 100 m.
Such constellation of devices require an extreme attention on power consumptions, that can be accomplished only by using next generation silicon sensors, energy-aware software applications and low-power, medium-to-long range wireless communications.
An IoT architecture must take into account the environmental constraints where the sensors will be deployed.
The constellation of sensors and edge devices capable of collecting, processing and transmit data from the field will exploit wireless connections that preserve bandwidth, battery duration and extend the sensor’s life spanning multiple years without maintenance.

1.8.1.1 Engineering Process inputs

To be defined during the project.

1.8.1.2 Engineering Process analysis

Table 11 Matching of the UC and the AHT Engineering Processes & potential Objectives reachable by each EPP

AHT-EPP	1 (R)	2 (FD)	3 (PE)	4 (DC)	5 (OM)	6 (M)	7 (E)	8 (TE)	Missing ?
UC-EP match	U	C	C	C	C	U	U	P	N
OBJ-AHT #1		X	X	X	X				
OBJ-AHT #2		X	X	X					
OBJ-AHT #3									
OBJ-AHT #4		X	X						
OBJ-AHT #5									
OBJ-AHT #6				X	X			X	
OBJ-WP2 #1									
OBJ-WP2 #2									
OBJ-WP2 #3		X	X	X	X				
OBJ-WP2 #4				X	X			X	

1.8.2 SoS engineering of IoT edge devices: Smart City - AI driven Env. Monitoring (IUNET)

This use case is applied to whole development lifecycle of an IoT and SoS for a smart energy smart home application.
The UC-08_02 will integrate in the Edge side processing enabling kit the component of the “Artificial Intelligence Driven Camera” at minimum marginal cost consisting in Ultralow power QVGA camera, a vector processor based on RISC-V GAP8 architecture and a multi-protocol radio capable to switch and select the most appropriate IoT wireless standard. The ultralow-power machine learning optimized core, will be used as vector processor with a Low Power QVGA Image Sensor. An on-board energy harvester will satisfy the energy requirements, and make the system energy-neutral.

1.8.2.1 Engineering Process inputs

UC-EP phases:

- **Requirements:**
  - Performance requirements collected by end-users.
- **Functional design:**
  - Performance requirements are analysed to generate a list of Technical requirements of the HW and SW design of the camera.
- **Procurement:**
  - Hardware components for Camera Assembly
- **Engineering:**
  - Image processing training and validation phases will be executed as offline procedure

    - Image Classification will eventually run on the AI-drive camera after an offline test.
    - New software releases will be assessed at server side and offline, before updating.
    - Release of the new software versions
- **Deployment**
    - The software is finally released
- **Maintenance**
    - Analysis of possible bugs raised from a large scale deployment

In principle, all the phases of the AHT-EP are applicable to the specific use case domain, although there is more interest in focusing on specific phases, mainly Functional Design, Engineering, and Deployment/Commissioning. Tools for evolution phase are not yet integrated but are planned to be. Training is not needed for this uses.

The improvement of the toolchain shall improve the interfaces between the different phases of the UC-EP, helping to automate the exchange of information between the different phases, and thus leading to a reduction of development time.

Management of the AI-drive cameras need to be fully automatized; and Evolution Phase is currently not supported.

The AHT-EP will help in promoting this phase by providing new technologies to automatize novel methodologies.

For all the components the EP phases can be applied at different scale levels for describing the life-cycle of the components and subcomponents.

1.8.2.2 Engineering Process analysis

Table 12 Matching of the UC and the AHT Engineering Processes & potential Objectives reachable by each EPP

AHT-EPP	1 (R)	2 (FD)	3 (PE)	4 (DC)	5 (OM)	6 (M)	7 (E)	8 (TE)	Missing ?
UC-EP match	C	C	C	C	C	C	P		N
OBJ-AHT #1		X	X	X	X	X	X		
OBJ-AHT #2		X	X	X		X			
OBJ-AHT #3									
OBJ-AHT #4		X	X	X					
OBJ-AHT #5									
OBJ-AHT #6									
OBJ-WP2 #1		X	X	X			X		
OBJ-WP2 #2			X	X					
OBJ-WP2 #3		X	X			X	X		
OBJ-WP2 #4									

1.8.3 SoS engineering of IoT edge devices: Smart City Condition monitoring (IUNET)

In this use case will be developed Health Monitoring sensors responsible for collecting the measure of different physical quantities for conditioning monitoring. The heterogeneity of measurement will include also data size and sampling rate. Sampling by event can be also feasible.
In this scenario, the data that will be collected by the demonstrator that will be realized in this use case and the tools developed in this use case, compliant with the Arrowhead Framework (AF), aim to provide the means to overcome these issues, simplifying the design process, reducing engineering costs and also the maintenance costs for the end user.
The investigation of smart SHMS solutions has important effects from both social and economic point of views and for these reasons, it has been chosen as use case to demonstrate the effectiveness of tools developed within the AF to reduce the engineering costs facilitating the extensive introduction on the market of SHMS solutions.
The demonstrator is going to be a structural health monitoring system (SHMS) for a target structure (e.g. a section of a bridge or a construction, that could be civil or industrial).
The SHMS will consist of multiple IoT networks, including networks of sensors installed on the target structure, a network of environmental monitoring sensors provided by Eurotech, that collects and analyzes air quality parameters, electromagnetic fields, and ionizing radiation (ReliaSens), and additional third parties datasources, such as for example meteo data services.

Health Monitoring Sensor design phase: it includes the design of the component and its testing.
Procurement & Engineering: Hardware components for sensor board and its validation
Deployment: the board is released to be connected by a specific connectors
OPERATION: HMS provides raw data

1.8.3.1 Engineering Process inputs

In this UC will be optimised the maintenance process, minimizing operational risk levels and maintenance costs (through condition monitoring). To meet such a requirement we need to:

- Collect data from multi-vendor heterogeneous sensors and sensor networks (i.e. edges and extreme edges) and make the collected data consistent with a shared data model
- Create tools to optimize the data collection process and associated costs
- Create tools to support prognostics based on condition monitoring

The demonstrator will be used to validate a tool-chain prototype to support the engineering process of condition monitoring systems that might consist of a chain of four tools:

- A tool to support *functional specification*, having as output the floorplan of the sensing infrastructure, mapped onto the target structure
- A tool to support sensor network *configuration design* and power management design, having as output the appropriate mix of sensors and energy harvesting devices, with the appropriate configurations
- A tool to support the *deployment* of the configuration of the sensing infrastructure according to the design plan

- A tool to support the *operation* and *evolution* of the sensing infrastructure by providing data to context sensitive optimization tools possibly provided by third parties.

The tools need to be made interoperable thanks to a shared data model understood by all tools. Such a data model has to describe all entities involved in the engineering process and the associated properties. Most likely it will rely on standard ontologies, such as SAREF (to model devices) and SOSA (to model sensors and actuators).

1.8.3.2 Engineering Process analysis

Table 13 Matching of the UC and the AHT Engineering Processes & potential Objectives reachable by each EPP

AHT-EPP	1 (R)	2 (FD)	3 (PE)	4 (DC)	5 (OM)	6 (M)	7 (E)	8 (TE)	Missing ?
UC-EP match	N	P	P	P	P	U	P	U	U
OBJ-AHT #1		X	X	X	X		X		
OBJ-AHT #2									
OBJ-AHT #3				X	X		X		
OBJ-AHT #4									
OBJ-AHT #5									
OBJ-AHT #6									
OBJ-WP2 #1				X	X		X		
OBJ-WP2 #2				X					
OBJ-WP2 #3		X	X	X	X		X		
OBJ-WP2 #4									

1.8.4 SoS engineering of IoT edge devices: Smart Energy - Smart Home (ST-I)

In this use case, we will develop the ***Edge side processing enabling kit*** that has two main components:
The first component called *last-meter IoT sensor nodes at minimum marginal cost* will group three sensing services useful for the monitoring of the home energy consumption.
In the following the functional blocks of the LF-NILM and HF-NILM and Gas meter:

- LF-NILM: measures current from a clamp connected to the home main meter
- HF-NILM: likewise, however the measurements are sampled at a higher frequency: hardware data are pre-processed on board and current harmonics are evaluated
- Cloud-Based Services: Data are collected and sent in burst mode via Wi-Fi on the cloud (Microsoft Azure, Kura)
- Human-Computer Interface (HCI): A mobile application installed on users smartphones or a web services can visualise the results of the analysis.

- Gas meter: measure of gas power consumption will be available for to the smart energy services in order to provide a more comprehensive view of the power consumptions to customers.

The second component, called *task partitioning and allocation*, will be applied to the electric smart meter attached to LF-NILM.

