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Deliverable D10.2
Standardisation report year 1

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Abstract
This document constitutes deliverable D10.2 Standardisation report year 1 of the Arrowhead Tools project. project

ECSEL EU project 826452 - Arrowhead Tools
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1. Executive Summary

The present document reports the standardisation activities associated with WP10 along year 1 of Arrowhead Tools project. Activities which collect on the one hand the involvement and interests of the consortium in standardisation, gathered as a result of D10.1 Standardisation base line, and on the other hand the standardisation requirements per each use cases, analysing the information of the whole year.

Taking into account the consideration that the Arrowhead Tools Project has the objectives to develop cost and time-based on more effective engineering tools as well as interoperability among heterogenous systems, the standardisation plays a crucial role for the digital inclusion in response to actual industrial requirements.

Likewise, the analysis done is not focused on creating and driving new standards but intends to try and influence standards and frameworks that are of particular interest to the project and its members. As well as contributions for the development of effective use cases in the areas of Language, Semantics, Communications and Smart Manufacturing Reference Model as major points.

For all that considerations the document remarks three different issues:

- **Outstanding outcomes from D10.1 Standardisation base line**
  The results obtained from the partners´ inputs (36 partners as a significant sample of the consortium) reflecting the existing need in industrial environments related to seven major groups of standardisation areas which were identified such as System and Software, Information and Representation, Semantics and Language, Communication, Reference Model, Cybersecurity and Safety and Domain-Specific Standard.

- **Impact of standardisation approach for the use cases.**
  Based on the premise that the advance technology implementations such as System Integrations, Big Data Analytics, Machine Learning, Artificial Intelligence, Decision Support System and Vertical and Horizontal Integration together with automatized process facilitate the currently needs of industrial sector, one of the key element to attaint is the integration of the standardisation approach as can be seen in [1] and [2]. The impacts and benefits which are identified among others are:
  - **Increase of process efficiency** since "IEC 62264 Enterprise-control system integration" also known as ISA-95 in part 2 in conjunction of AutomationML can help to reduce of the production cycle by 40% or more [3], [4].
  - **Facilitate the interoperability associated with communication protocols** such as OPC UA (IEC 62541) because of assuring technological independence between industrial systems, operating systems and machines from different manufactures
  - **Provide Data and file formats and semantic approach** because it enables a common vocabulary, the context in which each item of vocabulary is used is known as well as rules for the formation of the sentences and the interpretation is in the manner intended. Ecl@ss, ProStep, AutomationML, AAS, HTML, JSON or RDF are some of the standards to consider.

- **Develop RESTful Services in Industrial Settings** because it allows to have resource-oriented information model, stable interfaces as well as reduction of resource Consumption.
- **Ensure the IT/OT security** using standars such as ”ISA-62443-4-2, Security for Industrial Automation and Control Systems” NIST 800-82 Guide to Industrial Control Systems (ICS) Security and well-kown ”ISO 27001 Information technology - Security techniques - Information security management systems – Requirements” all of them within NIST Cybersecurity Framework.
- **Facilitate the integration and management of Engineering processes** taking into account **t**he automation engineering model performed in IEC 81346 and IEC 62424 Representation of process control engineering or IEC 62890 Life Cycle Management.

- **Use Case standardisation requirements**

  Without changing the common methodology followed by Arrowhead Tools project with use cases, and based on the template facilitated by “IEC 62559-2:2015 Use case methodology”, the information was gathered. The deliverables from Milestone I and personal communication with partners responsible for use cases, helped identifying the standardisation requirements showing the following considerations:

  - 146 standards were identified for 22 used cases and sub-cases. The results obtained from the partners´ feedback reflect a strong necessity to propose a general approach in terms of interoperability and integration raw data, pre-processed information associated with a common data format, communication protocols and semantic perspective.
  - STD 90 - JavaScript Object Notation (JSON) Data Interchange Format, Extensible Markup Language (XML), SysML, UML,CSV, RDF, OPC-UA, MQTT, HTML, Wifi ISO/IEC/IEEE 15288:2015 Systems and Software engineering — System life cycle processes and ISO/IEC 12207 - Information Technology / Software Life Cycle Processes are the principal standards identified by use case in response of Language, Semantic, Interoperability and Communication areas identified as interest in D10.1. Standards less representative can be seen in Appendix 2 which show the total sample.
  - The global strategy of standardisation associated with Smart Manufacturing Reference Models such as RAMI 4.0 is required since the analysis developed shows that the use cases did not have as a priority at the begging of the project (AS-IS) but they have considered the standardisation approach for the end of the project (To-BE).

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Table 1. Standardisation Contacts and Involvement

2. Introduction

2.1 Objectives and Scope

The deliverable "10.2 Standardisation report effort year 1" is fully related to the activities under the Arrowhead Tools "WP 10 Standardisation" in response to Phase I. The deliverable overcomes the whole view of Phase I with the inclusion of the approach of Arrowhead tools Use Cases considering the standardisation. Thereby, the D10.1 is showed a whole view of the standards which Arrowhead Tools members are interested or part in Standardisation Development Organizations (SDOs), Working Groups or Task Forces and the D10.2 is the overview of accompanied standards by each Use Cases. The next steps associated with "Task 10.1 Language standards", "Task 10.2 Reference model and methodology standards" and "Task 10.3 Interface and industrial communication standards" will be able to base consequently on work previously developed.

Once having the whole view of standards from the consortium and use cases, the next steps are fully related to specific areas of standardisation such as Language standards, Smart Manufacturing Reference Models or Interface and industrial communication standards together with use cases where some of the work is under development.

The Arrowhead Tools project does not intend to create and drive new standards but pretends to try and influence standards and frameworks that are of particular interest to the project and its members. For this reason, there will be contributions, specially associated with the outstanding gaps in Phase II and Phase III and there will consequently be in D10.3 and D10.4

Phase II will be concentrated on supporting the development of specific standards or group of standards among the use cases and sub-use cases. To complete Phase III, the purpose is to tackle a Guide to implement standardisation strategies in Industrial companies as well as measure the impact of the standards in terms of engineering cost, productivity and efficiency. That outcome would be part of Phase III as added value for all work done before.

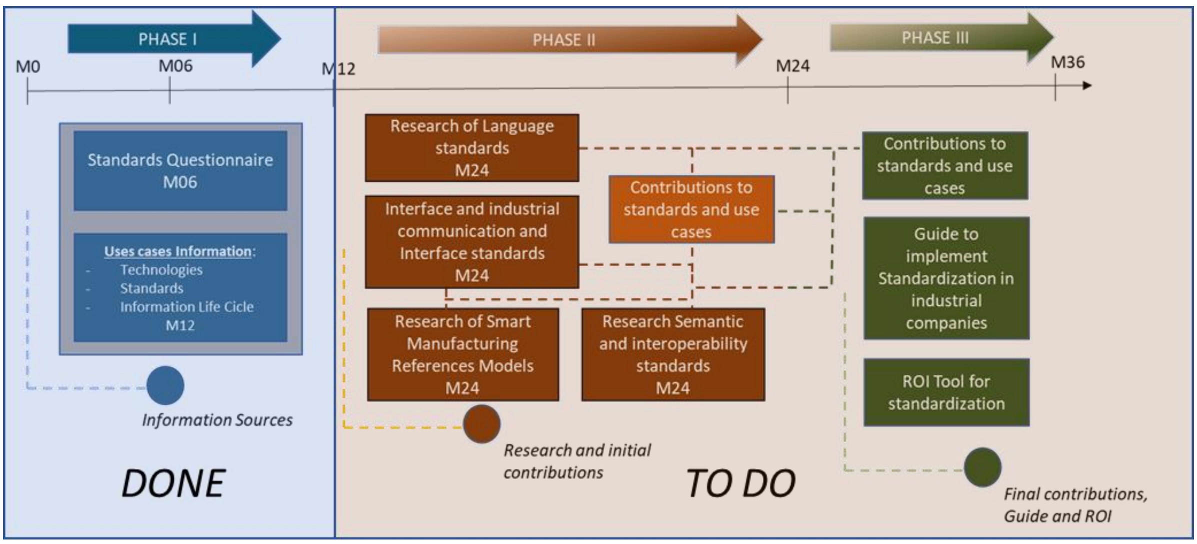

Figure 1. WP10 Workplan

The goal of the deliverable is to stablish the **current and the future approach of the Arrowhead Tools Use Cases related to standardisation**. The involvement of the Arrowhead Uses Cases is critical not only for the development of the Use Cases but also to provide contributions to standardisation ecosystem for manufacturing and engineering area. Not in vain, the use of the engineering solutions together with the standardisation can satisfy the aim of a significant reduction in development cost and time-based on more effective engineering tools and toolchains as well as useful instruments to achieve interoperability and prevent vendor lock-in.

To achieve the main objective above, the following specific objectives will be addressed:

- Summarize the analysis carried out in D10.1 to contextualize the current scenario in smart manufacturing associated with standardisation and the interests from the consortium.
- Describe the advantages of Standardisation in current manufacturing processes and its relevance in digital transformation for Arrowhead tools Use Cases.
- Describe the methodology developed to focus on the information gathered and its categorization from the Arrowhead Use Cases.
- Categorize the information received associated with a type of standards and relevance areas in smart manufacturing and engineering tools and toolchains for helping the development of the challenges of the use cases.

2.2 Outstanding outcomes from D10.1 Standardisation base line

The contextualisation of standardisation in current manufacturing processes and its relevance in digital transformation exploring the main challenges industrial companies must approach while implementing structured standards. The interconnected industries should consider three kinds of integrations; End-to-end integration, Horizontal integration, and Vertical integration with enough flexibility to maximise efficiency. The main standards identified to the industry 4.0 by the principles standardisation stakeholders are the ones of communication protocols, interface and data exchange, semantic, interoperability, management and software frameworks.

On the other hand, the smart manufacturing reference architectures and models that support a company in setting up its entire production based on a jointly agreed standard solution, such as RAMI 4.0, Smart Manufacturing ecosystem developed by NIST and IIRA. Furthermore, the document describes the most relevant Standards Setting Organisations (SDOs) and alliances.

Each Arrowhead Tools partner received a standardisation survey receiving a response of 36 of them, as a significant sample of the consortium gathered for the D10.1. The partner survey main objective was to identify the standardisation involvement and interest in a particular standard or standards group, and how each organization relate to the specific standard or group. The roles were: Charing/co-chairing, actively contributing, member (rather monitoring or observing), member on national level, user, or interested.

A major target point for Arrowhead Tools partners is to automate more – on the factory floor, throughout the supply chain and during the maintenance during the lifespan of the products.

The results obtained from the partners´ inputs reflect the existing need in industrial environments in terms of interoperability in the transmission of data as well as its format and suitable representation between the different OT-IT layers. Interoperability for the use of IoT / SoS Engineering solutions to favour the digital transformation that allows meeting the global objectives of the Arrowhead Tools project and standardisation. With the partners´ inputs receiving a response of 37 institutions´ interests related to standardisation, seven major groups of standardisation areas have been identified:

- ***System and Software***
  The current requirements of industrial environments that compel the management of industrial control systems as an asset within the upper layers of the automation pyramid through IT software solutions, such as *ISO / IEC 42010 Systems and software engineering*, *ISO 15288 Systems and software engineering - System life cycle processes* or *IEC 62890 Life Cycle Management.*

- ***Information and Representation***
  The standard format with which data is transmitted and the representation of the properties of heterogeneous industrial devices and systems, becoming a real need to agilely comply not only with the much-desired interoperability, but also for the representation of digital twins and management of their life cycle. One example could be the *ISO 10303 (STEP) Industrial automation systems and integration - Product data representation and Exchange*.

- ***Semantics and Language***
  The representation and knowledge associated with specific applications and domains require the use of languages prepared for it. The principal standards are related to W3C and OMG.

- ***Communication***
  Partners are users or are interested in interoperable protocols and which can be used in different layers of an industrial environment such as OPC-UA (IEC 62541), the recent UMATI standard for machine tools or the well-known OneM2M, MQTT.

- ***Reference Model***
  The need to standardize industrial processes and their representation throughout their life cycle and in the automation pyramid through one of the standards previously seen in the areas of Communication, Semantics, etc, as seen in RAMI 4.0 and IIRA reference architecture and models.

- ***Cybersecurity and Safety***
  The partners are aware of Cybersecurity, not only at the IT level with the *ISO / IEC 27001* standard, but also at the OT level with the *IEC 62443*. Nor can´t ignore the interest in Safety in industrial environments as equally or more important than at the software level.
  Finally highlight the awareness of authentication and trust for contactless devices, web applications, or for AI.

- ***Domain-Specific Standard***
  It should be noted the active participation of partners in standards associated with Industry 4.0 technologies and therefore facilitators for the introduction of solutions and engineering tools in the working committees of Robotics (*ISO / TC 299)*, Artificial intelligence (*ISO / IEC JTC 1 / SC 42)*, Internet of Things, Blockchain and Digital Twin. Nor can´t forget specific regulations for the Oil & Gas sector, semiconductors or standards associated with Energy and environmental management.

3. Standardisation approach based on Use Cases

3.1 Benefits and Motivation. How impact standardisation approach for the use cases (Engineering costs)

The Industry sector copes with the challenges of the adaptation to the requirements market required such as high degree of specialization and, at the same time, products must be customized requiring flexible and agile response. Therefore, industries must adapt its productive environments to flexibility and specialization and as a consequence traditional manufacturing system must be transformed to smart, flexible and reconfigurable manufacturing systems [5].

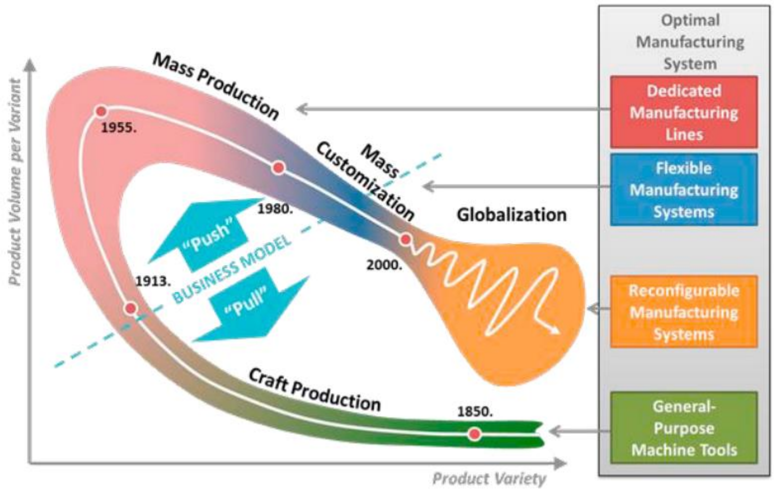

Figura 1: Optimal Manufacturing System [5]

In order to maintain its major role in driving productivity, innovation and business global and local value chain providing jobs to 36 million people in Europe [6], industry has gradually been adapted with the support of advanced technology.

Advanced and disruptive digital and physical technologies associated with the Industry 4.0 ecosystem among with the integration and interoperability IT-OT solutions developed enable industries to increase the digital transformation. However, changing the technological level of industries is not a simple task. The following three key points are relevant [7] as can be seen in Figure 2:

- Industries need to guarantee interoperability and integration of heterogeneous systems and engineering tools along the product life cycle management.

- Industries must unable the offers of Manufacturing as a Service. They need to have the ability to product and service integrated into single product for delivering value in use to the customer during the whole life cycle of a product joining the virtual and physical production engineering for shorter time to market.

- Industries requires high level of ICT integration to support collaborative product development, collaborative manufacturing and all other value adding processes It can be realized through vertical integration called Production Networks or through horizontal integration called Manufacturing Networks

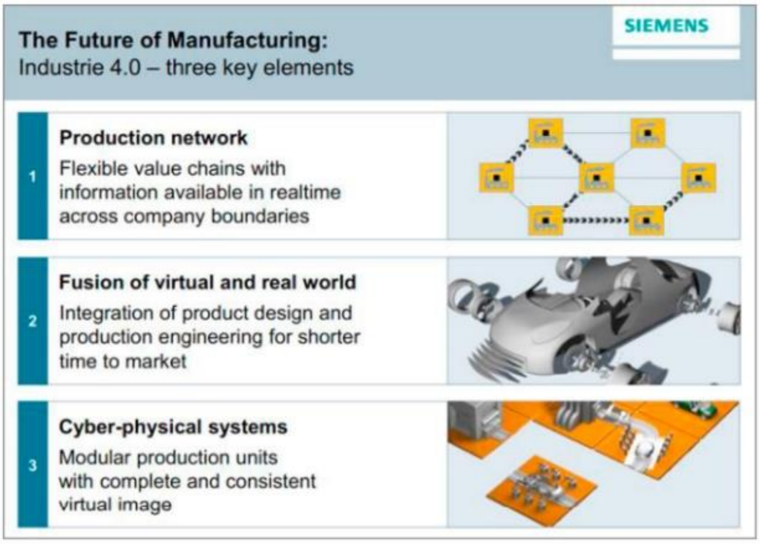

Figura 2: Key elements for Industry 4.0 implementation [7]

To compare the different approaches and requirements between the traditional manufacturing model and Smart Industry 4.0 the Figure 3 summarizes the characteristic described above.

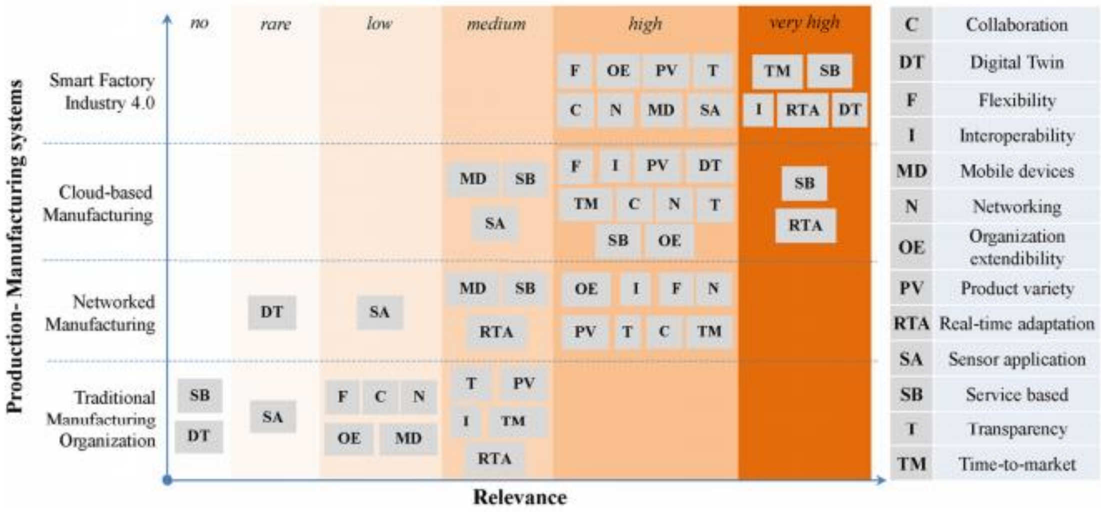

Figure 2: Comparison of the different production and manufacturing systems [8].

Finally, the agile responses from unplanned event in engineering allows to react, learn faster and provide value proposition for competitiveness. Aside from the results-oriented dimension, the question of what organizational forms – in interplay with information systems – will be able to achieve speed and agility is of central importance. The ability to control and reduce latency periods will become a relevant criterion of competitiveness.

Against this backdrop, the overarching goal of the digital transformation of companies is to create a learning, agile enterprises which, based on suitable interoperable IT-based technologies and the capability of organizational learning, is able to adapt to the requirements market conditions are forced.

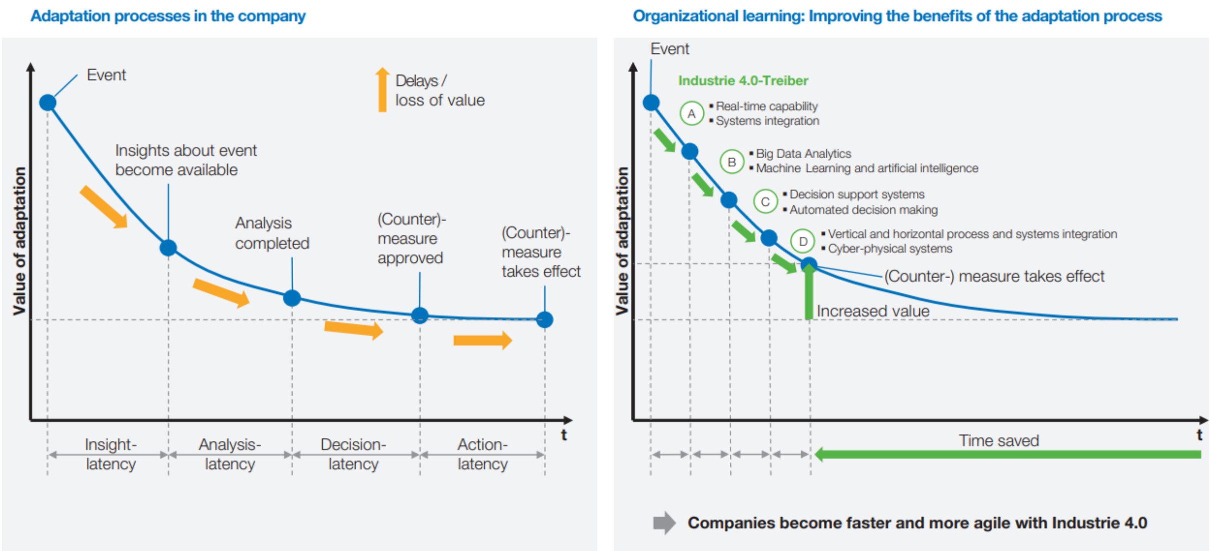

Figure 3: Adaptation process in the company [9]

Furthermore, the implementation of digital transformation strategy among with standardisation approach helps to attain the efficacy in engineering development and the reduction of the cost as Figure 4 shows. The concept for that, was developed together with the E4TC (European

Transformation Center) Institute in Aachen. The main topic of the institute is to take care of the practical, optimal application of software solutions and to digitize engineering and manufacturing processes in the sense of Industry 4.0 with the integration of these solutions.

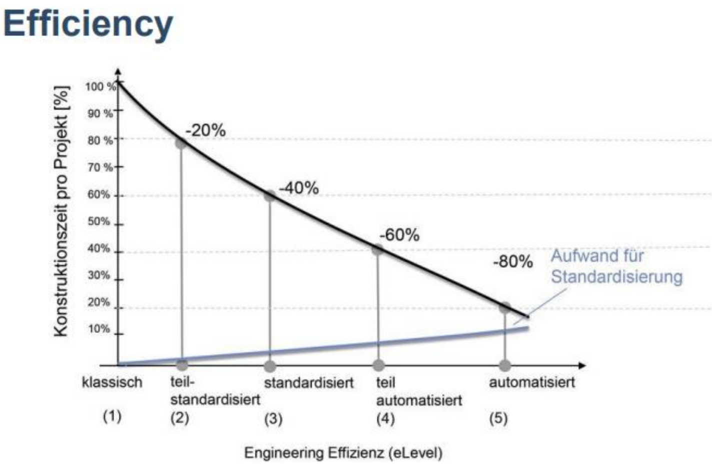

Figure 4: Eficciency associated with automatization, standardisation and digital tranformation for Engineering aplications [1], [2]

Therefore, to develop the technical innovation for Industry 4.0 based on the vertical and horizontal integration of manufacturing systems, as continuous digital engineering throughout the product lifecycle, and finally the decentralization of computing resources is accomplished with the help of standardisation approach.

The principal benefits to introduce the standardisation common guidelines across industry use cases are the following:

- **Increase of process efficiency**

  Vertical integration enables a dynamic adaptation to changing environments. Data in real time associated with the productivity can be used to optimize process efficiency and performance. Advanced, smart production systems can be altered in real-time, making small batches, last-minute changes, or completely customized products economically feasible. Standards such as "IEC 62264 Enterprise-control system integration" also known as ISA-95 in part 2 in conjunction of AutomationML can help with the following figures [3], [10] :
  - Through modern engineering paradigms like collaborative engineering, smart engineering, as well as digital engineering, development time is further reduced, and product supply is ultimately matching product demand [1].
  - A reduction of the production cycle by 40% or more.
  - Reduction of delivery time processes by 30% or more.
  - Reduction of defective parts by 15% in quality tasks
  - Paybacks come from 2%-3% year to year productivity improvements.

- **Interoperability associated with Communication protocols**

In order to ensure the networking of the elements involved such as industrial machines, PLCs and/or industrial control systems in the value-added process, as well as their ability to communicate via various platforms, interfaces, along with transmission technologies must be ensured. The main component of vertical and horizontal integration is the Internet technology but historically there have been several private protocols that they are not compatible among them.

For that reason, the standard OPC UA (IEC 62541) is the current OPC Foundation's technology for secure, reliable and interoperable transport of raw data and pre-processed information from the shop floor into production planning systems. Its organization based on layers has the main advantage to allow interchangeability between their implementations, **assuring technological independence** [11].

Furthermore, its service oriented as well as platform independence approach enables to create new and easy possibilities of communicating with Linux/Unix systems or embedded controls. Namely, **OPC UA can be used as a uniform interface to access information from machines from different manufacturers** [12]**.** For example, IIoT condition monitoring systems can access and check information from machines via OPC-UA known as Industrie 4.0 communication. This approach is already beneficial compared to integrations seen in other many different communication solutions.

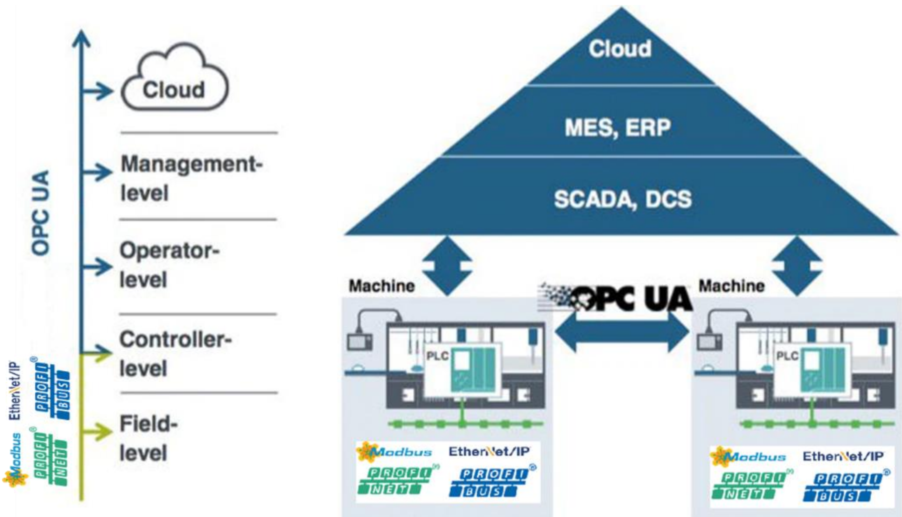

Figure 5: OPC-UA Scheme between layers, industrial devices and software [13]

Another remarkable characteristic of OPC-UA is that its integrated webserver ensures a fast transfer of large data volumes per https, the basic network protocol used to distribute information on the World Wide Web.

Finally, the advantages of protocols like OPC-UA simplify the integration of industrial assets and help to increase efficiency based on simple connections to monitor and optimise industrial systems. Furthermore, as these connections do not depend on existing fieldbus or real-time communication systems, the use case plug & work allows a more flexible commissioning and retrofitting of machines, plants and factories. That type of features saves time and costs [12].

- **Data, file formats and semantic**

A prerequisite for cross-platform and systems data exchange is the definition and use of uniform standards for data formats. In order to avoid redundant data generation data losses and set up intermediate layers, data formats must be transferable secured, efficient and without loss as well as high time respond. Data formats define the syntax of the data representation and therefore represent a rule and structure system between the applications and systems.

A file format, on the other hand, defines syntax and semantics approach. From semantic perspective and implementation is essential for the interpretability of the data since it contains its meaning. Semantics play an important role in communication between machines in particular, since machines often cannot suppose these relationships from the context of the information. Furthermore, during the product life cycle, information will need to be exchanged that can be understood by all partners in the same way.

In order to achieve the meaning of the same to all communication partners in the context of machine-to-machine and machine-to-human communications as long as [14]:

1) A common vocabulary is used,
2) The context in which each item of vocabulary is used is known,
3) Agreed rules governing the formation of sentences to be used when exchanging messages are adhered to and,
4) The subsequent step to be taken following the exchange of vocabulary or sentences is interpreted in the manner intended

For example, those semantics will encompass standardized library directories:

- Incorporating standardized designations of properties like ecl@ss.
- Standardized engineering libraries like ProStep,
- The AutomationML exchange format.
- Additional technological languages from the internet industry such as HMTL/JSON or RDF.
- The initiative Asset Administration Shell [15] (AAS) works as an interface connecting physical and logical assets to the I4.0 compliant network, setting up an I4.0 compatible Cyber Physical Production System (CPPS). It is proposed by Plattform Industrie 4.0. The asset itself can be composed of other assets. That is the case of a machine or complex industrial assets whose sub-systems can be represented individually, it is also the case of a production line or even the entire factory. The representation of an asset, once abstracted by an AAS, is also known as the digital twin. Once an asset is encapsulated by an AAS it becomes an I4.0 Component (Figure 6) and can participate in the I4.0 compatible CPPS.

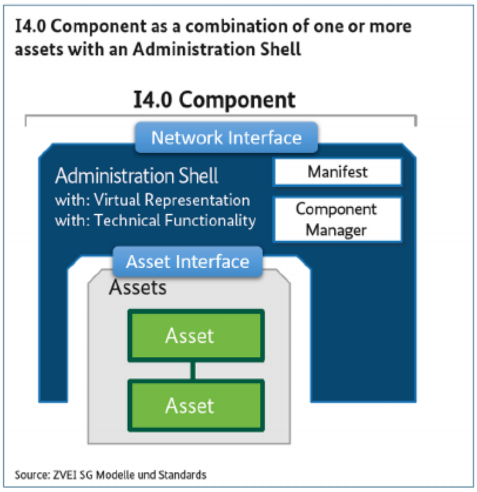

Figure 6: Representation of the Administration Shell application to an Assetto form an I4.0 Component

The principal characteristics are:

- Provide a digital representation of a Physical Asset as well as properties and capabilities with a common structure
- Integrates the assets into Industry 4.0 communication.
- Is the standardise and secure communication interface.
- Is addressable in the network and identifies the asset without unambiguously.
- Enables integrated value chains.
- Establishes cross-company interoperability.

Projects such as the Semantic Web enables semantic information representation on the Internet in order to make existing data in diverse formats such as texts, pictures and videos more readable and interpretable for industrial assets, in particular, machines, thereby intensifying the possibilities of intelligent web services.

Apart from that, to attain data format, previous activities to define the system modelled is relevant to complete the whole cycle of development engineering tools. In particular the benefit of that type of tools such as SysML are [16]:

- Improved communications.
- Assists in managing complex system development.
- Improved design quality.
- Early and on-going verification & validation to reduce risk.
- Enhanced knowledge capture.

- **RESTful Services in Industrial Settings**

RESTful communication is a set of design principles. The background idea is asssociated with the hypertext-based web which is commonly used for the interfaces of decentralized software architectures. These design principles are technology-independent and are not bound to a specific protocol and nowadays can be used in

Ethernet-based communication in the domain of cyber-physical systems together with Internet of Things architectures. The advantages are the same that we can discover in OPC-UA and aming to use in the context of Industrial Seetings. They are [17]:

- Resource-Oriented Information Model:

  Many service oriented architectured use service as a facade to abstract and loose coupling of componets and service providers. However, in Cyber Phisical Systems operations are never fully detached from some physical counterpart. Furthermore, industrial assets are not just service providers although they have an inherent state. Due to the fact that, interfaces for interacting resources representation have their own singularity. For that reason, as resource-oriented information model can explore the structure of resources and their interdependencies according to the REST principles of connectedness.

- Stable Interfaces

  There are few services in a RESTful architecture, due to the fact that the differences of the resources are encapsulated in the representation formats. The common resources are manipulated considering and using a fixed set of operation such as four create, read, update and delete. (PUT, GET, POST, and DELETE). Since they are intended for widspread objective, RESTful service definitions are very stable. When introspection capabilities are part of the RESTful services, components are likely to remain usable even along the long-term future.

- Reduced Resource Consumption:

  For short period of time-interactions, interfaces reduce the overhead of session initialization and termination. Adiotionally, there is only an minimum amount of information per-connection, such as a socket descriptor. Thre is no state per-connection, therefore it is required less synchronization points in spite of concurrent message processing on multiple processor.

- **IT/OT security**

The new way of working in Industrial ecosystem have arisen new security threats since the formerly separated production and businees network are now interconnected. Furthermore, due to the requirements of real-time capabilities limited computing resources and external connetions, conventional security measures are not fully advisable and feasible [18]. On the other hand, it is evident that the damage is not only related to the monetary aspect but also affets the operational safety of machines and systems.