1.8.4.1 Engineering Process inputs

Edge side processing enabling kit (last-meter IoT sensor nodes at minimum marginal cost)

- LF-NILM
  - The engineering process is made by the following phases:
  - **Requirements:**
    - User requirements collected by mean the involvement of tester users, focus group and user surveys and saved on excel spreadsheet
  - **Functional design:**
    - User requirements are analysed and summarized by mean the involvement of tester users, focus group and user surveys
    - Technical requirements are analysed in order to meet as much as possible the design outcomes
  - **Procurement:**
    - NILM Hardware
  - **Engineering:**
    - NILM core is developed in an embedded project that drives the front-end rules and the notification system towards the mobile application
    - NILM training phase and NILM validation and classification can run on different platforms.
    - New software releases are run over a huge number of samples days for testing the reliability and avoiding crushes
    - New software releases are tested by some beta-testing users for some days and feedbacks are crucial for deciding the time of release in production infrastructure
    - Release of the new software versions
  - **Deployment**
    - The software is finally released
  - **Maintenance**
    - Analysis of possible bugs raised from a large scale deployment
- HF-NILM
  - The engineering process is made by the following phases:
  - **Requirements:**
    - Performance requirements collected by the involvement of users and innovators.
  - **Functional design:**
    - Performance requirements are analysed to generate a list of Technical requirements of the HW and SW design of the meter.
  - **Procurement:**

        - Hardware components for NILM assembly
    - **Engineering:**
        - NILM training and validation phases will be executed as offline procedure
        - NILM classification will eventually run on the Smart meter device, after an offline test.
        - New software releases will be assessed at server side and offline, before updating.
        - Release of the new software versions
    - **Deployment**
        - The software is finally released
    - **Maintenance**
        - Analysis of possible bugs raised from a large scale deployment
- Gas Meter
    - **Operation:**
      Actually the base line of a gas meter does not include an integration to any IoT systems: gas companies provide an estimated lectures of the consumptions (best cases: based on customers input) that requires lectures from operators once ore more times in a year

Edge side processing enabling kit (task partitioning and allocation)

- **functional design:**
    - Application model in Matlab, and then translate manually in c fixed point code
    - Mapping the task of a stream application on the edge multi-core devices is done manually.
    - The partitioned code is compiled and simulated in a proprietary platform simulators that is cycle approximates.
    - Final validation is performed on prototype boards
- **Evolution:**
    - Introduction of new objective function for optimise the partitioning and placement of tasks on the edge devices.
    - Support new communication standards
    - Support new devices and architectures

For the *Edge side processing enabling kit (last-meter IoT sensor nodes at minimum marginal cost)* In principle, all the phases of the AHT-EP are applicable to the specific use case domain, although there is more interest in focusing on specific phases, mainly Functional Design, Engineering, and Deployment/Commissioning. Tools for evolution phase are not yet integrated but are planned to be. Training is not needed for this uses.

Whereas, the *Edge side processing enabling kit (task partitioning and allocation)* will produce a tool that will be used in the Design and Evolution phases only. It will not have explicit relation with other EP phases.

The improvement of the toolchain shall improve the interfaces between the different phases of the UC-EP, helping to automate the exchange of information between the different phases, and thus leading to a reduction of development time.

The automatization functionality offered by the *Edge side processing enabling kit (task partitioning and allocation)* will be exploited by developers that are actually called at manually

partition and map the tasks of the algorithm on the most appropriate device and memory layer available on the edge device.
Edge side processing enabling kit (last-meter IoT sensor nodes at minimum marginal cost)

i. LF-NILM
Management of surveys collected from users are manually curated and analysed, the process can be partially automatized.
Evolution Phase is currently not supported for LF-NILM. The AHT-EP will help in promoting this phase by providing new technologies to automatize novel methodologies.

ii. HF-NILM
Management of the meters need to be fully automatized; and Evolution Phase is currently not supported for HF-NILM.
The AHT-EP will help in promoting this phase by providing new technologies to automatize novel methodologies.

iii. Gas Meter
An innovative device designed to ensure precise resources accounting (electricity, gas, heat and water).It provides automatic data collection from meters with pulse output, stores readings and transmits them to the dispatching server via the built-in modem over the NB-IOT network.

Deployment on the smart grid is missing at the moment, it will be developed during the project.
The automatization functionality offered by the *Edge side processing enabling kit (task partitioning and allocation)*
Currently the task is performed manually, with the task partitioning and mapping module the task will be semi or completely automatized.
All the phases in the UC-EP can be somehow mapped into the AHT-EP.
In principle, the logical order of the EPP adopted is similar to the order of the AHT-EP. This is structured into iterations/sprints, during which an increment in the product shall be delivered, therefore within the same iteration there can be simultaneously activities belonging to different phases of the AHT-EP.
For all the components the EP phases can be applied at different scale levels for describing the life-cycle of the components and subcomponents.
In Table 14 the list of standard used in this UC.

Table 14 List of Standards for each AHT-EPP.

	Standard
Req. & Specs	
Funct. Des.	IPXact, systemverilog, ansiC,
Eng. & Com.	ansi C
Depl. & Com.	
Op. & Man.	TU G.9903/PLC-G3, ITU G.9904/PRIME v1.3.6 and PRIME v1.4.

Mainte.	
Evo.	
Train.	

IPXact, systemverilog, ansiC, IEC62047, ISO 14001

1.8.4.2 Engineering Process analysis

Table 15 Matching of the UC and the AHT Engineering Processes & potential Objectives reachable by each EPP

AHT-EPP	1 (R)	2 (FD)	3 (PE)	4 (DC)	5 (OM)	6 (M)	7 (E)	8 (TE)	**Missing ?**
UC-EP match	C	C	C/P	C	C	C	P	P	N
OBJ-AHT #1	X	X	X	X	X	X	X		
OBJ-AHT #2			X	X	X		X		
OBJ-AHT #3									
OBJ-AHT #4			X	X			X		
OBJ-AHT #5				X	X	X			
OBJ-AHT #6					X	X		X	
OBJ-WP2 #1			X			X	X		
OBJ-WP2 #2			X	X			X		
OBJ-WP2 #3	X	X	X		X	X	X		
OBJ-WP2 #4					X	X		X	

1.8.5 SoS engineering of IoT edge devices: Smart Energy - Industrial (ST- I)

In this project, Condition Monitoring applications in an end to end framework will be exploited by implementing a use cases strictly correlated with smart sensor vibration and ultrasound nodes.
A new cloud-based tool will be developed and adopted for Industry 4.0 combining the information coming from the physical entities object of monitor and surveillance on their operative status.

1.8.5.1 Engineering Process inputs

Condition monitoring and anomaly detection is the process to monitor relevant physical characterizes such as vibration, noise, temperature, power adsorption of an equipment and part of this to recognize the trend versus an anomalous behaviour. Advanced monitoring is based on the appropriate set of sensors in which sensor fusion capability reinforce the status detection and providing the required data collection enable their analysis through the different vertical layer providing advanced services on base of this information and elaboration chain.
Industrial scenario consists of:

Smart sensor nodes deployed at the critical machines
Collection of sensors data and pre-processing with / without machine learning at the edge (either the node or a gateway / industrial PC)
High level analytics on company premises or on cloud for provisioning the nodes with updated algorithms.
The paragraph illustrates, in a synthetic way, how the scenario contributes to the engineering costs reduction.

- REQUIREMENTS: n.a.
- FUNCTIONAL SPECIFICATIONS:
  - AF speed up the process and reduce the skills needed for functional specification
- PROCUREMENT AND DESIGN:
  - Reduction of designing and implementation time for data management and facilitation of the algorithm testing and validation process using AF platform.
- DEPLOYMENT:
  - Reduction of implementation and integration time of the machinery smart monitoring service in cloud using the AF platform framework.
  - Cost reduction in easy scaling the services for load monitoring from multiple section/departments of the given factory.
- OPERATION: Cost reduction because of:
  - Efficiency in data management
  - Simplification in delivery and integration of the energy monitoring services with different relevant data management and visualization, and other high-end third-party applications.
- MAINTENANCE:
  - Reduced cost associated with change in maintenance algorithms
  - Cost reduction in maintaining data warehouse
- EVOLUTION:
  - UUpgrade of predictive algorithms with recent advancement of machine learning and new data points.
  - Integrating and scaling with ERM services for operative plan.
  - The infrastructure inherently supports future integration of new edge devices, things, platforms thanks to the AF platform framework

- TRAINING: n.a.