Standars such as ”ISA-62443-4-2, Security for Industrial Automation and Control Systems” which provides a flexible framework to address and mitigate current and future security vulnerabilities in industrial automation and control systems as well as NIST 800-82 Guide to Industrial Control Systems (ICS) Security and well-kown ”ISO

27001 Information technology - Security techniques - Information security management systems – Requirements” all of them within NIST Cybersecurity Framework to reduce the threaths of security and innpropaite works of industrial systems and enginnering applications.

To protect sensitive know-how and allow for trust-based collaboration confidentiality and integrity of transferred data must be ensured at all times. In the case of breakdowns, the expected damage is not only limited to business economic aspects, but may also affect the operational safety of machines and systems [19]. The implementation of effective safety concepts, systems must be secured thoroughly and whenever possible, already in the development stage known as Security by Design and on the rest of the levels as Defense in Depth [8, 9]. The realization and implementation of IT security measures, therefore, takes an essential position within the Industry 4.0 and for the development of applications not only to ensure either integrity of the data but also the effective functioning.

- **Facilitate the integration and management of Engineering processes**

The automation engineering model performed in IEC 81346 as well as IEC 62424 Representation of process control engineering or IEC 62890 Life Cycle Management facilitate the integration and management the Engineering Processes as well as the Information related to a product along its Life Cycle represented in the following figures.

Figure 7: The extended auotmation enginering model in Arrowhead Tool based on IEC 81346

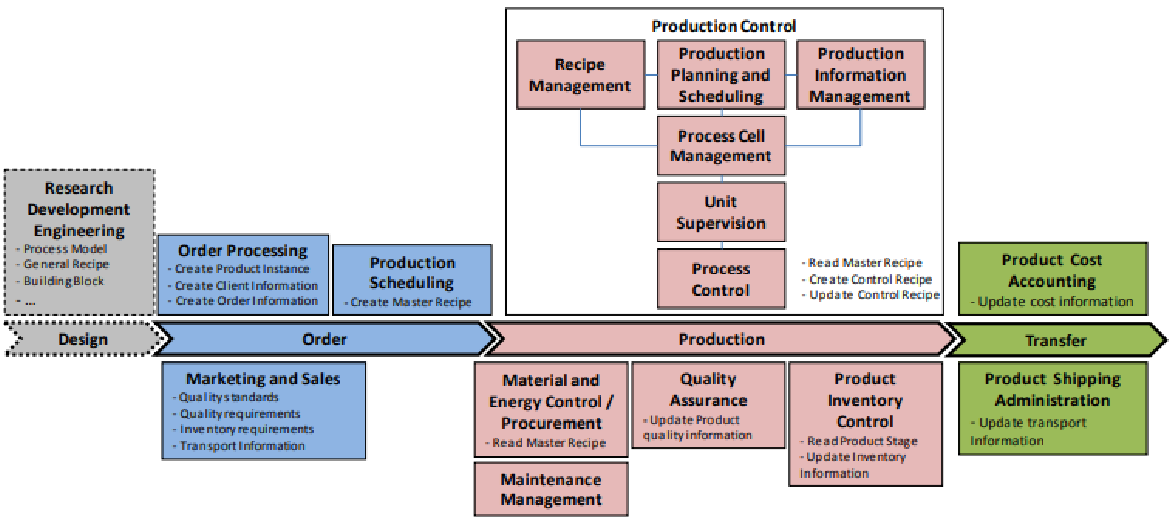

Figure 8: Product Information along Life-cycle [20]

The benefits which these types of standards can contribute are:

On the one hand, it enables a company to grow revenues by improving innovation in some of the life cycle process or phase, reducing time-to-market for products or enginnering developments providing superb support and/or setting up new services [21].

Furthermore, these standards can enable a company to reduce product/digital developments-related costs. It is relevant to reduce the cost in order to have more competitiveness. In terms of digitalization and manufacturing needs along life cycle, virtual representation of the industrial assets are necessaries together with data representation. That stimulates the Digital Twin developments as well as the interoperability across the life cycle. The Figure 7 shows a proposed Life-Cycle plant in Industry 4.0 where the data associated with the assets along the different phases of the production should be published in an I4.0 Repository. These data, as there has been mentioned in data, file formats and semantic section should be standardized

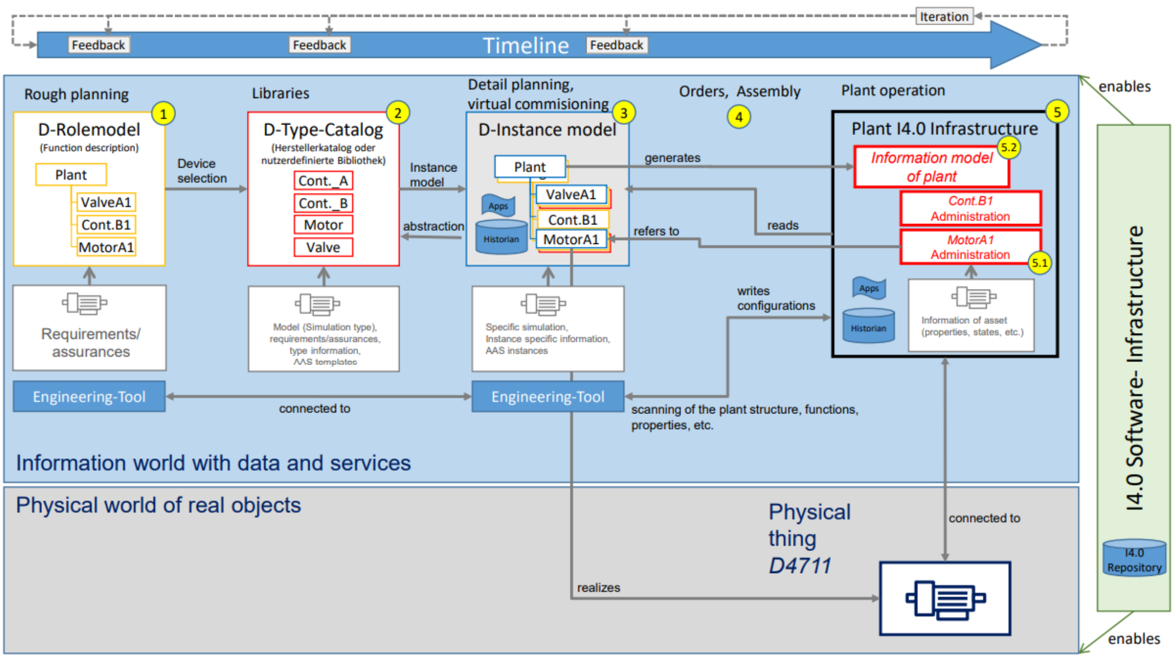

Figure 9: Life-cycle plant in Inudstry 4.0 [22]

3.2 Methodology to support Use Case Management processes in Standardisation

Within the standardisation technical committees or working groups usually comprises short-description of each project as well as corresponding use-cases on a high level. The information to gather data from each use case is based on the "IEC 62559-2:2015 Use case methodology" which defines the structure of a use case template for various purposes like the use in standardisation organizations for standards development or within development projects for system development. Furthermore, the template based on IEC 62559 was developed for general application in various domains and systems.

The methodology is in line with the WP 10 plan and the rest of WP of Arrowhead Tools which describes two steps approach, where initial functional descriptions and requirements to include in IEC 62559 template are provided by information gathered in M1 by domain and technical experts so that use cases can tackle the technical challenges. At this point, the 22 use cases from Arrowhead Tools project are considered although they do not have project dedication in WP10. Further on, use cases are classified and structured for better identification and analysis considering the extended automation enginering model in Arrowhead Tool based on IEC 81346.

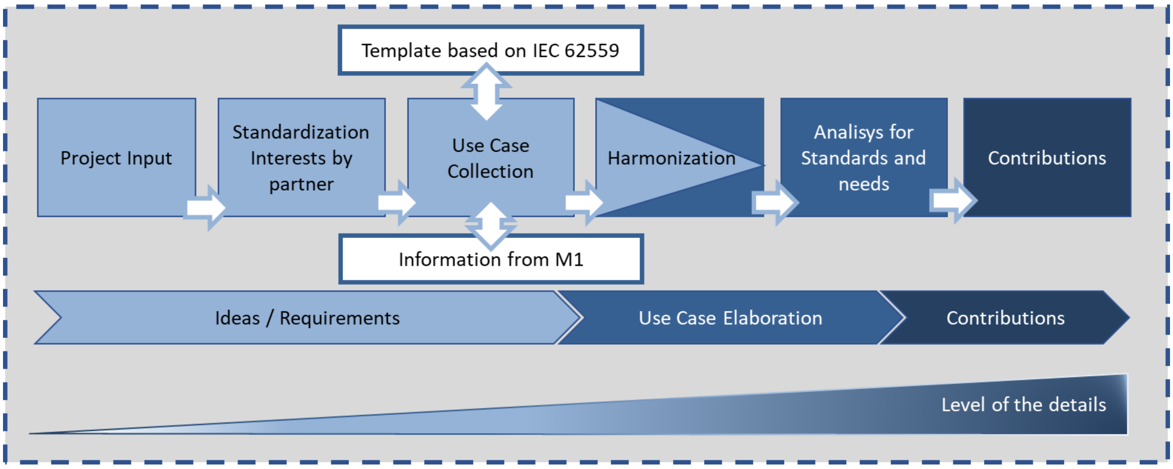

Figure 10: Methodology for Use Cases Management Processes for standrization pupose

Finally, as can be seen in Figure 10, use cases are completed with the contributions of their standardisation needs. Standards in favour of developing the functionalities and technical challenges of the use cases in appropriate and remarkable way as well as in line with the objective of Arrowhead Tools project to gain the interoperability and the reduce of engineering costs. The standards identified are in conjunction with the D10.1.

The last and key point to consider is the "Contributions" which will overcome in Phase II and Phase III explained in the Introduction Section along with the inputs of Harmonization and Analysis from Use Cases and the standardisation interest by partners.

3.3 Template based on IEC 62559-2:2015 Use case Methodology

The initial template based on "IEC 62559-2:2015 Use case Methodology" has the characteristics of Software Engineering with the features of high granularity and abstraction level since for project management it is relevant to describe use cases and their functionalities in a structured and organised way. The section titles in a short overview are:

1. Description of the use case,
2. Diagrams of use case,
3. Technical details,
4. Step by step analysis of use case,

5. Information exchanged,
6. Requirements,
7. Common terms and definitions,
8. Custom information.

On the other hand, that template is defined as generic and adaptable for other domains and systems. Furthermore, WP 10 is not focused on modifying the methodology of the IEC 62559 standard, but to use it as a tool to gather the standards that are used and will be used in each use case. As consequently the template based on IEC 62559 has been firstly adapted to include the relevant information gathered in D10.1 and M1 as well as adding the key elements of standardisation needs for use cases in D10.2.

For further information related to the template of the standard IEC 62559 is displayed in Annex I. Considering the template and characteristics in standard IEC 62559, the final template developed for that purpose is presented in table below:

<table>
<tr><td>Use Case Name</td><td colspan="2"><Use Case></td></tr>
<tr><td>Use Case Objective</td><td colspan="2"><Objective></td></tr>
<tr><td>Smart Manufacturing Benefit</td><td colspan="2"><Benefit></td></tr>
<tr><td>Life Cycle Phase</td><td colspan="2"><Lifecycle>
Requirement, Functional Design, Procurement and Engineering, Deployment and commissioning, Operation and Management, Maintenance, Evolution, Training</td></tr>
<tr><td>Diagram/Architecture</td><td colspan="2"></td></tr>
<tr><td>Standardisation Requirements</td><td><u>AS-IS</u>
<u>System and Software Standards</u>
• Life Cycle Management
• Software life cycle processes
• SQuaRE
• REST APIs
• ERP/MES
• Function Blocks

<u>Information and Representation Standards</u>
• Product data representation and exchange
• Framework for object-oriented information exchange</td><td><u>TO-BE</u>
<u>System and Software Standards</u>
• Life Cycle Management
• Software life cycle processes
• SQuaRE
• REST APIs
• ERP/MES
• Function Blocks

<u>Information and Representation Standards</u>
• Product data representation and exchange
• Framework for object-oriented information exchange</td></tr>
</table>

	• eCl@ss and Common data Dictionary • G-CODE • Worksite data exchange • Geographical metadata standard **Semantic and Language Standards** • XML, JSON, RDF • SPARQL • SysML • UML • HTML/CSS3 • Ontologies • LDP 1.0 **Communication Standards** • MT Connect, ETHERCAT, Sercos, Fieldbus • OPC-UA • UMATI • MQTT • M2M • WIFI • RDF and NFC • EAP, COAP • Internet Protocols: HTTP, SSH, FTP, TCP/IP, IPSEC, SMTP, UDP **Cybersecurity and Safety Standards** • IEC 62443 • ISO 27001 • NIST SP 800-82 • Encrypted Communication • Encrypted DDBB • Authentication	• eCl@ss and Common data Dictionary • G-CODE • Worksite data exchange • Geographical metadata standard **Semantic and Language Standards** • XML, JSON, RDF • SPARQL • SysML • UML • HTML/CSS3 • Ontologies • LDP 1.0 **Communication Standards** • MT Connect, ETHERCAT, Sercos, Fieldbus • OPC-UA • UMATI • MQTT • M2M • WIFI • RDF and NFC • EAP, COAP • Internet Protocols: HTTP, SSH, FTP, TCP/IP, IPSEC, SMTP, UDP **Cybersecurity and Safety Standards** • IEC 62443 • ISO 27001 • NIST SP 800-82 • Encrypted Communication • Encrypted DDBB • Authentication

	• Network monitoring • Firewall • IEC 61508 • OWASP • Road Vehicles safety and cybersecurity • Security for Contactless Devices • Safety for Electrical/programmable electronic **Reference Model Standards** • RAMI, IIRA, ASS, NIST • Digital Factory **Domain-Specific Standards** Robotics, Artificial Intelligence, IoT, Digital Twin, Integration Life Cycle, Blockchain, Environmental Management **Framework Development and Specific Applications for development** Node.JS, Angular JS, JAVA, Javascript, .NET, Eclipse, Node Red, PHP, Python, Haddoop, Spark, MONGO DB…	• Network monitoring • Firewall • IEC 61508 • OWASP • Road Vehicles safety and cybersecurity • Security for Contactless Devices • Safety for Electrical/programmable electronic **Reference Model Standards** • RAMI, IIRA, ASS, NIST • Digital Factory **Domain-Specific Standards** Robotics, Artificial Intelligence, IoT, Digital Twin, Integration Life Cycle, Blockchain, Environmental Management **Framework Development and Specific Applications for development** Node.JS, Angular JS, JAVA, Javascript, .NET, Eclipse, Node Red, PHP, Python, Haddoop, Spark, MONGO DB…

Table 2: Template for Use Cases based on IEC 62559-2:2015 Use Case Methodology

The principal point to highlight of Table 2 is the "Standardisation Requirements for each Use Case". The content is divided in 8 different areas associated with the analysis done in D10.1 to reflect the areas where Use Cases can work standardisation. Furthermore, there are two columns (AS-IS, TO-BE) to show the progress of the use case from the beginning to the end of the Arrowhead Project related to standards. AS-IS reflect the standards that are active al the beginning of the project in each use case, and TO-BE column gathers the standards that could be implemented during the lifetime of the project or afterwards.

3.4 Representative information of the Standardisation Use Cases

The present sub-chapter identifies the principal standardisation requirements of each Use Case. The main objective is to summarize what type of standards identified in D10.1 such as System and Software Standards, Information and Representation Standards, Semantic and Language Standards, Communication Standards, Reference Model Standards, Cybersecurity and Safety Standards, Domain-Specific Standards or other standards are representative for developing the use cases.

On the other hand, there are two relevant consideration which should be remarked. Firstly, the information gathered for each use case can be updated along the project for better development in terms of quality and performance. Moreover, the use cases when filling out the Standard template, identified the most relevant standards for their own industrial/product/service situation, prioritizing the most urgent issues balancing with their own capacities. This does not mean that the use cases only need guidelines on the identified issues.

The following is showed the standardisation requirements per use case considering information in M1, the templated generated of that purpose as well as meetings and internal communication with the partners involved

USE CASE NUMBER	USE CASE NAME	STANDARIZATION REQUIREMENTS
1	**Automated Formal Verification**	- **System and Software Standards** OSLC Lifecycle Integration Core and REST
2	**Engineering processes and tool chains for a diagnostic imaging system**	- **System and Software Standards** OSLC Lifecycle Integration Core and REST - **Information and Representation Standards** XML/XMI - **Semantic and Language Standards** SysML, EMF, Simulink - **Communication Standards** TCP/IP - **Framewrok Development and Specific Applications for development** Eclipse, IBM Rhapsody, MATLAB/Simulink, UNITY, Java, Matlab, C++, C#
3	**Integration of electronic design automation tools with product lifecycle tools**	<u>5 Scenarios</u>**:** Recovery traceability link, create traceability link between two system artefacts, index a system artefact, search for a system artefact, check quality of a system artefact. <u>Standardisation Requirements</u>: - **System and Software Standards** ISO 15288:2015, ISO 12207:2017, OSLC RM/AM/TCR - **Information and Representation Standards** UML 2 SysML ReqIF, MSExcel, IBM Doors requirements, SRL (System Representation Language) and ISO 10303 – STEP - **Semantic and Language Standards** XML, JSON, RDF 1.1, SKOS 2, OSLC KM 2 (SRL endpoint)

		- **Communication Standards** HTTPS - **Cybersecurity and Safety Standards** IEC 61508-2:2010 - **Framework development** .NET, C++, Swagger, CAKE API, OSLC4Net
4	**Interoperability between (modelling) tools for cost effective lithography process integration**	**6 Scenarios:** Write system specification,, Logical modelling of the system, Physical modelling of the system, Implementation, Verification and validation of the system and Make documentation **Standardisation Requirements** - **System and Software Standards** ISO 15288:2015, ISO 12207:2017 - **Information and Representation Standards** OpenOffice XML metamodel. UML/SysML for logical modelling. (Not verified), FMU/FMI metamodel (for physical models). (Not verified), Asset representation metamodel. (Not verified), Test case representation metamodel. (Not verified) - **Semantic and Language Standards** OpenOffice XML metamodel, UML/SysML, FMU/FMI - **Communication Standards** HTTP/HTTPS - **Framework Development and Specific Applications for development** Python, Matlab Simulink, etc.
5	**Support quick and reliable decision making in the semiconductor industry**	**4 Scenarios** Run TePEx analysis, Run WHF analysis, Visualize test results, Manage engineering process **Standardisation Requirements** - **System and Software Standards** ISO 15288:2015, ISO 12207:2017 - **Information and Representation Standards** Digital reference Ontology, W3C RDF Data Cube Vocabulary, ISO SDMX, OSLC EMS (Estimation and Measurement) shape, SRL (System Representation Language) shape - **Semantic and Language Standards** CSV, OWL2, XML, JSON, RDF 1.1, SKOS 2, OSLC KM 2 (SRL endpoint) - **Communication Standards** HTTP/HTTPS - **Framework Development and Specific Applications for development** R, Java, .NET, C++, Swagger, CAKE API, OSLC4Net
7	**CNC machine automation**	- **System and Software Standards** ISO16262 ECMA script - **Semantic and Language Standards** XML, JSON, GCODE ISO 6983 - **Communication Standards** ETHERCAT, Sercos2, Sercos III, CanOpen, MTCOnnect, OPC-UA, UMATI - **Cybersecurity and Safety Standards** IEC 61508
8.1	**SoS engineering of IoT edge devices (Environmental Monitoring)**	- **System and Software Standards** Advanced Device Management (“THINGS” virtualization) - **Information and Representation Standards** VORTO language for Digital Twins - **Communication Standards**

		Lora/LoraWan/SigFox - **Cybersecurity and Safety Standards** Emergency Data Exchange Language (EDXL) - **Framework Development and Specific Applications for development** VORTO language for Digital Twins
8.3	**SoS engineering of IoT edge devices (Condition Monitoring, SHM)**	**Scenario:** Data Exchange using a common Format - **Semantic and Language Standards** JSON-LD, BSHM, - **Communication Standards** CAN, OMG-DDS - **Reference Model Standards** SAREF, SOSA, NDE4.0, AAS - **Domain-Specific Standards** Diverse standards for mechanical vibration, behaviour of structural components and others. See more information in Table X
8.4	**SoS engineering of IoT edge devices (Smart Home)**	**Scenario:** Model engineered product in CAD software, Database Query. Database Returns Value, Data Exchange using a common Format (Model), PLC Programming, Data Exchange using a common Format (PLC Logic) - **Semantic and Language Standards** XML, JSON, PLC Programming, Data Exchange using a common Format (Model) - **Communication Standards** MQTT - **Framework development** Eclipse Kura
9	**Machine operation optimisation**	- **Information and Representation Standards** Worksite data exchange - ISO-15143-3/AEMP 2.0 - **Communication Standards** CANBus - **Framework development** .NET
10	**Rapid HW development, prototyping, testing and evaluation**	- **Semantic and Language Standards** XML, JSON - **Communication Standards** WiFi, HTTP, ETHERNET, I2C / SPI / UART / RS232
11	**Configuration tool for autonomous provisioning of local clouds**	- **System and Software Standards** REST APIs - **Semantic and Language Standards** XML, JSON - **Communication Standards** GPRS, LORA, LTE-M,NB-IoT, SigFOx, Ethernet, Bluetooth, Wifi, NFC - **Cybersecurity and Safety Standards** X.509 - **Reference Model Standards** RAMI, IIRA, ASS, NIST, Digital Factory - **Framework Development** Node JS
12	**Digital twins and structural monitoring**	- **Information and Representation Standards** ISO 10303 - STEP

13	**Deployment engine for production related sensor data**	- **System and Software Standards** SOA, REST - **Communication Standards** MQTT, SMTP, FTP, IMAP, RabbitMQ - **Framework Development** Azure, Files, MongoDB, Microsoft SQL Server
15	**Smart Kitting to Manage High Diversity**	- **System and Software Standards** REST - **Information and Representation Standards** UML - **Semantic and Language Standards** JSON, XML CSV - **Communication Standards** Ethernet, WiFi, IPv4 or IPv6, TCP, TLS, HTTP - **Framework Development** Visual Studio Code, vim, Java, JavaScript, SQL, CSS
16	**Production Support, Energy Efficiency, Data Analytics and Smart Maintenance**	- **System and Software Standards** VDI3832 Measurement of structure-borne sound of rolling element bearings in machines and plants for evaluation of condition - **Information and Representation Standards** Product data representation and exchange - **Semantic and Language Standards** Framework for object-oriented information exchange - **Reference Models** RAMI, IIRA, ASS, NIST, Digital Factory - **Domain-Specific Standards** VDI 3832, VDI 3839, DIN 1311, ISO 2954, ISO18431, ISO 13373, ISO 13374, ISO 13379, VDI 3836, ISO 10816, ISO 15242
17	**Linking Building Simulation to a Physical Building in Real-Time**	- **Semantic and Language Standards** JSON - **Communication Standards** OPC-UA, BACnet, Modbus, Https, TCP/IP, UDP, - **Cybersecurity and Safety Standards** IEC 62443
18	**Use case - Secure sharing of IoT generated data with partner ecosystem**	- **Information and Representation Standards** RDF, SiSML - **Semantic and Language Standards** XML, JSON, CSV - **Communication Standards** Ethernet or WiFi, IPv4 or IPv6, TCP, TLS, HTTP & HTTPS, OPC-UA, MQTT, Ethernet, LoRaWAN, or NB-IoT,OneM2M - **Cybersecurity and Safety Standards** X.509 - **Reference Model Standards** RAMI, IIRA, ASS, NIST, Digital Factory, Fiware, IIC - **Framework Development** - Java, SQL, Visual Estudio, SQL,
19	**Deployment and configuration**	- **System and Software** REST API - **Semantic and Language Standards** JSON - **Framework Development** Java, MySQL

20	**Elastic Data Acquisition System**	- **Information and Representation Standards** Working on that - **Semantic and Language Standards** JSON, CSV - **Communication Standards** OPC-UA, UMATI, PPMP, HTTP, COAP **Framework Development** .NET, SQL_SERVER
21	**Data-based digital twin for electrical machine condition monitoring**	- **System and Software Standards** REST - **Information and Representation Standards** Common data model (MIMOSA) - **Semantic and Language Standards** JSON - **Communication Standards** HTTP, MQTT - **Reference Model** OSA-EAI
22	**Arrowhead Framework training tool**	- **Framework Development** Google Blockly

Table 3: Summary of Standaridization Requirements by Arowhead Tools project use cases

Once gathering the standards related with each of the use cases, repetitive common standards are identified having a strong necessity to identify the most relevant standards to all use cases. Furthermore, the continuous and massive utilization of some standards will help shape the future support of WP10 in further tasks. The Figure 11 shows that relevant information divided in 8 graphs considering the standardisation areas identified in 10.1, except Arrowhead Training Tool and is displayed from the most representative to the less.

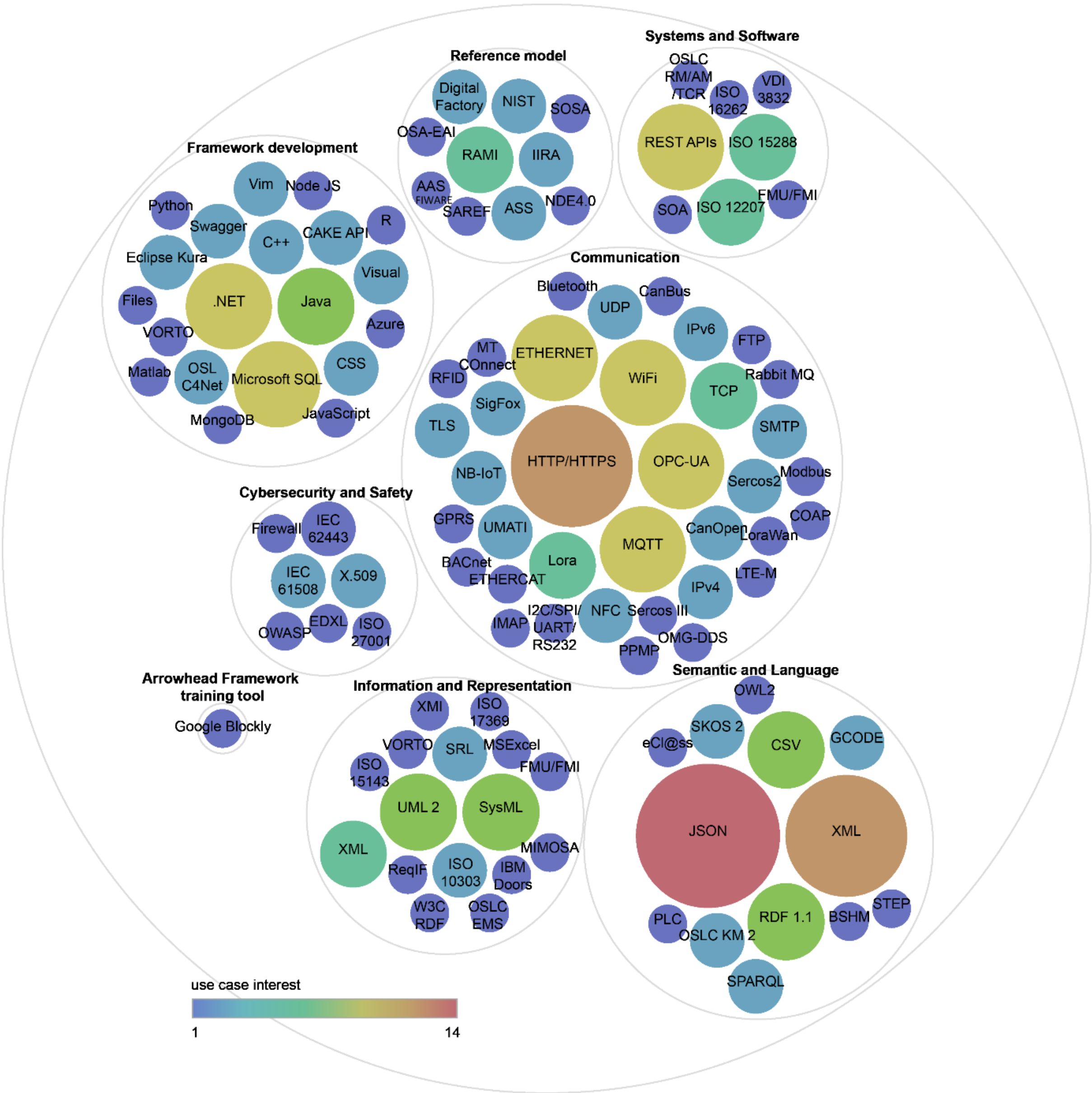

Figure 11. Use Case Standards– Displayed by Representative.

Furthermore, from each group of standards identified and classified in D10.1, there are 21 standards that will be used or considered to be applied for a minimum of 3 use cases. Those 21 standards represent 6 standard groups from the 8 identified as interest groups in D10.1. The sample can be seen in the following Table 3.

		Use Cases																						
Standard Group	**Specific Standard**	**1**	**2**	**3**	**4**	**5**	**7**	**8.1**	**8.3**	**8.4**	**9**	**10**	**11**	**12**	**13**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**Total**
Semantic and Language	JSON		■	■		■	■		■	■		■	■			■		■	■	■	■	■		14
Communication	HTTP/HTTPS		■	■	■	■						■				■		■	■		■	■		10
Semantic and Language	**XML**		■	■	■	■	■			■		■	■			■			■					**10**
Communication	OPC-UA		■				■											■	■		■			5
Communication	**MQTT**		■							■					■				■			■		**5**
Communication	WiFi		■									■	■			■			■					5
Communication	**ETHERNET**		■									■	■			■			■					**5**
Framework development	.NET			■		■					■								■		■			5
Framework development	**Microsoft SQL**														■	■			■	■	■			**5**
Systems and Software	**REST APIs**												■		■	■				■		■		**5**
Framework development	Java					■										■			■	■				4
Information and Representation	**UML 2**		■	■	■											■								**4**
Information and Representation	**SysML**		■	■	■														■					**4**
Semantic and Language	**RDF 1.1**		■	■		■													■					**4**
Semantic and Language	CSV					■										■			■		■			4
Communication	**Lora**							■					■						■					**3**
Communication	**TCP**															■		■	■					**3**
Information and Representation	XML		■		■														■					3
Reference model	RAMI												■				■		■					3
Systems and Software	**ISO 15288**			■	■	■																		**3**
Systems and Software	ISO 12207			■	■	■																		3

Table 4. Relation Use Cases and Specific Standards

All use case and standards relationship are further displayed in Appendix 2 of the present deliverable.

Finally, some of the use cases identified an specific necessity in a Standard Group, but did not identify a particular standard, without gathering those requirement in Figure 11 or Table 4. The table below compiles the specific claims of all use cases that didn´t identified a precise standard.

Standard Group	Use Case	Requirement
Communication	2	Protocols, or protocols for Contactless Devices
Information and Representation	4	Asset representation metamodel. (Not verified), Test case representation metamodel. (Not verified)
Systems and Software	8.1	Advanced Device Management (virtualization)
Semantic and Language	8.4	Data Exchange using a common Format (Model)
Information and Representation	16	Product data representation and exchange

Standard Group	Use Case	Requirement
Semantic and Language	16	Framework for object-oriented information exchange
Information and Representation	20	information and representation standard interest

Table 5. Use Case General Requirements

4. Appendixes

1. Appendix 1 – Use Cases Standardisation Questionnaires
2. Appendix 2 – Use Cases and Standards Relationship

5. References

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6. **Conclusions**

The deliverable 10.2 "Standardisation report effort year 1" respond to the need of gathering the standardisation interests of all partners as entities as well as requirements that are part of a specific use case intended to be displayed in Phase I of WP10. A major target point for Arrowhead Tools is digitalisation and automation solutions for the European industry, which will close the gaps that hinder the IT/OT integration.

From the responses of the Use Case template based on "IEC 62559-2:2915 Use case methodology", and information from Milestone I, 146 standards were identified for 22 used cases and sub-cases. The results obtained from the partners´ feedback reflect a strong necessity to propose a general approach in terms of interoperability and integration raw data, pre-processed information, the uniformity of the data format and the important role of the semantics as well as communication.

At that point, the most common and claimed necessity of the use cases and sub-use cases involved in D10.1 is the STD 90 - JavaScript Object Notation (JSON) Data Interchange Format and Extensible Markup Language (XML). The format data as well as representation and knowledge associated with specific applications and domains requires the use of languages prepared for it, being one of the issues that should be addressed in further activities of Phase II and Phase III of the WP10 Planning. From semantic perspective and implementation is essential for the interoperability of the data since it contains its meaning. Semantics play an important role in communication between machines in particular, since machines often cannot suppose these relationships from the context of the information. Furthermore, during the product life cycle, information will need to be exchanged in a way that can be understood by all partners, and JSON and XML will be the case for a 63,3% of the participating use-cases. Likewise, UML, SysML and RDF are representative standards consider for Systems Modelling that should also be part of the Phase II of the W 10 Planning. However, it would be an error to forget other standards that are going to use to reach the challenge such as ISO 10303 or RDF to mention two of them.