1.8.5.2 Engineering Process analysis

Table 16 Matching of the UC and the AHT Engineering Processes & potential Objectives reachable by each EPP

AHT-EPP	1 (R)	2 (FD)	3 (PE)	4 (DC)	5 (OM)	6 (M)	7 (E)	8 (TE)	Missing ?
UC-EP match	U	C	C	C	P	P	P	U	N
OBJ-AHT #1		X	X	X	X	X	X		
OBJ-AHT #2									
OBJ-AHT #3				X	X	X			
OBJ-AHT #4					X	X			
OBJ-AHT #5									
OBJ-AHT #6									

OBJ-WP2 #1									
OBJ-WP2 #2									
OBJ-WP2 #3		X	X	X	X	X	X		
OBJ-WP2 #4									

1.9 Machine operation optimisation (ACCIONA)

The use case is focused on the development of a digital platform for remote monitoring and optimization of earthworks in construction projects. Therefore, the production environment targeted for digitalization is a construction site where heavy machinery of different types (e.g. trucks, excavators, etc.) perform excavations in certain areas of the construction site, transport the excavated materials, and either dump the materials in a landfill, or use them as filler in other areas of the construction site.
The main objective is to track the operations of the machinery in real time in order to monitor the progress of the earthworks, detect deviations from the original plan, analyse productivity and key performance indicators, and detect opportunities for optimization of the operations.
The envisioned platform consists mainly of three layers:

- IoT layer (in the construction site): composed by data collection units installed in the earthworks machinery in order to collect operation data (e.g. location, fuel consumption, etc.).
- Data processing layer (cloud): data collected in the construction site are processed in order to analyse patterns, detect events, and determine/measure earthworks' activities.
- Web interface: it provides configuration and data analysis/visualization functionalities.

Currently there is an operational prototype of the platform, which allows collecting location data form the construction machinery, which are then processed in the cloud, and visualized through a web interface.

1.9.1 Engineering Process inputs

There is a development team, composed by ACCIONA employees and external subcontractors, working constantly on the evolution of the platform, adopting agile methodologies and the Scrum framework. Thus, evolution of the platform is implemented iteratively in sprints, usually of one-month duration.
The engineering process currently adopted by the use case is based on agile methodologies and the Scrum framework. Thus, the UC-EP is structured into iterations/sprints, each of which must deliver an increment in the product that provides added value to the product users/stakeholders and to the company. Within each iteration/sprint, different phases of the UC-EP can be covered, namely:

1. ***Requirements:*** requirements are managed through a product backlog, i.e. a prioritized list of desired features, which is managed across the whole life cycle of the product. In the planning of each sprint, it is decided which items within the product backlog will be implemented in said iteration. The selected items constitute the sprint backlog.
2. ***Functional design:*** in the development of the product, the development team tries to identify separate blocks or modules of the platform as functionally independent as possible in order to minimize the potential impact of changes in a module on the rest of modules. In each iteration/sprint, the aim is to release a new version of the product that incorporates all the functionalities specified within the product backlog items that must be implemented during said sprint. For doing so, the development team break down each product backlog item into a set of tasks. This breakdown shall be as detailed

as possible, so that one person of the team can complete a task (or change a phase of the task) preferably in less than one day. The definition of the task must include some acceptance criteria to assess whether it has been completed properly. The tasks are executed in one of the next phases of the UC-EP (Procurement and Engineering, Deployment and Commissioning, or Operations and Management), depending on the nature of the task.

3. ***Procurement and Engineering***:
    - ***Procurement*** in the context of the use case, the Procurement phase of the UC-EP target mainly two purposes: acquisition of hardware components for the IoT layer (e.g. GPS modules, power components, protections, etc.), and of cloud infrastructure for hosting the upper layers of the platform. The purchase process is subject to the general rules of the company (ACCIONA). Usual practice is trying to identify at least three alternative suppliers, ask quotations from them, and select the best one based on a combination of criteria: price, technical quality of the offer, delivery terms, payment conditions, technical support, etc. If the supplier selected was not previously registered in the supplier database of the company, it would be necessary to carry out a registration process, thus adding more time to the purchase process. Management of procurement tasks within an iteration/sprint of the product is carried out following the same stages as the engineering tasks that are described in the next paragraph.
    - ***Engineering***. The Engineering phase within the UC-EP targets the development, testing and documentation of the software and hardware modules of which the digital platform is composed. As it has been described for the Functional Design phase of the UC-EP, the product backlog items to be developed within an iteration/sprint are broken down into tasks, which evolve through the following stages within the sprint: Analysis, Development, Quality Control, Documentation, and Done. In the Analysis stage, an analyst drills down into the requirements of a task, and produces a specification of the work to be done in the next phases of the UC-EP. If the aim of the task is the development/evolution of a software or hardware module, then the analyst produces the functional specification/design of the module. After the Analysis, a developer will develop/evolve the software/hardware module according to the design. Then, a tester would perform the Quality Control of the module. Several iteration loops between Analysis and Development, and Development and Quality Control can take place until the task result is deemed suitable, and then the task goes through the Documentation phase, in which the software/hardware module produced will be documented. Once the outcomes of the task comply with the acceptance criteria that were defined, it reaches the last stage of Done.

4. ***Deployment and Commissioning***: this phase of the UC-EP encompasses all the activities addressing the installation and commissioning of the digital platform in an operational environment, i.e. a construction site. The installation may have either only testing purposes for validating new functionalities implemented in the platform, or may be aimed for real use of the platform as a strategic/management tool within a construction project. All deployment and commissioning activities are planned and executed following the same phases that have been described previously for the Engineering activities.
    - ***Deployment*** comprises mainly two different types of activities: installation of data collection units in the construction machinery, and configuration of project-specific data within the platform backend. The latter comprises different aspects such as registry of the machinery, configuration of the project construction

working areas, definition of earthworks tasks, configuration of user accounts, etc.
    - ***Commissioning*** comprises different activities for ensuring the proper operation of the platform deployed in a construction site. One key aspect of the commissioning will be ensuring the quality of the data collected from the machinery, as well as ensuring the proper handling of the data collection equipment installed.
5. ***Operations and Management:*** this phase of the UC-EP encompasses all the activities addressing the operation and management of the specific implementations of the platform in real construction projects. One key aspect is the monitoring of the correct operation of the platform in each project (i.e. correct operation of the IoT equipment deployed in the construction site, and correct operation of the platform backend/frontend). Another important activity is to provide technical support to the platform users for the resolution of technical issues, for updates in the project-specific configuration of the backend/frontend, and for answering questions regarding platform usage.
6. ***Maintenance:*** this phase of the UC-EP would cover the resolution of technical issues emerging from the operation of the digital platform in a construction project. From the use case perspective, there is little distinction between the Maintenance phase and the Operations and Management phase.
7. ***Evolution:*** according to the Scrum framework adopted in the UC-EP, the engineering process is structured into iterations/sprints, and each iteration must deliver an increment of the product to the users/stakeholders. According to this, there is little distinction in the UC-EP between the Evolution Phase and the Engineering Phase, as they are implemented following a similar approach.
8. ***Training:*** the minimum training requirement for the UC-EP is that all members of the team are familiar with the Scrum framework (events, artefacts, etc.).

In the following the methodologies and tools of the UC-EP, used across the lifecycle of the Use Case:

- All Phases: There are some methodologies and tools of the UC-EP that cover virtually all the phases of the AHT-EP, namely: the adoption of the Scrum framework, and the use of Microsoft Teams as global management, documentation and communication tool.
- ***Requirements:*** use of the product backlog as an artifact to manage the requirements. Use of Excel as tool for managing the product backlog.
- ***Functional Design:*** According to the scrum framework, product backlog items are broken down into tasks. A ‘virtual board’ in Microsoft Teams is used for specification of the tasks.
- ***Procurement and Engineering***
    - ***Procurement:*** internal rules of the company (ACCIONA) are used for procurement of hardware components. Procurement tasks in the UC-EP are managed similarly to Engineering tasks. Although ACCIONA uses administration tools for managing purchases, these are not considered to be included within the scope of the UC-EP.
    - ***Engineering:*** ‘virtual board’ in Microsoft Teams for tracking the different sub-phases of tasks within the Engineering phase. Repository of Microsoft Teams for document storage. Microsoft Office tools (Word, Excel, Power Point) for elaborating specifications of software/hardware modules. GitHub for management of software versions. MySQL as databases. .NET as development framework.
- ***Deployment and Commissioning:*** ‘virtual board’ in Microsoft Teams for tracking the different sub-phases of tasks within the Deployment and Commissioning phase.

- ***Operations and Management:*** 'virtual board' in Microsoft Teams for tracking the different sub-phases of tasks within the Operations and Management phase.
- ***Maintenance:*** 'virtual board' in Microsoft Teams for tracking the different sub-phases of tasks within the Maintenance phase.
- ***Evolution:*** Same tools as for the Engineering Phase.
- ***Training:*** no specific tools for training, although all the development team shall be familiar with the Scrum framework.

In principle, all the phases of the AHT-EP are applicable to the specific use case domain, although there is more interest in focusing on specific phases, mainly Functional Design, Engineering, and Deployment/Commissioning. Besides, considering that the use case adopts the Scrum framework, there is virtually no distinction between Evolution and Engineering Phases.

The improvement of the toolchain shall improve the interfaces between the different phases of the UC-EP, helping to automate the exchange of information between the different phases, and thus leading to a reduction of development time.

For the moment, we have not identified lack of technologies to support the use case.

All the phases in the UC-EP can be somehow mapped into the AHT-EP.

In principle, the logical order adopted is similar to the order of the AHT-EP. However, since the SCRUM framework is adopted for the UC-EP, this is structured into iterations/sprints, during which an increment in the product shall be delivered, therefore within a same iteration there can be simultaneously activities belonging to different phases of the AHT-EP.

The scalability level has not been analysed yet, as no by-products have been foreseen for the moment in this UC-EP.

List of the standards currently adopted for the EP of the Use Case:

- SCRUM framework for global management of the whole UC-EP and of its different phases.
- CAN Bus is relevant for integration of data monitored in heavy construction machinery.
- ISO-15143-3/AEMP 2.0 is relevant for integration of data collected from mixed fleets of heavy construction machinery.

The phases of the UC-EP are quite similar to the phases of the AHT-EP. However, the Maintenance Phase would normally be considered included within the Operations & Management Phase. Besides, Evolution Phase would not be in practice distinguishable from the Engineering Phase due to the adoption of the Scrum framework for global management of the different phases, which means that all activities are structured into iterations or sprints that must deliver an increment into the product.

1.9.2 Engineering Process analysis

Table 17 Matching of the UC and the AHT Engineering Processes & potential Objectives reachable by each EPP

AHT-EPP	1 (R)	2 (FD)	3 (PE)	4 (DC)	5 (OM)	6 (M)	7 (E)	8 (TE)	Missing ?
UC-EP match	C	C	C	C	C			C	x
OBJ-AHT #1	X	X	X	X				X	
OBJ-AHT #2					X				
OBJ-AHT #3		X	X	X	X				
OBJ-AHT #4			X	X					
OBJ-AHT #5									
OBJ-AHT #6		X	X	X	X			X	

OBJ-WP1									
OBJ-WP2 #1									
OBJ-WP2 #2		X	X	X	X				
OBJ-WP2 #3	X	X	X	X	X				
OBJ-WP2 #4								X	

1.10 Rapid HW development, prototyping, testing and evaluation (ARCELIK)

The aim of the use case is to develop automated electronics validation test tool and tool chain for power supply circuits. The tool and tool chain supports different white and black goods communication protocols.
In the following the steps of the tool to be developed in the UC:

- Enter setup configuration and measurement set by operator via UI
- Receive test configuration data via AH local cloud
- Configure AC power supply and variable load
- Take measurement via FMC board
- Save measurement data and calculate necessary values
- Prepare test results table and send operator via AH Local Cloud

1.10.1 Engineering Process inputs

The AHT-EPP used in the UC are:

- ***Deployment and Commissioning***. Within this phase manual deployment and automated configuration of system will be performed. After deployment system will be tested and it's performance validated.
- ***Operations and Management***. To assure proper operation and management of system, operator UI will be provided with authorization and authentication for each individual user.
- ***Training***. User manuals and training documents will be provided to each individual user.

UTIA will develop for the use case the unified configuration and project-bringup-scripts to address industrial modules fitted with variable sizes of Zynq Ultrascale devices. These scripts will support maintenance and support upgrade of commercial tool chain (Xilinx Vivado HLS) and will support HW upgrades at level of Zynq Ultrascale+ module and upgrades of FMC data acquisition adapter cards in the design phase and on site testing phases.
UTIA will mainly support the design and early testing phases. The long-term maintenance of products is not supported by UTIA in the frame of the project.
The configuration and project-bringup-scripts developed in UTIA to address industrial modules fitted with variable sizes of Zynq Ultrascale devices will simplify the process of selecting of an optimal industrial module and device. Design process can start on larger device. The finally released system can be simply re-targeted to industrial module with minimal required size of device and memory.
EDI TestBed allows for faster prototyping and reduced costs of MVP implementation, thus allowing for much faster moving through the TRL levels.
The current lack of technology to support the use case is that the Xilinx Vivado HLS toolchain lacks the flexibility of targeting of a complete family of industrial Zynq Ultrascale+ modules with single set of configuration and project-bringup-scripts.

The configuration and project-bringup-scripts will be used first in the design phase and next in the testing and deployment phase to optimize the cost of the complete system.
The existing Xilinx Vivado HLS is targeting one concrete Zynq Ultrascale+ device.
The configuration and project-bringup-scripts will target complete families of industrial modules with Zynq Ultrascale+ modules with different size, temperature grades, memory size etc. EDI TestBed can scale up to 100 workstations at the moment.
In the UC-EP UTIA adopt AXI4 bus standard, AXI4-Streem bus standard. EDI do not adopt standards at the moment.

1.10.2 Engineering Process analysis

Table 18 Matching of the UC and the AHT Engineering Processes & potential Objectives reachable by each EPP

AHT-EPP	**1 (R)**	**2 (FD)**	**3 (PE)**	**4 (DC)**	**5 (OM)**	**6 (M)**	**7 (E)**	**8 (TE)**	**Missing ?**
UC-EP match	N	N	P	C	C	P	N	P	N
OBJ-AHT #1			X	X	X	X			
OBJ-AHT #2									
OBJ-AHT #3			X		X				
OBJ-AHT #4									
OBJ-AHT #5									
OBJ-AHT #6					X			X	
OBJ-WP1									
OBJ-WP2 #1			X	X	X	X			
OBJ-WP2 #2									
OBJ-WP2 #3			X		X				
OBJ-WP2 #4								X	

1.11 Configuration tool for autonomous provisioning of local clouds (DAC)

The aim of the use case is to show the applicability of part of Arrowhead Tools to deploy and manage local cloud in logistics. The use case will be focused mainly on the Authorization and Authentication system in connection with the on-boarding process of a new device. For the purpose of the use case, we assume that the complete, base model of a system is known and properly engineered.

1.11.1 Engineering Process inputs

Engineering activities currently performed in the phase:

- ***Deployment and Commissioning***. Within this phase, automatic deployment and configuration of the local cloud will be performed. On the basis of a complete model of a system, the initial configuration will be set-up. After deployment, the system will be tested and its proper work will be validated.

- ***Operations and Management***. To assure insight into the operation of the system and its structure, a tool for authorization and authentication management should be included in the use case.
- ***Maintenance***. Performance of the local cloud will be monitored through a performance assessment tool.
- ***Evolution***. The use case will support evolution of the system through an implemented on boarding process of the Arrowhead-compliant nodes.

It is important to note that the phases can occur in a different sequence, can be skipped, form cycles or go back.

In the following the tools of the UC-EPPs:

- On boarding tool - used for the Evolution phase only, but accessible from the Operations and Management phase
- Implementation of the AH producer/consumer on an edge device along with adequate procedure of on boarding
- Performance assessment tool - used foR the Maintenance phase only, but accessible from the Operations and Management phase
- Dockerized version of the core services - used for the whole lifecycle

All the phases are applicable for the use case, but to show the proof of concept of the use case, the number of phases has been narrowed down.

The part of the evolution phase responsible for the SoS vertical scalability will benefit from the automatization of the on boarding process which can reduce the time of introducing a new device to the local cloud. The dockerized version of a local cloud is expected to reduce the overhead of the cloud setup and deployment.

There is a lack of low-level implementation of end-device consumer or provider services, which will be implemented. There is also a lack of virtualized automatic deployment of a local cloud. The on-boarding process is meant to be used through the whole lifecycle of the local cloud. Thanks to this, the local cloud will be easily scalable by adding new consumers and providers.

The standards currently adopted are: SenML for sensor data encoding [Operation & Management], X.509 for certificate generation and management [Deployment & Commissioning, Evolution].