On the other hand, the communication matters are also relevant for the participant use cases. Partners are interested in interoperable protocols that can be used in diverse layers of the industrial environment, highlighting OPC-UA, MQTT as well as Internet protocols such as HTTP, WiFi and ETHERNET. The security, reliability and interoperability of transporting raw and pre-processed data are valuable for the Arrowhead Tools partners. The organization based on layers has the main advantage to allow interchangeability between their implementations, assuring technological independence via wireless or cabled. The protocols can be used as uniform interfaces to access information from machines from diverse manufacturers, simplifying the integration of components and plants, increasing the efficiency. In order to avoid redundant data generation data losses and set up intermediate layers, the standards and protocols highlighted above by partners are relevant for the use cases. Other protocols that are appropriate to point out are UMATI, CAN-Open, SigFox, Lora among others although less representative.

Another key element that use cases have showed interest to overcome their own challenges is the management of the development of the engineering tools associated with ISO/IEC/IEEE

15288:2015 Systems and Software engineering — System life cycle processes and ISO/IEC 12207 - Information Technology / Software Life Cycle Processes. That issue as is part of the impacts and benefits which are named in point 3.1 “Benefits and Motivation. How impact standardisation approach for the use cases (Engineering costs)” has the relevance. Furthermore, in order to attain the objective to reduce the cost and more effective engineering tools is highly relevant.

Apart from that, there are some other standards less representative but not least important because they will help to attain the objectives either technical or operational challenges of the use cases. For further information of which standards are shown Appendix 2.

Finally, although the standardisation approach was not the principal priority of the use cases at the beginning of Arrowhead Tools project since there are few cases considering (AS-IS) that issue, their subsequent standardisation analysis has showed the relevance for carrying out the use cases taking into account the standardisation approach (TO-BE) together with technological challenge as part of the development cost and time-based on more effective engineering tools.

For that reason, the objective of progress in Phase II and Phase III with contributions related to Language, Semantic, Interoperability and Communication standards as the analysis has showed in Phase I, will be to target a the global approach of standardisation focuses on Smart Manufacturing Reference Model such as RAMI 4.0 or Asset Administration Shell initiative.

7. Revision history

7.1 Contributing and reviewing partners

Contributions	Reviews	Participants	Representing partner
Table of Content and Survey Template	0.1	Michel Iñigo	MON
Partner contributions (conference calls and reminders)	0.2	Use Cases responsible and WP10 team	Partners, see Table 1. Standardisation Contacts and Involvement
Review of Contributions	0.3	Carolina Mejia, Michel Iñigo	MON
Analysis and Final Draft	0.4	Carolina Mejia, Michel Iñigo	MON

7.2 Amendments

No.	Date	Version	Subject of Amendments	Author
1	2020-04-01	0.4	Version for review	Michel Iñigo
2	2020-04-26	1.0	Header update	Mats Johansson

7.3 Quality assurance

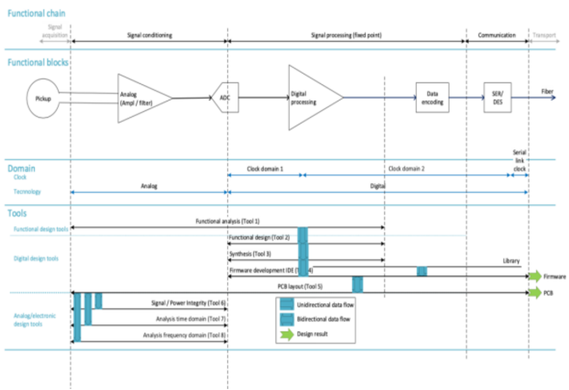
No	Date	Version	Approved by
1	2020-04-26	1.0	Jerker Delsing

8. Appendix 1 – Partner Questionnaires

<table>
<tr><th>Use Case 1</th><th colspan="2">Automated Formal Verification</th></tr>
<tr><td>Use Case Objective</td><td colspan="2">The use case primarily aims at systems developed for intelligent traffic surveillance in an SME (CAMEA) that is currently not using latest advanced verification techniques at all using advance verification techniques.</td></tr>
<tr><td>Smart Manufacturing Benefit</td><td colspan="2">Engineering processes in CAMEA where improving and automating verification and testing techniques can significantly reduce the cost and increase the performance of the development process.</td></tr>
<tr><td>Life Cycle Phase</td><td colspan="2">Requirements, Functional Design, Procurement / Engineering, Maintenance, Evolution, Training / Education</td></tr>
<tr><td>Diagram/ Architecture</td><td colspan="2"></td></tr>
<tr><td>Standardisation Requirements</td><td><u>AS-IS</u>
<u>System and Software Standards</u>
• -
<u>Information and Representation Standards</u>
• -
<u>Semantic and Language Standards</u>
• -
<u>Communication Standards</u>
• -
<u>Cybersecurity and Safety Standards</u>
• -
<u>Reference Model Standards</u>
• -
<u>Domain-Specific Standards</u></td><td><u>TO-BE</u>
<u>System and Software Standards</u>
• OSLC Lifecycle Integration Core
<u>Information and Representation Standards</u>
<u>Semantic and Language Standards</u>
• -
<u>Communication Standards</u>
• -
<u>Cybersecurity and Safety Standards</u>
• -
<u>Reference Model Standards</u>
• -
<u>Domain-Specific Standards</u>
• -</td></tr>
</table>

	• - **Framework Development and Specific Applications for development**	**Framework Development and Specific Applications for development**

Table 6:Use Case 1 - Automated Formal Verification

<table>
<tr><td>Use Case 2</td><td colspan="2">Engineering processes and tool chains for a diagnostic imaging system</td></tr>
<tr><td>Use Case Objective</td><td colspan="2">PHC will design and implement the new tool chain (WP4) for this use case and demonstrate it in the MRI RF Receive chain development process.</td></tr>
<tr><td>Smart Manufacturing Benefit</td><td colspan="2">Enable first time right designs and tools that aim to reduce the time and errors involved with manually converting between tool outputs to inputs.</td></tr>
<tr><td>Life Cycle Phase</td><td colspan="2">Requirements, Functional Design, Deployment and Commssioning , Maintenance, Training / Education</td></tr>
<tr><td>Diagram/ Architecture</td><td colspan="2">
</td></tr>
<tr><td>Standardisation Requirements</td><td><u>AS-IS</u>

<u>System and Software Standards</u>
• -

<u>Information and Representation Standards</u>
• -</td><td><u>TO-BE</u>

<u>System and Software Standards</u>
• OSLC Lifecycle Integration Core and REST

<u>Information and Representation Standards</u>
• XML/XMI</td></tr>
</table>

	Semantic and Language Standards • - **Communication Standards** • - **Cybersecurity and Safety Standards** • - **Reference Model Standards** • - **Domain-Specific Standards** • - **Framework Development and Specific Applications for development**	**Semantic and Language Standards** • SysML, EMF, Simulink **Communication Standards** • TCP/IP **Cybersecurity and Safety Standards** • - **Reference Model Standards** • - **Domain-Specific Standards** • - **Framework Development and Specific Applications for development** • Eclipse, IBM Rhapsody, MATLAB/Simulink, UNITY • Java, Matlab, C++, C#t

Table 7:Use Case 2 - Engineering processes and tool chains for a diagnostic imaging system

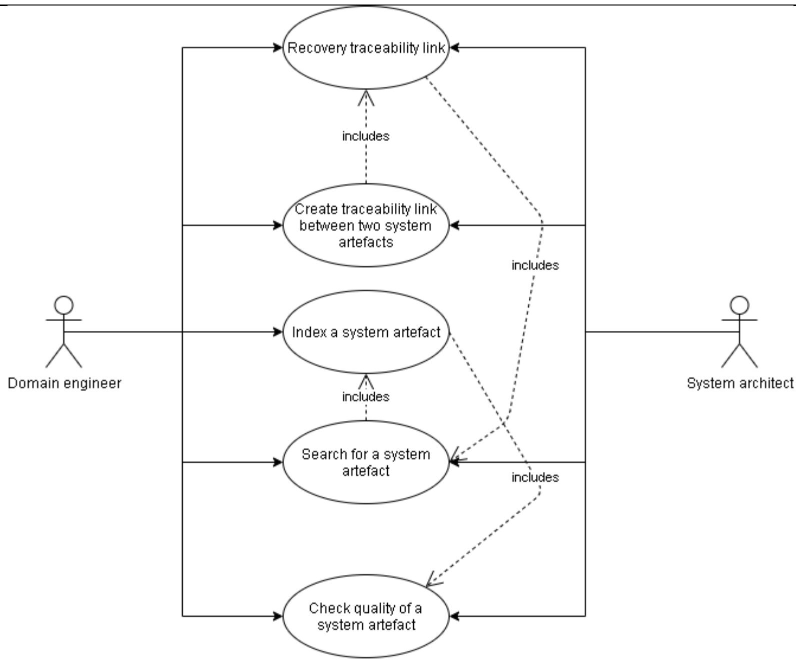
Use Case 3	**Integration of electronic design automation tools with product lifecycle tools**
Use Case Objective	This use case is applied to the whole development lifecycle of critical systems for IoT and SoS. More specifically, it focuses on the possibility of making a better reuse of physical models covering the abstraction, selection, representation and customization of system artefacts generated during the development lifecycle. The reuse of any system artefact goes beyond the mere discovery of potential reuse and it must focus on evaluating what can be reused (requirements, analytical models, descriptive models, test cases, etc.) when a match is discovered. To do so, quality usually has some impact since it is assumed that high-quality system artefacts may help to improve the reusability factor of a system artefact. 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.

<table>
<tr><td></td><td>Traceability is a critical activity to ensure that every system artefact exists for a reason.</td></tr>
<tr><td>Smart Manufacturing Benefit</td><td>The main benefit of this use case relies on the possibility of reusing previous engineering designs (at both logical and physical level) by providing a semantic-oriented reuse method that represents, indexes and provides means for searching existing system artefacts. When a new product must be designed, a system artefact (e.g. a requirement specification, a logical model, a physical model, a text-based query etc.) can be used to query the assets repository and get all potential system artefacts including traceability links (dependencies).

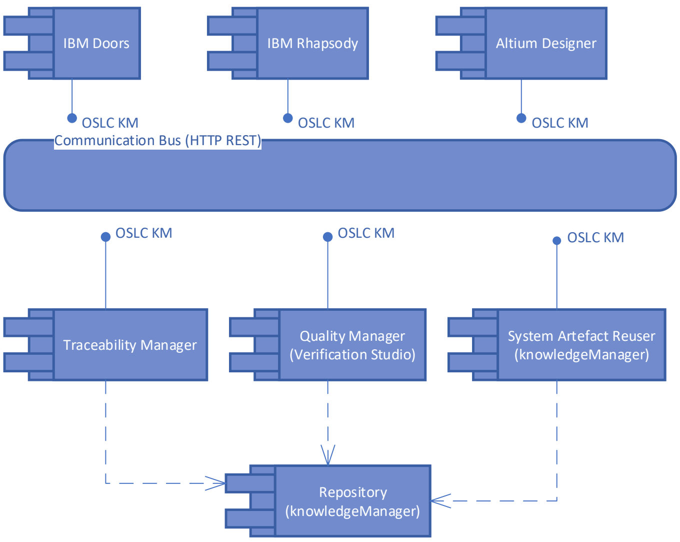
Then, other requirements to filter the search results can be used to determine which parts of an existing product can be reused depending on factors (mainly qualitative) such as certification, qualification, domain, availability, etc. As a result, this reusability service can decrease the time to develop a new system by reusing previous designs making the process more efficient.</td></tr>
<tr><td>Life Cycle Phase</td><td>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>
<tr><th>UC-EP Engineering process</th><th>AHT-EP</th></tr>
<tr><td>System Requirements Definition</td><td>Requirements</td></tr>
<tr><td>Architecture Definition</td><td>Functional Design</td></tr>
<tr><td>Design definition</td><td>Functional Design</td></tr>
<tr><td>Implementation</td><td>Procurement & engineering,

Training & education</td></tr>
<tr><td>Verification & Validation (Measurement process)</td><td>Procurement & engineering,

Deployment & Commissioning</td></tr>
<tr><td>Information Management</td><td>Not available</td></tr>
</table></td></tr>
<tr><td>Diagram/ Architecture</td><td>In the next diagram, the initial set of target actors and specific use cases are presented:</td></tr>
</table>



These scenarios will be implemented through the next functional architecture (tools included). Here, it is important to notice that the OSLC ports refer to standardized communication services under HTTP protocols (not necessarily OSLC-based, just REST-based services).



Scenario I	Recovery traceability link
Actor(s)	Domain Engineer, System architect
Preconditions	• A knowledge base (ontology) of the existing produces is available (SKB-System Knowledge Base).

	• A system artefact repository of the existing system artefacts represented using the ontology is available (SAS-System Asset Store). • Service interfaces on required tools (Traceability Manager) are up and running.
Postconditions	• A set of candidate system artefacts is returned by the service for recovering traceability links.
Main scenario	1. The actor selects a system artefact within a domain-specific tool (e.g. Altium). 2. The actor indicates characteristics to filter matched system artefacts (e.g. type of artefact). 3. The actor searches for candidate system artefacts to be linked. 4. The actor selects the system artefact to be linked to.
Exceptions	N/A

Scenario II	**Create traceability link between two system artefacts**
Actor(s)	Domain Engineer, System architect
Preconditions	• A knowledge base (ontology) of the existing produces is available (SKB-System Knowledge Base). • A system artefact repository of the existing system artefacts represented using the ontology is available (SAS-System Asset Store). • Service interfaces on required tools (Traceability Manager) are up and running.
Postconditions	• A new trace is created between the source and the selected system artefacts.
Main scenario	1. See UC: “Recovery traceability link” 2. The actor creates the trace.

Exceptions	The target system artefact does not exist (only the indexed representation).

Scenario III	Index a system artefact
Actor(s)	Domain Engineer
Preconditions	• A knowledge base (ontology) of the existing produces is available (SKB-System Knowledge Base). • A system artefact repository of the existing system artefacts represented using the ontology is available (SAS-System Asset Store). • Service interfaces on required tools (System Artefact Reuser) are up and running.
Postconditions	• A new system artefact is indexed by content.
Main scenario	1. The actor selects a system artefact within a domain-specific tool (e.g. Altium). 2. The actor configures the indexing process (e.g. type of artefact, etc.). 3. The actor indexes the system artefact.
Exceptions	The indexing process fails to index the system artefact.

Scenario IV	Search for a system artefact
Actor(s)	Domain Engineer, System architect
Preconditions	• A knowledge base (ontology) of the existing produces is available (SKB-System Knowledge Base). • A system artefact repository of the existing system artefacts represented using the ontology is available (SAS-System Asset Store).