1.11.2 Engineering Process analysis

Table 19 Matching of the UC and the AHT Engineering Processes & potential Objectives reachable by each EPP

AHT-EPP	**1 (R)**	**2 (FD)**	**3 (PE)**	**4 (DC)**	**5 (OM)**	**6 (M)**	**7 (E)**	**8 (TE)**	**Missing ?**
UC-EP match	N	N	N	C	C	P	P	U	N
OBJ-AHT #1				X	X	X	X		
OBJ-AHT #2									
OBJ-AHT #3				X	X	X	X		
OBJ-AHT #4									
OBJ-AHT #5				X	X	X	X		
OBJ-AHT #6									
OBJ-WP1									
OBJ-WP2 #1				X	X	X	X		
OBJ-WP2 #2				X	X	X	X		

OBJ-WP2 #3					X	X	X		
OBJ-WP2 #4									

1.12 Digital twins and structural monitoring (NTNU)

The use case is to develop digital twin of crane using both online and offline sensor data to provide structural monitoring.
Currently, we are working on the functional blocks of this use case:

- Determination of use the Palfinger crane mounted on NTNU research Gunnerus vessel as the testbed of the use case;
- Investigation of sensor types and how to install them on the specific crane;
- Crane model including dynamic model and 3D model are under development;

1.12.1 Engineering Process inputs

NTNU Ålesund is now negotiating with crane supplier for sensor installation proposal; contact crane operator for expertise information about operation and maintenance; creating 3D crane models.
NTNU Ålesund has used the tools for data analysis: Matlab; and tools NX and 20 sim for model generation. These tools are matched to the phases of “functional design”.
The planned improvement of the toolchain will make the digital crane system more reliable, in terms of model accuracy, data collection, data transmission and storage.
We may have some lack of knowledge of crane operation, maintenance and regulation in the “requirement” phase, but this will be solved after we investigate it with the help of local crane operators.
At present, we do not have steps that are unable to map on AHT-EP.
We are now between “Requirement” and “Functional design” phase.
Currently, Tellu and Jotne have made the demo test of digitalization of bicycle using on-board sensors. They have tested the EP from “Functional design” to “Operation”. The knowledge will be transferred and scaled to meet the requirement of the use case, especially in terms of data collection and transmission.
We follow the AHT-EP, such as IEC 81346 for the use case.

1.12.2 Engineering Process analysis

Table 20 Matching of the UC and the AHT Engineering Processes & potential Objectives reachable by each EPP

AHT-EPP	1 (R)	2 (FD)	3 (PE)	4 (DC)	5 (OM)	6 (M)	7 (E)	8 (TE)	**Missing ?**
UC-EP match	P	C	C	C	C	P	U	P	N
OBJ-AHT #1	X	X	X	X	X	X			
OBJ-AHT #2			X	X	X	X			
OBJ-AHT #3		X	X		X	X			
OBJ-AHT #4					X	X			

OBJ-AHT #5				X	X	X			
OBJ-AHT #6					X	X		X	
OBJ-WP2 #1				X	X	X			
OBJ-WP2 #2		X	X	X	X				
OBJ-WP2 #3	X	X	X		X				
OBJ-WP2 #4					X	X		X	

1.13 Deployment engine for production related sensor data (BOLIDEN)

The legacy way of working for production based integrations has been handled with same integration technology as traditional integration such as from and to Financial systems. There are also exception with individual solutions based on closed vendor solutions. With the use case of building up an SOA based integration platform the basis should be laid to significantly reduce complexity and speed to implementation while cater for requirements for production critical integrations. Based on the urgency to start building a platform, Boliden has decided to move forward with a SOA based approach not based on Arrowhead but is working with LTU towards a benchmarking and potential cross-build of functionality.
The functional block of the use case are

- Finalization of SOA based integration platform built
- Verification of effectiveness based on pilot and real-life implementations
- Benchmarking and enhancement of integration capabilities (LTU)

1.13.1 Engineering Process inputs

For the SOA based solution use case the relevant processes are Deployment and Commissioning, Operation & Management, Maintenance, Evolution, Training & Education since Boliden already implemented a large part. For the benchmarking part from LTU all phases are relevant.
Based on the implementation(s) and benchmark with arrowhead learning can be taking for implementations as well as separately build components and integration be used as part of a standard.
The UC have legacy, low overall scalability; SOA based, medium; currently enough but with expected growth and integration needs evolution has to happen.

1.13.2 Engineering Process analysis

Table 21 Matching of the UC and the AHT Engineering Processes & potential Objectives reachable by each EPP

AHT-EPP	**1 (R)**	**2 (FD)**	**3 (PE)**	**4 (DC)**	**5 (OM)**	**6 (M)**	**7 (E)**	**8 (TE)**	**Missing ?**
UC-EP match	P	P	C	C	C	C	P	C	N
OBJ-AHT #1	X	X	X	X	X	X	X		
OBJ-AHT #2									
OBJ-AHT #3		X	X	X	X	X	X		

OBJ-AHT #4									
OBJ-AHT #5									
OBJ-AHT #6								X	
OBJ-WP2 #1				X	X		X		
OBJ-WP2 #2				X	X	X			
OBJ-WP2 #3	X	X	X	X	X	X	X		
OBJ-WP2 #4								X	

1.14 Smart Diagnostic Environment for Contactless Module Testers (IFAT)

The SANE tool will be based on an existing (stand-alone) diagnosis tool (the so-called FADE tool). The FADE tool allows to calibrate and to diagnose the state of ISO-module test boxes before their first installation or in case of an error. Currently, the FADE tool lacks support for both remote diagnosis and maintenance.
Therefore, the first installation, the regular maintenance and the repair of ISO-module test boxes imposes high costs, which is due to maintenance contracts, high shipping costs (as servicing is currently only done at the IFAT Development Center Graz) and due to often required on-site expert support that is necessary to fix errors. Moreover, downtimes to search failures and measurement cycles (as the same tape must be re-measured after a successful repair) result in high costs.

1.14.1 Engineering Process inputs

The UC have the following steps that will be potentially covered by the AHT-EP:

- Analysis of the baseline & Requirements = Requirements
- Concept phase = Functional Design
- Implementation & Integration = Procurement & Engineering
- Deployment & Testing = Deployment & Commissioning
- Documentation & Training material = Training & Education

The Maintenance and Evolution phases are not used.
The planned improvement of the toolchain will speed up developments.

1.14.2 Engineering Process analysis

Table 22 Matching of the UC and the AHT Engineering Processes & potential Objectives reachable by each EPP

AHT-EPP	1 (R)	2 (FD)	3 (PE)	4 (DC)	5 (OM)	6 (M)	7 (E)	8 (TE)	**Missing ?**
UC-EP match	C	C	C	C	C	N	N	C	N
OBJ-AHT #1	X	X	X	X	X				
OBJ-AHT #2		X	X	X					
OBJ-AHT #3									
OBJ-AHT #4									
OBJ-AHT #5			X	X	X				

OBJ-AHT #6				X	X			X	
OBJ-WP2 #1				X	X				
OBJ-WP2 #2									
OBJ-WP2 #3	X	X	X	X	X				
OBJ-WP2 #4				X	X			X	

1.15 Smart Kitting to Manage High Diversity (VTC)

Current Production Engineering and Logistics Engineering related to kitting is to a large extent manual. Working with many different systems that have a low degree of interoperability.
This use case will focus on the kitting process that is a well-established internal logistics process for suppling assembly lines. Kitting is to ensure that material is delivered and presented to the operator at the main line in an optimal way. It gives the opportunity of optimizing material flow and to balance the workload efficiently and effectively. With the introduction of electromobility and automation, our assembly lines and material flow will be even more complex than today. The work of this use case consists in developing concepts for smart and automated kitting operations. Initially, specific focus on the engineering process related to preparation of kitting.

1.15.1 Engineering Process inputs

The use case is divided into three main phases:

1. At what kitting station shall the kit be prepared based on: How to Kit & Assemble (the assembly and kitting operations), What to Kit & Assemble (the part's characteristics, dimensions, geometries etc.) and the capabilities, capacity and restrictions of the kitting stations.
2. How to present/prepare the articles on the kitting wagon (virtual preparation)
   a. Layout of the kitting wagon
   b. Geometries (based on CAD)
   c. Weight of the article and how frequent it is picked

How to get the kitting wagon to the main assembly line carrying articles, assembly instructions and prepared tools while interacting with surrounding systems such as planning, logistics and manufacturing execution system.

1.15.2 Engineering Process analysis

Table 23 Matching of the UC and the AHT Engineering Processes & potential Objectives reachable by each EPP

AHT-EPP	1 (R)	2 (FD)	3 (PE)	4 (DC)	5 (OM)	6 (M)	7 (E)	8 (TE)	Missing ?
UC-EP match	C	C	N	N	C	N	N	N	N
OBJ-AHT #1	X	X			X				

OBJ-AHT #2									
OBJ-AHT #3	X	X			X				
OBJ-AHT #4	X	X			X				
OBJ-AHT #5									
OBJ-AHT #6									
OBJ-WP2 #1									
OBJ-WP2 #2									
OBJ-WP2 #3	X	X			X				
OBJ-WP2 #4									

1.16 Production Support, Energy Efficiency, Task Management, Data Analytics and Smart Maintenance (IFD)

Different kinds of predictive maintenance exist and are applied in practice as they all have their advantages and disadvantages. There is reactive maintenance if it is enough to wait for problems and solve them when they occur. In contrast, periodic maintenance is applied if unexpected breakdowns lead to high costs due to production standstill or consequential damages. Predictive maintenance tries to compute the ideal time instances for maintenance actions by applying a wear model in combination with operational data in order to avoid both unexpected standstills and unnecessarily early replacements etc. with the drawback of the modelling effort and the continuous preparation of operational data.
Different software exists that can support the planning of maintenance actions. Examples are the IDS Innomaster, Prüftechnik Omnitrend, Conimon WebApp, the Matlab Predictive Maintenance toolbox, and Bachmann WebLog Expert. Some vendors provide also specialized hardware, especially for vibration measurement, e.g. Beckhoff EL3632, Bachmann AICxx, and Delphin Expert Vibro.

1.16.1 Engineering Process inputs

The use case engineering process starts with the modelling of wear relevant aspects of the machine, especially regarding kinematic properties of rotating elements. Then, appropriate sensors are selected, e.g. vibration sensors with a suitable acceleration range and frequency range. The next step, diagram preparation including data filters, is not done by all providers as many of them only work with aggregated KPIs like RMS of unfiltered time signals. The last step, pattern recognition based on several diagrams, is recommended in expert literature and standards (e.g. VDI3832) but very rarely supported by software vendors for predictive maintenance.
Engineering activities currently performed in the phase:
Requirements: Relevant aspects for predictive maintenance are machine type, kinematic properties and production metadata. Further typical damages and faults of the machines under consideration from historical experience are helpful.
Functional Design: This block is less relevant in this use case.
Procurement & engineering: This step includes the selection of diagram types based on the concrete machine including properties as rotation frequency and external noise sources.

Additionally, feature evaluation methods have to be selected, i.e. KPIs that are relevant for condition estimation of the machine type.

Deployment & Commissioning: The hypothesis consolidation rules have to be adapted to the use case, i.e. the rules of pattern recognition for creating final hypotheses from diagram-specific primary hypotheses. In addition to that, the hypothesis generators have to be parameterized.

Operation & management**:** Based on breakdowns typical vibration patterns preceding the breakdown can be learnt for improving the prediction quality of the wear model.

Maintenance: The algorithms and platform have regularly be brought to the latest revision. The vibration sensors have to be checked regularly. After changes of the machine, changes of the model properties may be necessary.

Evolution: Operation and management leads usually to new information about wear relevant aspects of the machine. This information can be used to improve the analysis software.

Training and Education: Different stakeholders have to cope with the software, reaching from operation personal over diagnosis experts to managers. This requires training material for each kind of user.

The automatic machine diagnostic approach mainly spans across the domains of procurement & engineering, i.e., the selection and acquisition of the required measurement hardware, the deployment and commissioning, i.e., the configuration and installation of the measurement hard- and software, the operation and management phase, i.e., the continuous data acquisition, processing and presentation (machine diagnosis), maintenance and evolution (hard- and software support and improvement) as well as training and education, e.g., training maintenance operators to correctly interpret the KPIs and results.

In case of the automatic machine diagnostic approach, all phases are applicable, although the functional design to a lesser degree.

The planned improvements for the smart machine diagnostic platform will especially improve the Deployment & Commissioning steps due to the planned software additions to ease and automate the measurement hardware configuration. Additionally, a structured analysis of existing and missing meta data (in a first step) will improve a systematic diagnosis procedure in the last steps.

Hypothesis consolidation support is missing, requirements analysis in terms of meta data relevant for diagnosis (and diagnosis uncertainty estimation).

In case of the automatic machine diagnostic approach, the following order of the AHT-EP phases applies: 1. requirements, 2. procurement and engineering, 3. deployment and commissioning, 6. maintenance, 7. Training.

In case of the automatic machine diagnostic approach, the following standards are adhered to: VDI 3832, VDI 3839, DIN 1311, ISO 2954, ISO 18431, ISO 13373, ISO 13374, ISO 13379, VDI 3836, ISO 10816, ISO 15242.

In case of the automatic machine diagnostic approach, the functional design has a lower priority because the methods are relatively independent from the use case.

1.16.2 Engineering Process analysis

Table 24 Matching of the UC and the AHT Engineering Processes & potential Objectives reachable by each EPP

AHT-EPP	1 (R)	2 (FD)	3 (PE)	4 (DC)	5 (OM)	6 (M)	7 (E)	8 (TE)	**Missing ?**
UC-EP match	C	C	C	C	C	P	P	P	N
OBJ-AHT #1	X	X	X	X	X	X	X		
OBJ-AHT #2		X	X	X	X				

OBJ-AHT #3		X	X	X	X	X	X		
OBJ-AHT #4									
OBJ-AHT #5									
OBJ-AHT #6				X	X			X	
OBJ-WP2 #1						X	X		
OBJ-WP2 #2			X	X	X				
OBJ-WP2 #3	X	X	X						
OBJ-WP2 #4				X	X			X	

1.17 Linking a Building Simulator to a Physical Building in Real-Time (AEE INTEC)

The goal of the use case is to run a building and system simulation of a demonstration building in real time during the operation phase using real-time data recorded on site. The main tool to be developed is a building tracker that forces a simulation program to match the data from the building in real time.

Secondly, the connection between the building sensors and the software will be investigated including safety and security issues. The real-time information about the building status can then be used to optimize the control parameters of the building.

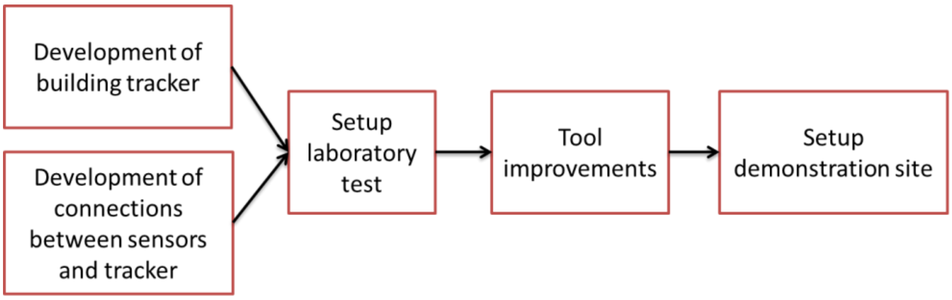


Figure 5 Steps for the building tracker

In a first step, the developed components will be tested in the laboratory. After in improvement phase, the building tracker will be tested on a demonstration building.

Up to now, optimization of a building's HVAC system is done during the planning phase:

- by means of building and system simulations using standard boundary conditions
- during the operation phase: by means of a monitoring program and manual adjustments to the control settings

1.17.1 Engineering Process inputs

A first draft of the possible software and hardware architecture to be used in the use case is proposed in the following.

The building control system will be coupled with a data logging system that will feed the real time data into the building simulation software via an OPC gateway. How available tools from the arrowhead framework will be used to ensure safe and reliable data transfer is currently under investigation by the use case team.
To assure the parties that individual components are secured to inter-operate with each other, automated standard compliance will be investigated. The standard compliance will be verified based on a given set of security and reliability requirements for which measurable indicators will be derived. Those reflect configurations of devices/systems/services recommended by security and reliability standards and guidelines. This will be used as a baseline to provide an approach for the Arrowhead Framework where standard compliance can be evaluated in an automated manner.

1.17.2 Engineering Process analysis

Table 25 Matching of the UC and the AHT Engineering Processes & potential Objectives reachable by each EPP

AHT-EPP	1 (R)	2 (FD)	3 (PE)	4 (DC)	5 (OM)	6 (M)	7 (E)	8 (TE)	Missing ?
UC-EP match	N	N	N	N	C	C	N	C	N
OBJ-AHT #1					X	X		X	
OBJ-AHT #2									
OBJ-AHT #3									
OBJ-AHT #4					X	X		X	
OBJ-AHT #5					X	X		X	
OBJ-AHT #6					X	X		X	
OBJ-WP2 #1									
OBJ-WP2 #2									
OBJ-WP2 #3					X	X		X	
OBJ-WP2 #4					X	X		X	

1.18 Secure sharing of IoT generated data with partner ecosystem (Boliden)

Approach for sharing of data has been handled individually in a diverse system landscape originating from different levels of aggregation, e.g. ABB systems, data warehouse, sensor sources or even Excel files. The use cases standardizes the way we handle and share production data in a coordinated way. Based on the urgency to start building this platform Boliden has decided to move forward not based on Arrowhead but is working with LTU towards a benchmarking and potential cross-build of functionality. The general relevance for the industry is still high as the battle for the data and adequate ways to protect visibility and usage are needed.
The functional block of the use case are

- Finalization of Sharing platform
- Verification of effectiveness in regards to security and vendor data cases based on pilot and real-life implementations
- Benchmarking and enhancement of integration capabilities (with LTU)

All phases are covered in use case approach, for Arrowhead components this is not in place yet. Note that Boliden has started this project well in advance of the go-live for the EU-project. Design, engineering, operation management, maintenance and evolution (system partly built).