	• Service interfaces on required tools (System Artefact Reuser) are up and running.
Postconditions	• A set of system artefacts matching the query is returned.
Main scenario	1. The actor selects a system artefact within a domain-specific tool or just selects some text. 2. The actor searches for similar system artefacts. 3. The actor explores the returned results.
Exceptions	N/A

Scenario V	**Check quality of a system artefact**
Actor(s)	Domain Engineer, System architect
Preconditions	• A knowledge base (ontology) of the existing produces is available (SKB-System Knowledge Base). • A system artefact repository of the existing system artefacts represented using the ontology is available (SAS-System Asset Store). • A quality metrics library is available. • Service interfaces on required tools (Verification Studio) are up and running.
Postconditions	• A set of quality metrics are returned.
Main scenario	1. The actor selects a system artefact. 2. The actor requests the quality metrics for that system artefact. 3. The actor explores the returned quality metrics.
Exceptions	N/A

Standardisation Requirements	**AS-IS**	**TO-BE** **System and Software Standards**

	System and Software Standards • ISO 15288:2015 • ISO 12207:2017 • ISO 29148:2011 • OSLC RM (Requirements) data shape • OSLC AM (Architecture) data shape **Information and Representation Standards** • UML 2 metamodel • SysML metamodel • ReqIF • MSExcel • IBM Doors requirements • Altium Schematic API **Semantic and Language Standards** • XML • UML (XMI) • SysML (XMI) **Communication Standards** • File **Cybersecurity and Safety Standards** • IEC 61508-2:2010 **Reference Model Standards**	• ISO 15288:2015 • ISO 12207:2017 • ISO 29148:2011 • OSLC RM (Requirements) data shape • OSLC AM (Architecture) data shape • OSLC TRC (Tracked Resource Set) **Information and Representation Standards** • UML 2 metamodel • SysML metamodel • ReqIF • MSExcel • IBM Doors requirements • SRL (System Representation Language) • ISO 10303 - STEP **Semantic and Language Standards** • XML • JSON • RDF 1.1 • SKOS 2 • OSLC KM 2 (SRL endpoint) **Communication Standards** • HTTPS **Cybersecurity and Safety Standards** • IEC 61508-2:2010 **Reference Model Standards** • Not applicable

	• Not applicable **Domain-Specific Standards** Not applicable **Framework Development and Specific Applications for development** .NET, C++, IBM Doors API, IBM Rhapsody API, Altium Schematic API	**Domain-Specific Standards** Not applicable **Framework Development and Specific Applications for development** .NET, C++, Swagger, CAKE API, OSLC4Net

Table 8:Use Case 3 - Integration of electronic design automation tools with product lifecycle tools

Use Case 4	**Interoperability between (modelling) tools for cost effective lithography process integration**
Use Case Objective	**According to the description in the document of WP4-"AHT Use Case Analysis"**, the main aim of this use case is to improve the design of complex lithography systems for the semiconductor industry. The engineering process of such system combines 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. These engineering disciplines each use a specific set of engineering methods, tools and technologies that are loosely coupled both on a syntactic and on a semantic level. The objective of this use case is then to develop a tool chain, mainly focusing 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. The transition between phases in the baseline is rather manual as descripted in the following: 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

<table>
<tr><td></td><td>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. Several tools are already implied in the loop although the level of integration in the baseline is low.</td></tr>
<tr><td>Smart Manufacturing Benefit</td><td>The main benefit of this use is aligned to the objective of “Reduction of solution engineering costs by 20-50%”. More specifically, through the integration of the following tools:

-Stateflow (Mathworks) is a control logic tool used to model reactive systems via state machines and flow charts within a Simulink model.

-LSAT (developed by ASML, TNO-ESI and TUE) provides a formal modeling approach for compositional specification of both functionality and timing of manufacturing systems.

-CIF (Compositional Interchange Format for hybrid systems, developed by TUE) is an automata-based modeling language for the specification of discrete event, timed, and hybrid systems.

-SDF3 (developed by TUE) is a tool for analysis and synthesis of Synchronous DataFlow Graphs (SDFGs). It includes an extensive library of SDFG analysis and transformation algorithms as well as functionality to visualize them.

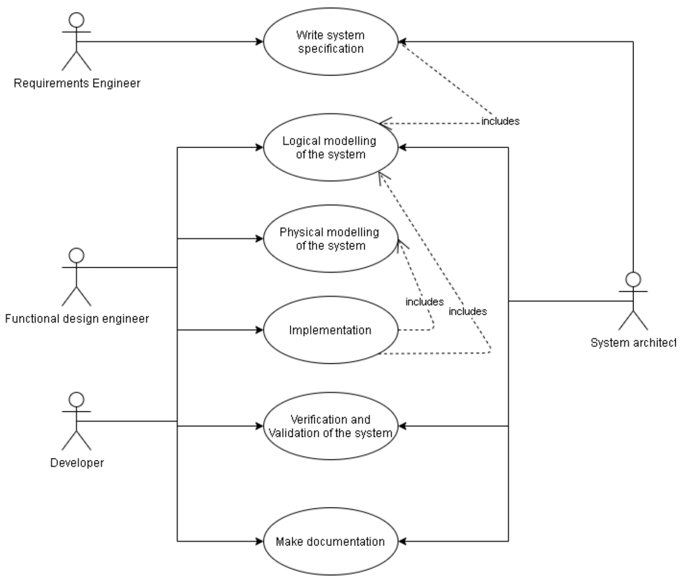
-mCRL2 (developed by TUE in collaboration with University of Twente) is a formal specification language with an associated toolset. The toolset can be used for modelling, validation and verification of concurrent systems and protocols.</td></tr>
<tr><td>Life Cycle Phase</td><td>The engineering process defined for this use case is based on the following workflow:

<table>
<tr><th>AHT-EP phase</th><th>UC-EP tool/methodology groups</th></tr>
<tr><td>Requirements</td><td>Matlab, Word documents</td></tr>
<tr><td>Functional design</td><td>Word documents & Visio diagrams
Matlab Stateflow / LSAT (scenario and platform specification)
CIF/SDF3 (scenario synthesis)
mCRL2 (formal analysis (model checking))</td></tr>
<tr><td>Procurement & engineering</td><td>Python code, ClearCase versioning</td></tr>
<tr><td>Deployment & commissioning</td><td>Linux patching</td></tr>
</table>
</td></tr>
</table>

Operations & management	ClearCase / AIR / FCO
Maintenance	ClearCase / AIR
Evolution	ClearCase / AIR
Training	Field procedures documented in Word

Diagram/ Architecture Scenarios

In the next diagram, the initial set of target actors and specific use cases are presented:



This UML diagram identifiers some actors that will play a different role for each use case. The specific use cases represent goals of the actors from en external point of view, no workflow. Although, the specific use cases are quite generic, they represent the major goals and the overview of the use case.

UC Name	Write system specification
Actor(s)	Requirements Engineer, System Architect
Preconditions	• An initial set of high-level needs. • A Matlab instance. • A MSWord instance. • A MSVisio instance.

Postconditions	• A system specification in the form of a documented logical model in MSWord and MSVision.
Main scenario	5. The actors perform a system analysis based on the high-level needs of the new system. 6. The Requirements engineer documents the system specification. 7. The actors create a logical model (descriptive) of the system under specification (architectural model).
Exceptions	N/A

UC Name	Logical modelling of the system
Actor(s)	Functional design engineer, System Architect
Preconditions	• The initial specification of the system. • A MSWord instance. • A MSVisio instance.
Postconditions	• A detailed logical model.
Main scenario	1. The actors specify the functional blocks of the system.
Exceptions	N/A

UC Name	Physical modelling of the system
Actor(s)	Functional design engineer,
Preconditions	• The initial specification of the system. • The detailed architectural model. • An instance of Matlab. • An instance of LSAT. • An instance of CIF/SDF3.

	• An instance of mCRL2.
Postconditions	• A physical model.
Main scenario	1. The functional design engineer divides the functional blocks and align to physical functions. 2. For each of the functional blocks, a physical model is produced using the different tools.
Exceptions	N/A

UC Name	Implementation
Actor(s)	Functional design engineer, Developer
Preconditions	• The detailed architectural model. • An instance of Matlab. • An instance of LSAT. • An instance of CIF/SDF3. • An instance of mCRL2. • A Python instance
Postconditions	• Source code implementing the different physical models.
Main scenario	1. The functional design engineer and developers provide an implementation of each physical model.
Exceptions	N/A

UC Name	Verification and validation of the system
Actor(s)	Functional design engineer, System architect
Preconditions	• The system specification. • The system implementation.

Postconditions	• The system is verified and validated (verification and validation items are passed).
Main scenario	1. Based on the system specification, a set of verification actions are created (usually test cases). 2. Based on the system specification, a set of validation actions are created (usually test cases). 3. The Functional design engineer verifies the functional components. 4. The Functional design engineer validates the functional components. 5. The system architect ensures the whole verification and validation of the system.
Exceptions	N/A

UC Name	Make documentation
Actor(s)	*
Preconditions	• The system specification. • The system models. • The system implementation. • The system verification and validation report.
Postconditions	• Documentation for different audience.
Main scenario	1. Depending on the engineering phase and the type of artifact generated (specification, model, source code, verification and validation evidences), the team in charge generate a documentation. 2. The engineering team ensures document consistency. 3. The system architect ensures consistency across documents.

<table>
<tr><td></td><td colspan="2"><table><tr><td>Exceptions</td><td>N/A</td></tr></table></td></tr>
<tr><td>Standardisation Requirements</td><td><u>AS-IS</u>
<u>System and Software Standards</u>
• ISO 15288:2015
• ISO 12207:2017
• Other domain specific standards.

<u>Information and Representation Standards</u>
• OpenOffice XML metamodel.
• Matlab specific metamodel.
• LSAT specific metamodel.
• CIF/SDF3 specific metamodel.
• mCRL2 specific metamodel.
• Python documentation metamodel.

<u>Semantic and Language Standards</u>
• OpenOffice XML metamodel.

<u>Communication Standards</u>
• File</td><td><u>TO-BE</u>
<u>System and Software Standards</u>
• ISO 15288:2015
• ISO 12207:2017
• Other domain specific standards.

<u>Information and Representation Standards</u>
• OpenOffice XML metamodel.
• UML/SysML for logical modelling. (Not verified)
• FMU/FMI metamodel (for physical models). (Not verified)
• Asset representation metamodel. (Not verified)
• Test case representation metamodel. (Not verified)

<u>Semantic and Language Standards</u>
• OpenOffice XML metamodel.
• UML/SysML.
• FMU/FMI

<u>Communication Standards</u>
• HTTP/HTTPS

<u>Cybersecurity and Safety Standards</u>
• Not applicable

<u>Reference Model Standards</u></td></tr>
</table>

	Cybersecurity and Safety Standards • Not applicable **Reference Model Standards** • Not applicable **Domain-Specific Standards** Not applicable **Framework Development and Specific Applications for development** Python, Matlab Simulink, etc.	• Not applicable **Domain-Specific Standards** Not applicable **Framework Development and Specific Applications for development** Python, Matlab Simulink, etc.

Table 9:Use Case 4 - Interoperability between (modelling) tools for cost effective lithography process integration

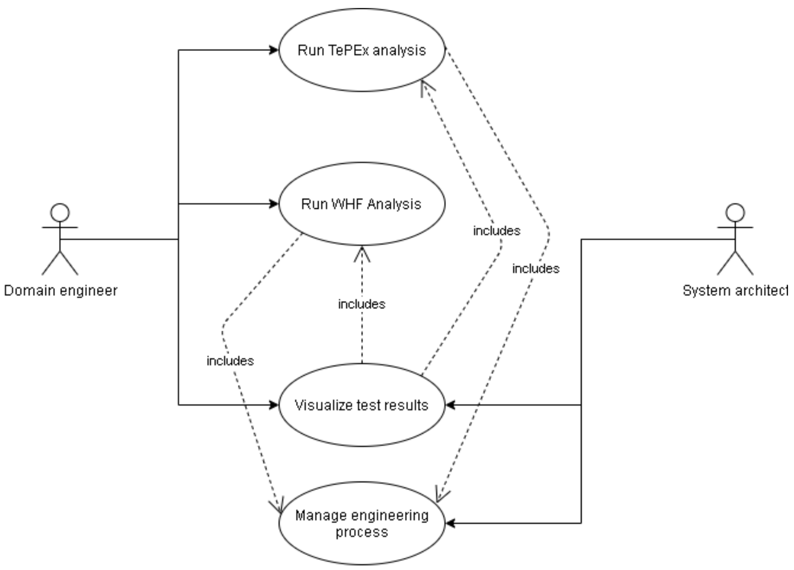
Use Case 5	**Support quick and reliable decision making in the semiconductor front-end manufacturing process**
Use Case Objective	The aim of the use case is to support quick and reliable decision making in the semiconductor industry by enabling faster diagnostic via automated monitoring and evaluation of testing data. More specifically, it is based on the use and integration of the following tools: • Tool1 (TePEx): Automated monitoring of testing data, for an earlier identification and reaction on malfunctioning testing equipment. • Tool2 (WHF): Integration of the wafer health factor for faster root cause analysis. • Tool3 (Set of tools for indexing, sharing and visualizing data, e.g. Elastic + Kibana) with the aim of enabling of an integrated and interoperable environment for single tools, to ease the access and exchange of data. • Tool4 (OWL Ontology): Provision of a semantic web for the supply chain to enable sharing and integration of information, data basis and tools with the aim enabling sharing and integration of information.

<table>
<tr><td>Smart Manufacturing Benefit</td><td>The main benefit of this use is aligned to the objective of “Reduction of solution engineering costs by 20-50%”. More specifically, the TePEx tool will be used to extract patterns in data related to the malfunctioning of testing equipment. The second tool, WHF, focuses on easing the process of detecting critical patterns originated by the testing process by itself. The production process can be then modified in an early state to lower the time and costs of producing devices with defects. Moreover, the use of an infrastructure to share and visualize data (e.g. Elastic and Kibana) will help engineers to have early insights in graphical manner. Finally, the last tool, an ontology, can be seen as mechanism to manage, generalize and document both the processes and datasets to perform engineering processes easing its tailoring to further products (see more information about the ontology here www.w3id.org/ecsel-dr).</td></tr>
<tr><td>Life Cycle Phase</td><td>The engineering process defined for this use case is based on the following workflow:

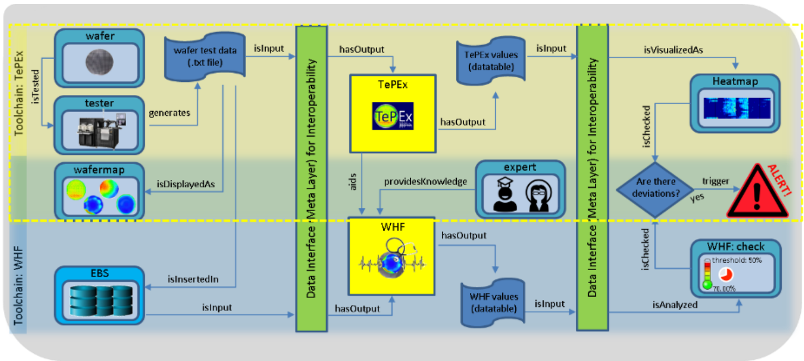

<table>
<tr><th>UC-EP Engineering process</th><th>AHT-EP</th></tr>
<tr><td>Tool evaluation</td><td>Requirements</td></tr>
<tr><td>Tool improvement</td><td>Functional Design</td></tr>
<tr><td>Tool improvement</td><td>Procurement & engineering,
Training & education</td></tr>
<tr><td>Tool integration</td><td>Deployment & Commissioning</td></tr>
<tr><td>Tool integration</td><td>Operation & management</td></tr>
</table></td></tr>
</table>

Diagram/Architecture

In the next diagram, the initial set of target actors and specific use cases are presented:



These scenarios will be implemented through the next flow diagram:



UC Name	Run TePEx analysis
Actor(s)	Domain Engineer
Preconditions	• A valid configuration of the parameters of the analysis. • An input dataset.
Postconditions	• A set of values are generated through the analysis and added to the input dataset.
Main scenario	

	1. The actor selects a configuration of the tool. 2. The actor selects the dataset to analyze. 3. The actor runs the tool. 4. The tool enriches the input dataset.
Exceptions	N/A

UC Name	Run WHF analysis
Actor(s)	Domain Engineer
Preconditions	• A valid configuration of the parameters of the analysis. • An input dataset.
Postconditions	• A set of values are generated through the analysis and added to the input dataset.
Main scenario	1. The actor selects a configuration of the tool. 2. The actor selects the dataset to analyze. 3. The actor runs the tool. 4. The tool enriches the input dataset.
Exceptions	N/A

UC Name	Visualize test results
Actor(s)	Domain Engineer, System Architect
Preconditions	• A dataset or an enriched dataset after the analytical processes.
Postconditions	• A dashboard displays the test results.
Main scenario	1. The actor enters in the tool. 2. The actor selects an execution of the analytical processes.