1.18.1 Engineering Process inputs

For the use case of secure data sharing the relevant processes are requirements, functional design, procurement & engineering, deployment and commissioning, operation & Management, Maintenance, Evolution, Training & Education. Boliden already implemented a large technical part but the secure sharing part has to be looked at in any case. For the benchmarking part all phases are relevant.
There are several impact areas where as a major impact could be the connection of security requirements on usage and access level down to specification and implementations close to data sources
The order in which the AHT-EP phases are adopted in the use case domain fits with generic description, however the activities with LTU will jump back and forth in the phases.
Legacy, low overall scalability; The new approach is expected to scale in general but one important outcome with be the scalability of security requirements to allow efficient sharing.
Special focus on the latter AHT-EP phases from deployment & commissioning to training & education for practical implementation tests. Focus on the early phases for identification of security needs to be implemented in stack.

1.18.2 Engineering Process analysis

Table 26 Matching of the UC and the AHT Engineering Processes & potential Objectives reachable by each EPP

AHT-EPP	1 (R)	2 (FD)	3 (PE)	4 (DC)	5 (OM)	6 (M)	7 (E)	8 (TE)	Missing ?
UC-EP match	C	C	C	C	C	P	P	P	N
OBJ-AHT #1	X	X	X	X	X		X		
OBJ-AHT #2									
OBJ-AHT #3		X	X	X		X	X		
OBJ-AHT #4									
OBJ-AHT #5	X	X	X	X	X	X	X	X	
OBJ-AHT #6					X			X	
OBJ-WP2 #1			X		X	X	X		
OBJ-WP2 #2			X	X					
OBJ-WP2 #3	X	X	X	X					
OBJ-WP2 #4					X			X	

1.19 Deployment and configuration (3E)

SynaptiQ Solar is the trusted B2B performance monitoring solution of key reference players, steadily growing in connected capacity with a CAGR +30%.
Description of the main steps of the UC-EP

- SynaptiQ Configurator Module: defines the data model and the driver model.
- SynaptiQ Mediation Module: handles the heterogeneous date inflow from on-site devices.
- SynaptiQ Data Engine: processes the inflow of information.
- SynaptiQ Operational: handles the visualization of the aggregated data and alarms.

1.19.1 Engineering Process inputs

In the following the AHT-EPPs of the UC:

- ***Requirements***: the engineer operational team receive a ticket from a customer with either a request:
  - to deploy the configuration they did in the SynaptiQ Configurator Module.
  - to create the configuration in the SynaptiQ Configurator Module.
- ***Functional design***: based on datasheet and plant details, the engineer operational team or the customer configure the PV plant in the SynaptiQ Configurator Module.
- ***Procurement and engineering***: tight with the functional design. The SynaptiQ Mediation Module is configured based on the SynaptiQ Configurator Module.
- ***Deployment and commissioning***: all configurations files are deployed via scripted jobs.
- ***Operation and management***: N/A
- ***Maintenance***: based on modification on PV plant, the configurations are updated.
- ***Evolution***: N/A
- ***Training***: internal trainings are provided for the different tools on demand. On the customer point of view, there are documentation links in the SynaptiQ Operational Module. Furthermore, the engineer operational team trains customer in webinar on a regular basis.

In principle, all the phases of the AHT-EP are applicable to the specific use case domain. Although there is more interest in focusing on specific phases: Functional design, Procurement and Engineering, Deployment and Commissioning.
The improvement in the toolchain shall improve the interfaces between the different configuration phases, helping to automate the configuration, and thus leading to a reduction of the configuration time.
No lack of technologies identified and the order followed will suite the phase number.
All the modules are custom modules and, thus, are fully scalable. For this UC will be used the Agile methodology as standard.
The phases of the UC-EP are quite similar to the phases of the AHT-EP. However, the “Requirements” and “Functional design” would be considered as one single module used as inputs of the “engineering” module.
The “Evolution” module would not be compliant per say as it would imply a re-configuration hence restarting from the “Requirements” and “Functional design” step.

1.19.2 Engineering Process analysis

Table 27 Matching of the UC and the AHT Engineering Processes & potential Objectives reachable by each EPP

AHT-EPP	**1 (R)**	**2 (FD)**	**3 (PE)**	**4 (DC)**	**5 (OM)**	**6 (M)**	**7 (E)**	**8 (TE)**	**Missing ?**
UC-EP match	C	C	C	C	N	C	N	C	N

OBJ-AHT #1	X	X	X	X					
OBJ-AHT #2									
OBJ-AHT #3									
OBJ-AHT #4		X	X	X		X			
OBJ-AHT #5									
OBJ-AHT #6				X	X			X	
OBJ-WP2 #1									
OBJ-WP2 #2									
OBJ-WP2 #3	X	X	X	X		X			
OBJ-WP2 #4				X	X			X	

1.20 Elastic Data Acquisition System (FAGORR)

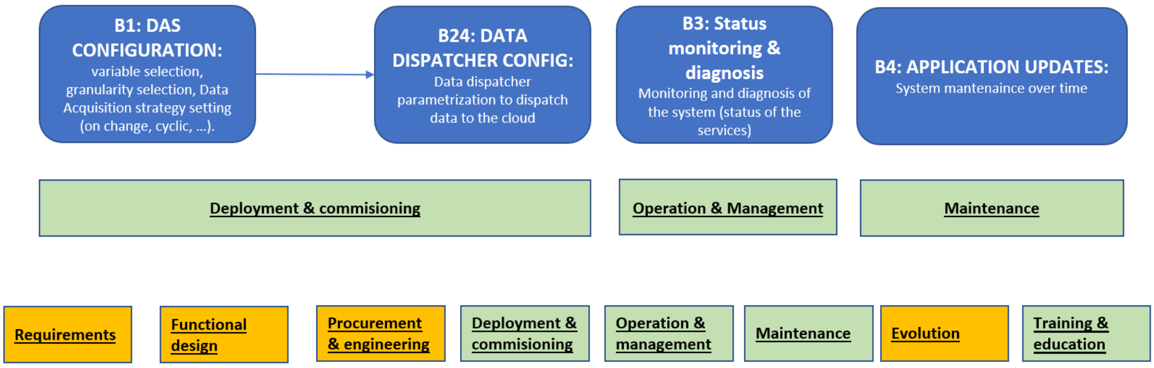
The aim is to develop an Elastic Data Acquisition System that implements different services that will help in Deployment & Commissioning, Operation and Management and Maintenance engineering processes.
The system is composed of different elements:

- PLC: Siemens, Beckhoff
- DAS: .NET based custom software
- BBDD: SQL Server / Redis
- Custom: Custom applications developed by engineers or Data Scientists.
- Format: .NET based software prepared to format the data.
- Dispatch: .NET based software prepared to send the data.
- Cloud: Fagor Arrasate´s IoT Platform

With the DAS is possible to define: 1) the PLC variables that are going to be monitored and 2) with which protocol each variable is going to be captured. Then automatically the systems starts monitoring those variables and these ones ares introduced in a database (BBDD).
The platform supports the deployment of Custom applications if needed such as machine learning applications, custom dashboards and so on. The function of the format is to convert the csv file to a json file with the PPMP specification. Finally the data is sent by the dispatcher with the correct format to the Cloud.

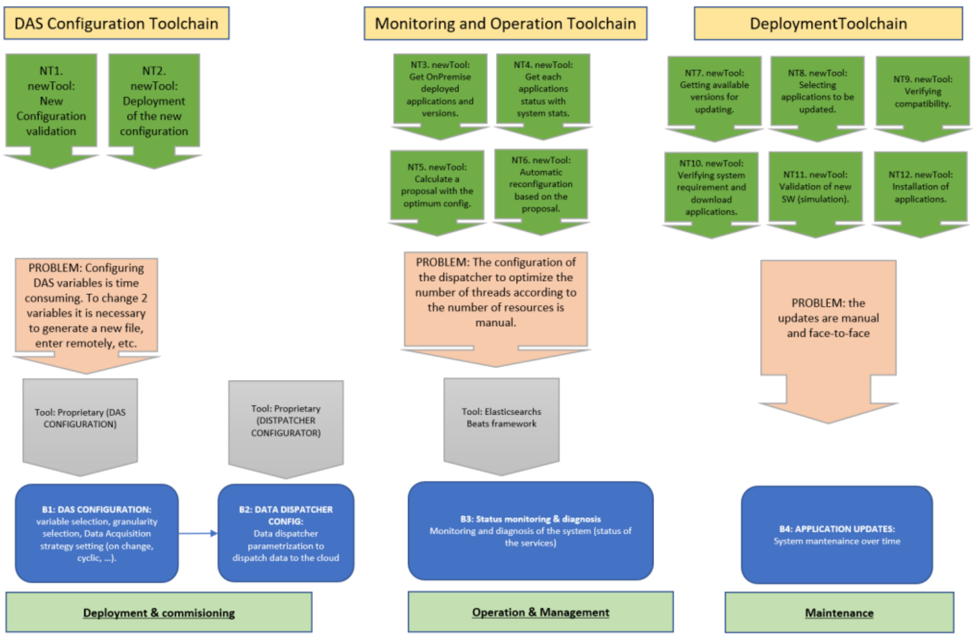
1.20.1 Engineering Process inputs

Thus, with the whole system is possible to define the PLC variables that are going to be uploaded to the cloud. To do this, several parameters must be specified, e.g. the sampling frequency for each variable and the industrial protocol to use or the final cloud endpoint to upload the variable.