	3. The tool displays a dashboard with heatmaps to represent the test results.
Exceptions	N/A

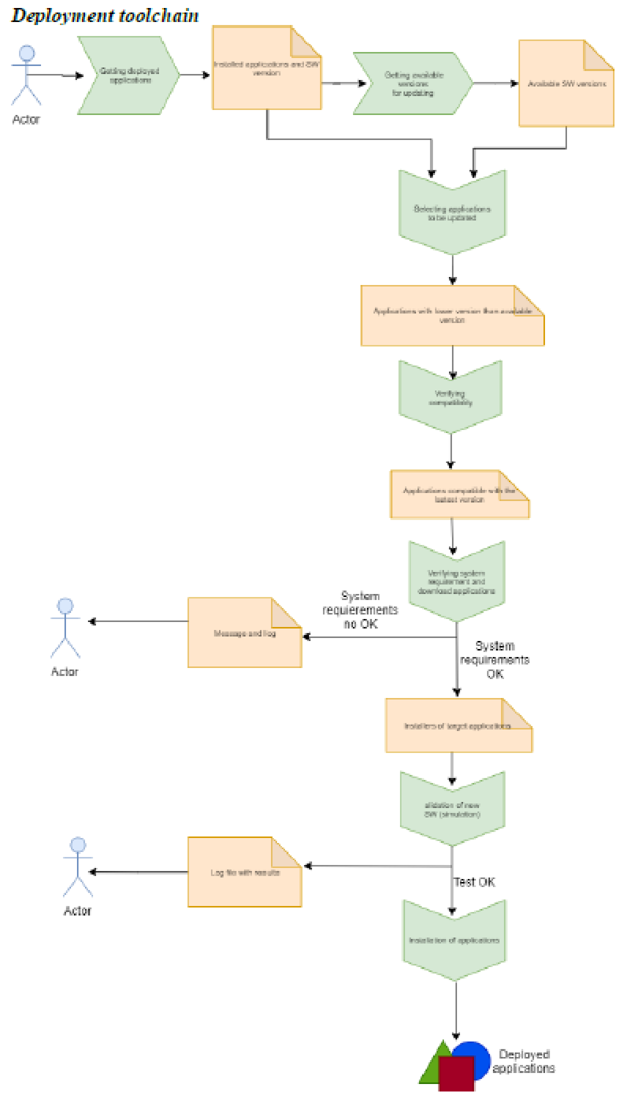
UC Name	Manage engineering process
Actor(s)	Domain Engineer
Preconditions	• The Digital Reference ontology.
Postconditions	• An instance of the analytical process and data management is created.
Main scenario	1. The actor enters in the tool. 2. The actor creates a new configuration as an instance of the classes for specifying an activity of the engineering process. 3. The tool validates the new instance. 4. The tool saves the new instance with the proper configuration of the analytical process.
Exceptions	N/A

Standardisation Requirements	**AS-IS** **System and Software Standards** • ISO 15288:2015 • ISO 12207:2017 **Information and Representation Standards** • CSV • Digital Reference ontology **Semantic and Language Standards** • CSV • RDF 1.1. • OWL 2 **Communication Standards** • File **Cybersecurity and Safety Standards** • Not applicable **Reference Model Standards** • Not applicable **Domain-Specific Standards** Not applicable	**TO-BE** **System and Software Standards** • ISO 15288:2015 • ISO 12207:2017 **Information and Representation Standards** • W3C RDF Data Cube Vocabulary • ISO SDMX • OSLC EMS (Estimation and Measurement) shape • SRL (System Representation Language) shape **Semantic and Language Standards** • CSV • XML • JSON • RDF 1.1 • SKOS 2 • OSLC KM 2 (SRL endpoint) **Communication Standards** • HTTP/HTTPS **Cybersecurity and Safety Standards** • Not applicable **Reference Model Standards** • Not applicable **Domain-Specific Standards** Not applicable

	Framework Development and Specific Applications for development R, Java, .NET	**Framework Development and Specific Applications for development** R, Java, .NET, C++, Swagger, CAKE API, OSLC4Net

Table 10:Use Case 5 - Support quick and reliable decision making in the semiconductor front-end manufacturing process

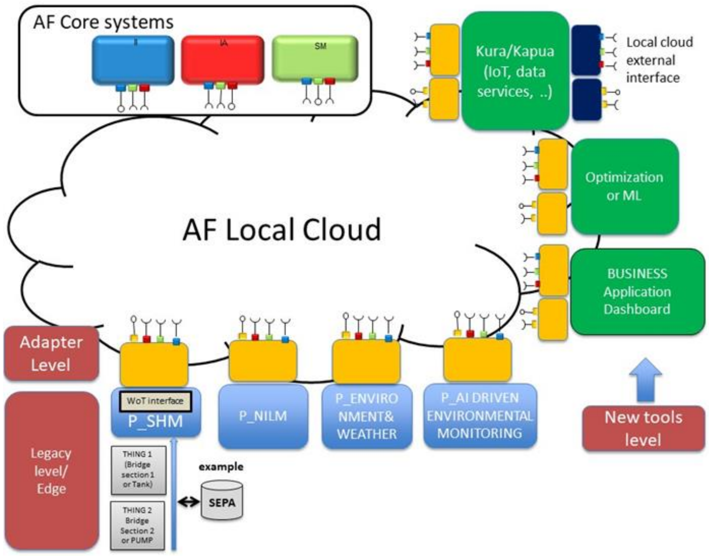
Use Case 7	**CNC machine automation**
Use Case Objective	Customizing an HMI for the parameterizing and tuning of the machine axes.
Smart Manufacturing Benefit	Tuning tools are located at the CNC or with a computer connected with DCOM protocols. The new tools should reduce by 50% the time needed by the customer.
Life Cycle Phase	Procurement and Engineering
Diagram/ Architecture	The three most important toolchains are based on smaller modular tools with defined input and output format. Furthermore, Deployment ToolChain has been developed: - Configuration Toolchain for CNC, PC and IOS - Control Loop Tuning Toolchain - Smart Graphical 2D5 Editor and Operations Management For further graphical information of the Tool Chains see deliverable D8.1. The deployment of the ToolChain is the following:

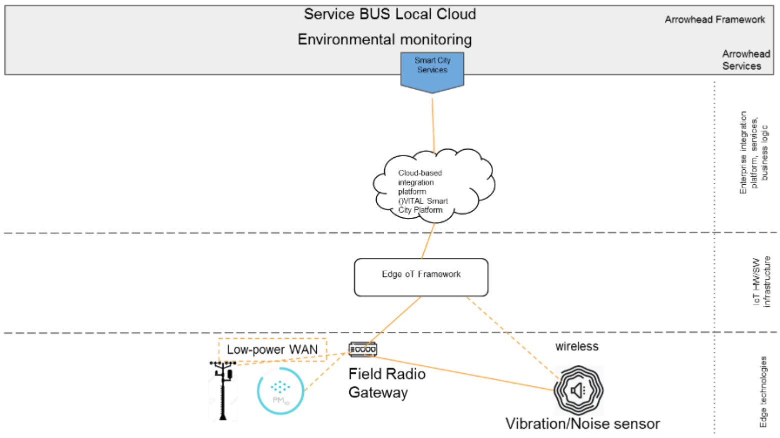
<table>
<tr><td></td><td colspan="2">
</td></tr>
<tr><td>Standardisation Requirements</td><td><u>AS-IS</u>
<u>System and Software Standards</u>
• -
<u>Information and Representation Standards</u>
• -
<u>Semantic and Language Standards</u>
• -
<u>Communication Standards</u></td><td><u>TO-BE</u>
<u>System and Software Standards</u>
• ISO16262 ECMA script
<u>Information and Representation Standards</u>
<u>Semantic and Language Standards</u>
• XML, JSON, GCODE ISO6983
<u>Communication Standards</u>
• ETHERCAT, Sercos2, Sercos III, CanOpen, MTCOnnect
• OPC-UA</td></tr>
</table>

	• ETHERCAT, Sercos, Fieldbus, CANOPEN **Cybersecurity and Safety Standards** • - **Reference Model Standards** • - **Domain-Specific Standards** • - **Framework Development and Specific Applications for development** • -	• UMATI **Cybersecurity and Safety Standards** • IEC 61508 Functional safety of electrical/electronic/programmable electronic safety related systems **Reference Model Standards** • - **Domain-Specific Standards** • - **Framework Development and Specific Applications for development** • -

Table 11:Use Case 7 - CNC machine automation

Use Case 8.1	**UC-8.1 SoS engineering of IoT edge devices (Smart Citiy Platform - Environmental monitoring with pervasive sensing and edge infrastructure.)**
Use Case Objective	Cost reduction of the engineering process through interoperability, configuration, monitoring and maintenance of heterogenous sensor deployments.
Smart Manufacturing Benefit	The bigger slice of costs in the Smart City platform planning, development and deployment is in the deployment and interconnection phase. In this phase, the configuration (remote and onsite) and onboarding (aka activation) of the device population takes place following rigorous procedures, manual and semi-automated tasks and in-field tests. An intervention on a wrong or missing configuration of a remote device is extremely expensive and it can account u to 100% of the development costs of the entire platform. Furthermore, the configuration and security hardening of each low-power, sensing device such as an intelligent sensor, requires an activity at both edge and cloud level, that must be in sync one each other and refer to a single deployment schema.
Life Cycle Phase	Procurement and Engineering,

<table>
<tr><td>Diagram/
Architecture</td><td colspan="2">


Scenario


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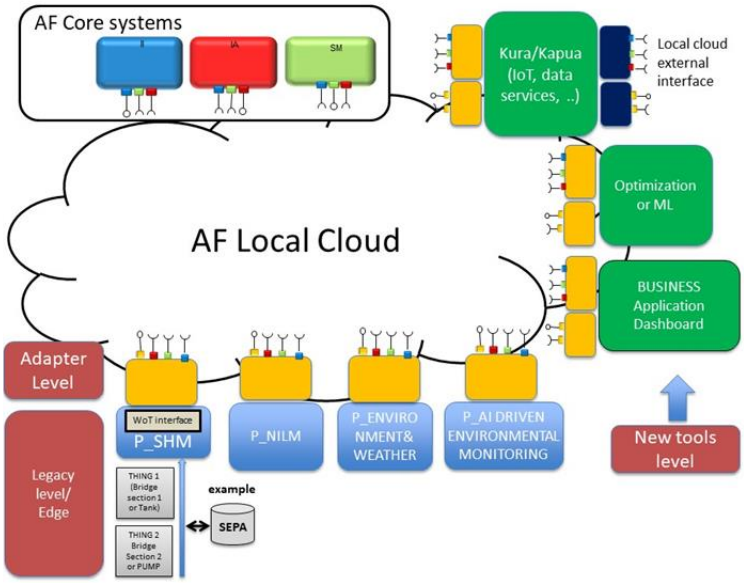
<tr><td>Standardisation Requirements</td><td>
<u>AS-IS</u>
<u>System and Software Standards</u>
• -
<u>Information and Representation Standards</u>
• -
<u>Semantic and Language Standards</u>
• -
<u>Communication Standards</u>
</td><td>
<u>TO-BE</u>
<u>System and Software Standards</u>
• Advanced Device Management ("THINGS" virtualization)
<u>Information and Representation Standards</u>
• VORTO language for Digital Twins
<u>Language Standards</u>
<u>Communication Standards</u>
• Lora/LoraWan/SigFox
</td></tr>
</table>

	Cybersecurity and Safety Standards • - **Reference Model Standards** • - **Domain-Specific Standards** • - **Framework Development and Specific Applications for development** • -	**Cybersecurity and Safety Standards** • Emergency Data Exchange Language (EDXL) **Reference Model Standards** **Domain-Specific Standards** N/A **Framework Development and Specific Applications for development** VORTO language for Digital Twins Eclipse DITTO Device-as-a-Service

Table 12: Use Case 8.1- SoS engineering of IoT edge devices (Smart Citiy Platform - Environmental monitoring with pervasive sensing and edge infrastructure.)

Use Case 8.3	**UC-8.3 SoS engineering of IoT edge devices (Condition Monitoring, SHM)**
Use Case Objective	Cost reduction of the engineering process through semantics-based on tool integration.
Smart Manufacturing Benefit	Easy reconfiguration of the SHM sensor systems: The system reconfiguration capability allows for the reduction of installation, maintenance and hardware costs. The semantics-based on interoperability allows for easy integration of the tool chain.
Life Cycle Phase	Procurement and Engineering,

<table>
<tr>
<td>Diagram/
Architecture</td>
<td colspan="2">


Scenario

Data Exchange using a common Format (Sensor Model)
Data Exchange using a common Format

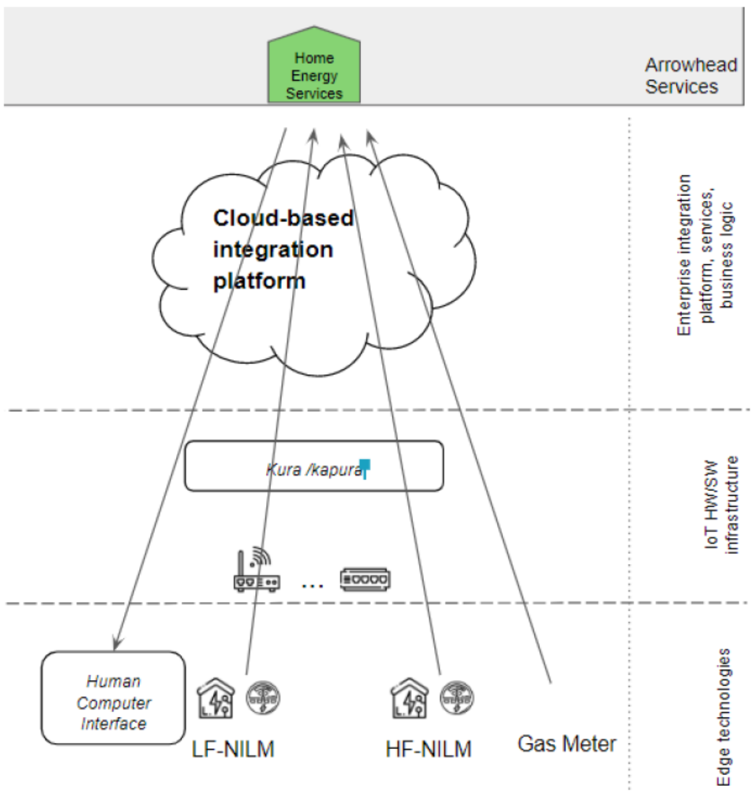
</td>
</tr>
<tr>
<td>Standardisation Requirements</td>
<td>
<u>AS-IS</u>
<u>System and Software Standards</u>
-
<u>Information and Representation Standards</u>
-
<u>Semantic and Language Standards</u>
-
<u>Communication Standards</u>
-
<u>Cybersecurity and Safety Standards</u>
-
</td>
<td>
<u>TO-BE</u>
<u>System and Software Standards</u>
-
<u>Information and Representation Standards</u>
<u>Semantic and Language Standards</u>
JSON-LD,
<u>Communication Standards</u>
CAN
OMG – DDS (Data Distribution Service)
<u>Cybersecurity and Safety Standards</u>
-
<u>Reference Model Standards</u>
SAREF, SOSA
NDE 4.0. [1]
</td>
</tr>
</table>

[1] Vrana, J. NDE 4.0: The Fourth Revolution in Non-Destructive Evaluation: Digital Twin, Semantics, Interfaces, Networking, Feedback, New Markets and Integration into the Industrial Internet of Things

	Reference Model Standards • - **Domain-Specific Standards** • - **Framewrok Development and Specific Applications for development** • -	• AAS. **Domain-Specific Standards** ISO 14963:2003. *Mechanical Vibration and Shock – Guidelines for dynamic tests and investigations on bridges and viaducts*. ISO 18649:2004. *Mechanical Vibrations – Evaluation of measurement results from dynamic tests and investigations on bridges*. ISO 16587:2004. *Mechanical Vibration and Shock – Performance parameters for condition monitoring of structures*. CEN/WS063 – CWA 16663:2013. Ageing behaviour of Structural Components with regard to Integrated Lifetime Assessment and subsequent Asset Management of Constructed Facilities. ISO 55000:2014, Asset Management – Overview, Principles and Terminology. CEN DS/CWA 15740:2008, Risk-Based Inspection and Maintenance Procedures for European Industry (RIMAP). SEMI MS1-0812 Wafer-Wafer Bonding Alignment Targets SEMI MS2-1113 Test Method for Step Height Measurements of Thin Films SEMI MS3-0915 Terminology for MEMS Technology SEMI MS4-0416 Test Method for Young's Modulus Measurements of Thin, Reflecting Films Based on the Frequency of Beams in Resonance SEMI MS5-0813Test Method for Wafer Bond Strength Measurements Using Micro-Chevron Test Structures SEMI MS6-0308 Guide for Design and Materials for Interfacing Microfluidic Systems

		SEMI MS7-0708 Specification for Microfluidic Interfaces to Electronic Device Packages SEMI MS8-0309 Guide to Evaluating Hermeticity of Microelectromechanical Systems (MEMS) Packages SEMI MS9-0611 Specification for High Density Permanent Connections between Microfluidic Devices SEMI MS10-0912 Test Method to Measure Fluid Permeation through MEMS Packaging Materials JESD22-A114E ESD HBM JESD22-C101E ESD CDM JESD22 Reliability Tests Environmental Compatibility Standards QC 080000 Hazardous Substances Process Management System Requirements (HSPM) standard ISO 50001 Energy management ISO 14001 Environmental management systems ISO14015 Environmental management - Environmental assessment of sites and organizations. **Framework Development and Specific Applications for development** • -

Table 13: Use Case 8.3 - SoS engineering of IoT edge devices (Condition Monitoring, SHM)

Use Case 8.4	**SoS engineering of IoT edge devices (Smart Home)**
Use Case Objective	The aim is to establish seamless interoperability between modelling and analysis tools to facilitate *multi-disciplinary engineering* teams to efficiently develop, verify, evolve, and deploy calibration, performance and diagnostics test *scenarios*, based on physics and inverse physics models, that are required to compensate for hardware imperfections on nanometre scale. Key requirements are syntactic and semantic *modularity* enabling scenarios to be developed.
Smart Manufacturing Benefit	Reduction of designing and implementation time for data management and facilitation of the algorithm testing and validation process using AF platform. Simplification in delivery and integration of the energy monitoring services with different relevant data management and visualization, and other high-end third-party applications.
Life Cycle Phase	Procurement and Engineering,
Diagram/ Architecture	 **Scenario:** Model engineered product in CAD software, Database Query. Database Returns Value, Data Exchange using a common Format (Model), PLC Programming, Data Exchange using a common Format (PLC Logic) • **Actors:** Technology Engineering, System Engineering, Electronic Engineering, Information Communication Technology (ICT), Engineering.