These AHT-EPPs are not applicable in this UC because the scope of the UC is the deployment of a product on the client's premises, and does not cover the following EPs.

- Requirements.
- Functional Design.
- Procurement & Engineering.
- Evolution.
- Training & Education.



The planned improvement of the toolchain potentially impact on the following engineering process by reducing time in:

- Deployment phase
- Operation phase (monitoring of the remote system)
- Problem resolution. Currently the system software update is error-prone, and consumes a lot of time, thus, the automatization of this will improve the system.

Available technology are enough for the phases addressed in the use case.

The tools developed within this use case will be used by the Machine Manufacturer, thus they are designed for and by them. The machine manufacturer doesn't want to sell these tools, but to use them in order to provide new business models based on data.
Deployment & commissioning adopt the two following standards:

- OPCUA: For the configuration of the plant level data acquisition.
- PPMP: For data interoperability with the cloud.

1.20.2 Engineering Process analysis

Table 28 Matching of the UC and the AHT Engineering Processes & potential Objectives reachable by each EPP

AHT-EPP	1 (R)	2 (FD)	3 (PE)	4 (DC)	5 (OM)	6 (M)	7 (E)	8 (TE)	Missing ?
UC-EP match	N	N	N	C	P	C	N	N	N
OBJ-AHT #1				X	X	X			
OBJ-AHT #2									
OBJ-AHT #3				X	X	X			
OBJ-AHT #4				X	X	X			
OBJ-AHT #5									
OBJ-AHT #6									
OBJ-WP2 #1					X	X			
OBJ-WP2 #2									
OBJ-WP2 #3				X	X	X			
OBJ-WP2 #4									

1.21 Data-based digital twin for electrical machine condition monitoring (ABB)

The use case will develop data-based digital twin for electrical machine condition monitoring
The functional blocks of the use case will consists of:

- Electrical machine FEM digital twin
- Updated FEM digital twin
- Machine-learning (ML) tools
- Dynamically optimal parameters for electrical drives
- Smart predictive maintenance tools
- Digital twins for virtual performance testing
- SoA development for electrical motor services offered as automatic cloud services
- Concept creation for condition monitoring and operation parameter optimization.

1.21.1 Engineering Process inputs

The UC will utilize different analysis methods for electrical machine performance evaluation and condition monitoring consisting functional design, engineering, operation management, maintenance and evolution phases.
Physical electrical motor and inverter, distributed control system, ELMER etc. simulator, machine learning and analytical tools, dynamic and digital twin modelling, motor performance evaluation, failure prediction are matched e.g. functional design, operation and maintenance management phases.
Planned improvements of the toolchain will makes easier to manage decision making in operation and maintenance management phases.
Although there are a lot of low cost hardware and software solutions available, industrially functioning, both robust and reliable low cost, light way digital hardware and software solutions are less, if none available.
The UC AHT_EP order of blocks is the following: Designing, procurement, modelling, simulation & testing for operation management and maintenance.
The AHT-EP is partly scalable within product families, outside that more work needed.
Basic guidelines of the standards of the field, e.g. ISO 13374 for condition monitoring part of the operation and maintenance phases.

1.21.2 Engineering Process analysis

Table 29 Matching of the UC and the AHT Engineering Processes & potential Objectives reachable by each EPP

AHT-EPP	1 (R)	2 (FD)	3 (PE)	4 (DC)	5 (OM)	6 (M)	7 (E)	8 (TE)	Missing ?
UC-EP match	P	P	C	C	C	C	P	P	
OBJ-AHT #1	X	X	X	X	X	X			
OBJ-AHT #2		X	X	X	X		X		
OBJ-AHT #3		X	X	X	X	X			
OBJ-AHT #4		X	X	X	X	X			
OBJ-AHT #5				X	X	X			
OBJ-AHT #6								X	
OBJ-WP2 #1		X	X	X			X		
OBJ-WP2 #2									
OBJ-WP2 #3	X			X	X	X			
OBJ-WP2 #4								X	

1.22 Arrowhead Framework training tool (STM)

Scratch is a visual programming language and online community targeted primarily at children. Using Scratch, users create their own interactive stories, games and animations, then share and discuss their creations with one another.
Scratch Extensions make it possible to connect Scratch projects with external hardware (such as LEGO WeDo or PicoBoard) or sources of information on the web. They add a collection of

building blocks that can be used to interact with a particular device or data source. The Scratch blocks library already features a number of existing blocks for creating algorithms with data and control structures and event. It also includes components to plug-in actuators (motion) and data acquisition (\data").

The target is the ARROWHEAD STUDIO4EDUCATION tool.

Verification Trials will be conducted with professionals from different partners within Arrowhead Tools. Trial will also be made with students at several partner Universities e.g. LTU and BME. Trials will further be conducted in French schools to encourage students to develop IoT Arrowhead-based projects, all using the ARROWHEAD STUDIO4EDUCATION tool.

In the use case will be used the STM32 Discovery kits, a cheap and complete solution for the evaluation of the outstanding capabilities of STM32 MCUs. They carry the necessary infrastructure for demonstration of specific device characteristics, a HAL library and comprehensive software examples allow to fully benefit from the devices features and added values. Extension connectors give access to most of the device's I/Os and make the connection of add-on hardware possible. With the integrated debugger/programmer the discovery kits are ideal for prototyping.

1.22.1 Engineering Process inputs

To be developed during the project.

1.22.2 Engineering Process analysis

Table 30 Matching of the UC and the AHT Engineering Processes & potential Objectives reachable by each EPP

AHT-EPP	1 (R)	2 (FD)	3 (PE)	4 (DC)	5 (OM)	6 (M)	7 (E)	8 (TE)	Missing ?
UC-EP match	U	U	U	U	U	U	U	C	U
OBJ-AHT #1	X	X	X	X	X	X	X	X	
OBJ-AHT #2									
OBJ-AHT #3									
OBJ-AHT #4									
OBJ-AHT #5									
OBJ-AHT #6	X	X	X	X	X	X	X	X	
OBJ-WP1									
OBJ-WP2 #1									
OBJ-WP2 #2									
OBJ-WP2 #3	X	X	X	X					
OBJ-WP2 #4	X	X	X	X	X	X	X	X	

2. Bibliography

[1] P. Azzoni, G. Urgese e F. Montori, «WP124 Use Cases survey,» 2019.

3. List of abbreviations

Abbreviation	Meaning
AHT	ArrowHead-Tools
SOA	Service Oriented Architecture
DoA	Declaration of Agreement
UC	Use Case
UC-EP	Use Case Engineering Process
AHT-EP	ArrowHead-Tools Engineerign Process

4. Revision history

4.1 Contributing and reviewing partners

Contributions	Reviews	Participants	Representing partner
X	X	Gianvito Urgese	POLITO
X	X	Paolo Azzoni	Eurotech
x		Lukáš Maršík	CAMEA
x		Geran Peeren	PHC
x		Jose María Alvarez Rodríguez	UMLA
x		Ramon Schiffelers	ASML
x		Anja Zernig	KAI
x		Lars Oscarsson	LIND
x		Carlos Yurre	FAUT
x		Sara Bocchio	ST-I
x		Davide Brunelli	IUNET
x		Edoardo Patti	POLITO
x		Enrico Macii	POLITO

x		José Luis Burón	ACCIONA
x		Mustafa Kucukkuru	ARCELIK
x		Marek Tatara	DAC
x		Kjell Bengtsson	NTNU
x		Markus Frank	BOLIDEN
x		Christian Hanser	IFAT
x		Germar Schneider	IFD
x		Jon Rodriguez	FARR
x		Aitor Agirre	FARR
x		Jan Westerlund	ABB
x		Richard Hedman	VTC
x		Kjell Bengtsson	Jotne
x		Tullio Salmon Cinotti	UNIBO
x		Antonio Lionetto	ST-I
x		Maurizio Griva	REPLY
x		Roberto Vezzani	IUNET
x		Dagmar Jaehnig	AEE INTEC
x		Tom Tourwé	3E
x		Marcello Coppola	STM

4.2 Amendments

No.	Date	Version	Subject of Amendments	Author
1	2019-10-30	0.1	First Draft	Gianvito Urgese
1	2019-11-27	0.4	Second Draft	Gianvito Urgese

4.3 Quality assurance

No	Date	Version	Approved by
1	2019-12-03	1.0	Jerker Delsing