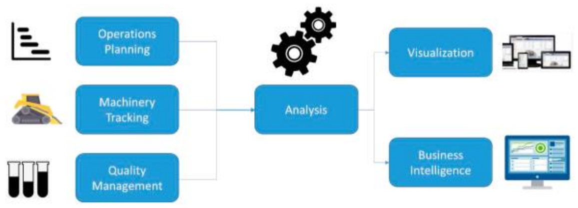
<table>
<tr><td></td><td colspan="2">

<u>Entities:</u> Electronic devices, semiconductor technology; Evaluation boards; Communication Interfaces and Protocols; ICT Design; SW/FW development and application
<u>Relations (Human-Machine):</u> CAD;Simulation and modelling SW packages;Circuitry Design Check;Statistical Analysis;Digital Interface Protocol, data exchange, baud rate, backhaul transmission alignment.
<u>Relations (Machine-to-Machine)</u> Database Query: Database Communication to get product data. Engineering Data Exchange: Common data format to exchange engineering data (.xml etc.).

</td></tr>
<tr><td>Standardisation Requirements</td>
<td>
<u>AS-IS</u>
<u>System and Software Standards</u>
-
<u>Information and Representation Standards</u>
-
<u>Semantic and Language Standards</u>
-
<u>Communication Standards</u>
-
<u>Cybersecurity and Safety Standards</u>
-
<u>Reference Model Standards</u>
-
<u>Domain-Specific Standards</u>
-
<u>Framework Development and Specific Applications for development</u>
-
</td>
<td>
<u>TO-BE</u>
<u>System and Software Standards</u>
-
<u>Information and Representation Standards</u>
Common Format (PLC Logic)
<u>Semantic and Language Standards</u>
Data Exchange using a common Format (Model)
PLC Programming
XML, JSON
<u>Communication Standards</u>
MQTT
<u>Cybersecurity and Safety Standards</u>
-
<u>Reference Model Standards</u>
-
<u>Domain-Specific Standards</u>
-
<u>Framework Development and Specific Applications for development</u>
Eclipse Kura
</td></tr>
</table>

Table 14:Use Case 8.4 - SoS engineering of IoT edge devices (Smart Home)

<table>
<tr><td>Use Case 9</td><td colspan="2">Machine operation optimisation</td></tr>
<tr><td>Use Case Objective</td><td colspan="2">Development of a digital platform for remote monitoring and optimization of earthworks in construction projects</td></tr>
<tr><td>Smart Manufacturing Benefit</td><td colspan="2">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.</td></tr>
<tr><td>Life Cycle Phase</td><td colspan="2">Deployment & CommissioningOperation & Management,Maintenance,
Training & Education</td></tr>
<tr><td>Diagram/ Architecture</td><td colspan="2">
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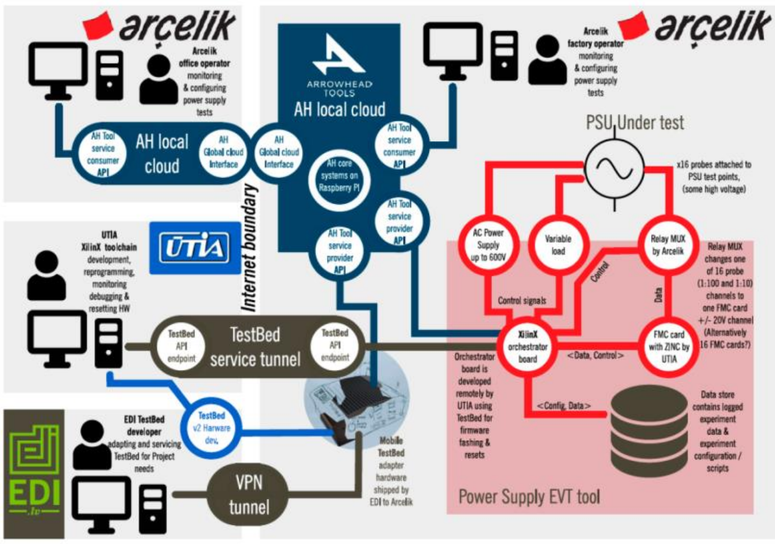
<tr><td>Standardisation Requirements</td><td><u>AS-IS</u>

<u>System and Software Standards</u>
• -
<u>Information and Representation Standards</u>
• -
<u>Semantic and Language Standards</u>
• -
<u>Communication Standards</u>
• -
<u>Cybersecurity and Safety Standards</u>
• -
<u>Reference Model Standards</u>
• -
<u>Domain-Specific Standards</u>
• -</td><td><u>TO-BE</u>

<u>System and Software Standards</u>
• -
<u>Information and Representation Standards</u>
• Worksite data exchange - ISO-15143-3/AEMP 2.0
<u>Semantic and Language Standards</u>
<u>Communication Standards</u>
• CANBus.
<u>Cybersecurity and Safety Standards</u>
• -
<u>Reference Model Standards</u>
• -
<u>Domain-Specific Standards</u>
• -</td></tr>
</table>

	<u>Framework Development and Specific Applications for development</u> • -	**<u>Framework Development and Specific Applications for development</u>** • .NET software

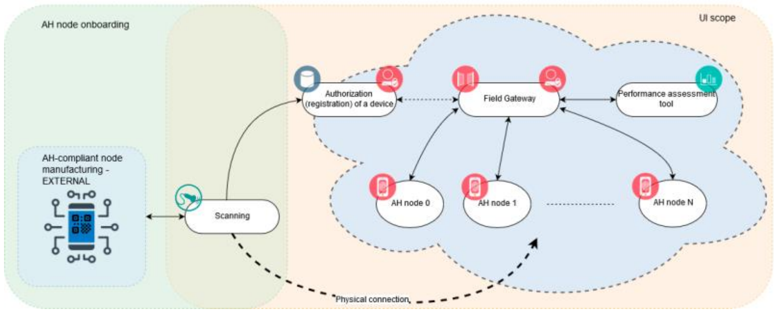
Table 15: Use Case 9 - Machine operation optimisation

Use Case 10	**Rapid HW development, prototyping, testing and evaluation**	
Use Case Objective	Design and produce an EVT tool that achieves connection to the machines in higher hierarchy to receive commands through Arrowhead Tools Framework, reports the operation results and measurements in suitable formats to be stored, and handles the entire operation without manpower.	
Smart Manufacturing Benefit	Converting operations into automated test procedure that allows the real time measurement tracking and storing each measurement data in the cloud for further calculations.	
Life Cycle Phase	Operation & Management, Maintenance, Training & Education	
Diagram/ Architecture		
Standardisation Requirements	**<u>AS-IS</u>** **<u>System and Software Standards</u>** • -	**<u>TO-BE</u>** **<u>System and Software Standards</u>** • -

	Information and Representation Standards • - **Semantic and Language Standards** • - **Communication Standards** • - **Cybersecurity and Safety Standards** • - **Reference Model Standards** • - **Domain-Specific Standards** • - **Framework Development and Specific Applications for development** • -	**Information and Representation Standards** • - **Semantic and Language Standards** • XML, JSON **Communication Standards** • WiFi, HTTP, ETHERNET • . I2C / SPI / UART / RS232 **Cybersecurity and Safety Standards** • - **Reference Model Standards** • - **Domain-Specific Standards** • - **Framework Development and Specific Applications for development** • -

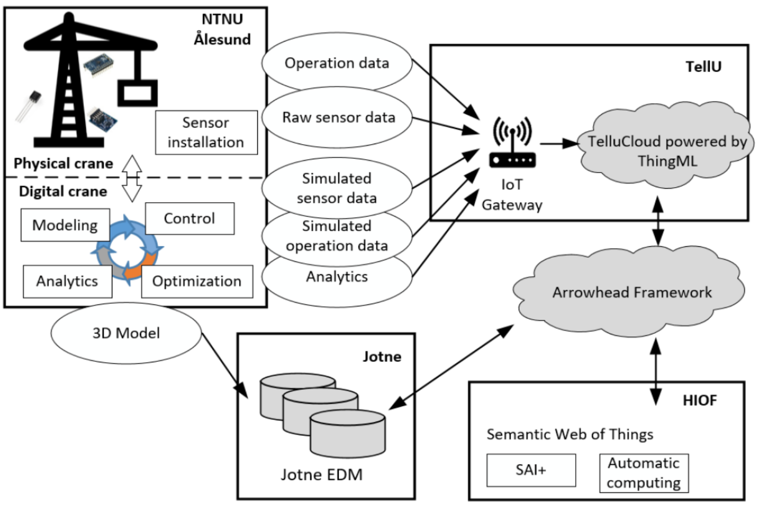
Table 16: Use Case 10 - Rapid HW development, prototyping, testing and evaluation

Use Case 11	**Configuration tool for autonomous provisioning of local clouds**
Use Case Objective	Test the applicability of part of Arrowhead Tools to deploy and manage local cloud in logistics mainly on the Authorization and Authentication system in connection with the on-boarding process of a new device.
Smart Manufacturing Benefit	The automatic deployment procedure and provisioning of local clouds minimizes the manual work required by the user to set up and maintain a single instance of a local cloud. The same goals are assigned to the developed onboarding process, where the devices are expected to connect automatically, with minimal human effort (after initial handshake and configuration). At the same time, the whole authentication process should remain secure and reliable
Life Cycle Phase	Deployment & Commissioning, Operation & Management, Evolution, Maintenance

Diagram/ Architecture	 	
Standardisation Requirements	**<u>AS-IS</u>** **<u>System and Software Standards</u>** • - **<u>Information and Representation Standards</u>** • - **<u>Semantic and Language Standards</u>** • - **<u>Communication Standards</u>** • - **<u>Cybersecurity and Safety Standards</u>** • - **<u>Reference Model Standards</u>** • - **<u>Domain-Specific Standards</u>** • - **<u>Framework Development and Specific Applications for development</u>** • -	**<u>TO-BE</u>** **<u>System and Software Standards</u>** • REST APIs **<u>Information and Representation Standards</u>** • - **<u>Semantic and Language Standards</u>** • XML, JSON, **<u>Communication Standards</u>** • GPRS, • LORA • LTE-M • NB-IoT • SigFOx • Ethernet, • Bluetooth, • Wifi • NFC **<u>Cybersecurity and Safety Standards</u>** • X.509 **<u>Reference Model Standards</u>** • RAMI, IIRA, ASS, NIST • Digital Factory **<u>Domain-Specific Standards</u>**

		• - **Framework Development and Specific Applications for development** • Node.JS,

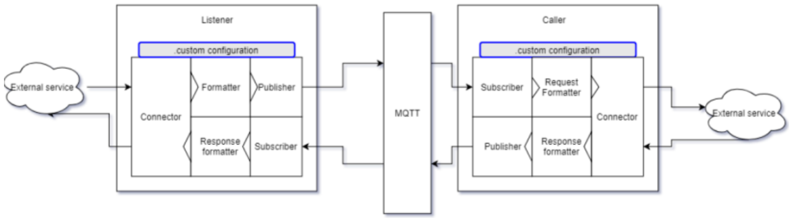
Table 17: Use Case 11 - Configuration tool for autonomous provisioning of local clouds

Use Case Name 12	**Digital twins and structural monitoring**	
Use Case Objective	The aim of this Use Case is to address the most critical R&D challenges in Digital Twin for predictive maintenance of cranes.	
Smart Manufacturing Benefit	The benefits are: - An optimal sensor distribution to identify the magnitude, direction, and applications points of real loads - Efficient and reliable methods for data filtering and sensor calibration. - Generate valid dynamic model together with 3D model to make the digital crane behaviour - Develop new data-driven methods that can predict failure conditions without human interference - A generic and cloud based framework must be developed to support the development of Digital Twin with complex structures and mechanical systems -	
Life Cycle Phase	Deployment and commisioning	
Diagram/ Architecture		
Standardisation Requirements	**AS-IS**	**TO-BE**

	System and Software Standards • - **Information and Representation Standards** • - **Semantic and Language Standards** • - **Communication Standards** • - **Cybersecurity and Safety Standards** • - **Reference Model Standards** • - **Domain-Specific Standards** • - **Framework Development and Specific Applications for development** • -	**System and Software Standards** • - **Information and Representation Standards** • ISO 10303 - STEP **Semantic and Language Standards** **Communication Standards** • - **Cybersecurity and Safety Standards** • - **Reference Model Standards** • - **Domain-Specific Standards** • - **Framework Development and Specific Applications for development** • -

Table 9: Use Case 12 - Digital twins and structural monitoring

Use Case Name 13	**Deployment engine for production related sensor data**
Use Case Objective	Building up a SOA based integration platform.
Smart Manufacturing Benefit	Reduce complexity and speed to implementation while cater for requirement for production critical integrations.
Life Cycle Phase	Deployment & Communications, Operation & Management

<table>
<tr><td>Diagram/
Architecture</td><td colspan="2">
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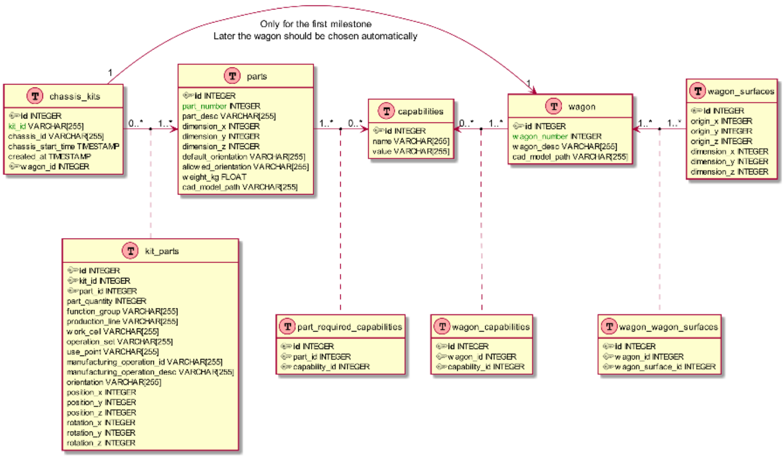
<u>System and Software Standards</u>
• -
<u>Information and Representation Standards</u>
• -
<u>Semantic and Language Standards</u>
• -
<u>Communication Standards</u>
• -
<u>Cybersecurity and Safety Standards</u>
• -
<u>Reference Model Standards</u>
• -
<u>Domain-Specific Standards</u>
• -
<u>Framework Development and Specific Applications for development</u>
• -</td><td> <u>TO-BE</u>
<u>System and Software Standards</u>
• SOA
• REST
<u>Information and Representation Standards</u>
• -
<u>Semantic and Language Standards</u>

<u>Communication Standards</u>
• MQTT
• SMTP
• FTP
• IMAP
• RabbitMQ
<u>Cybersecurity and Safety Standards</u>
• -
<u>Reference Model Standards</u>
• -
<u>Domain-Specific Standards</u>
• -
<u>Framework Development and Specific Applications for development</u>
• Azure
• Files
• MongoDB</td></tr>
</table>

		• Microsoft SQL Server

Table 18: Use Case 13 - Deployment engine for production related sensor data

Use Case 15	**Smart Kitting to Manage High Diversity**
Use Case Objective	Adjust the actual kitting manufacturing process with electromobility and automation functions.
Smart Manufacturing Benefit	Developing concepts for smart and automated kitting operations. Initially, specific focus on the engineering process related to preparation of kitting. The developed solution will need to be interoperable with existing Volvo legacy systems related to process planning and manufacturing execution.
Life Cycle Phase	Deployment & Commissioning
Diagram/ Architecture	

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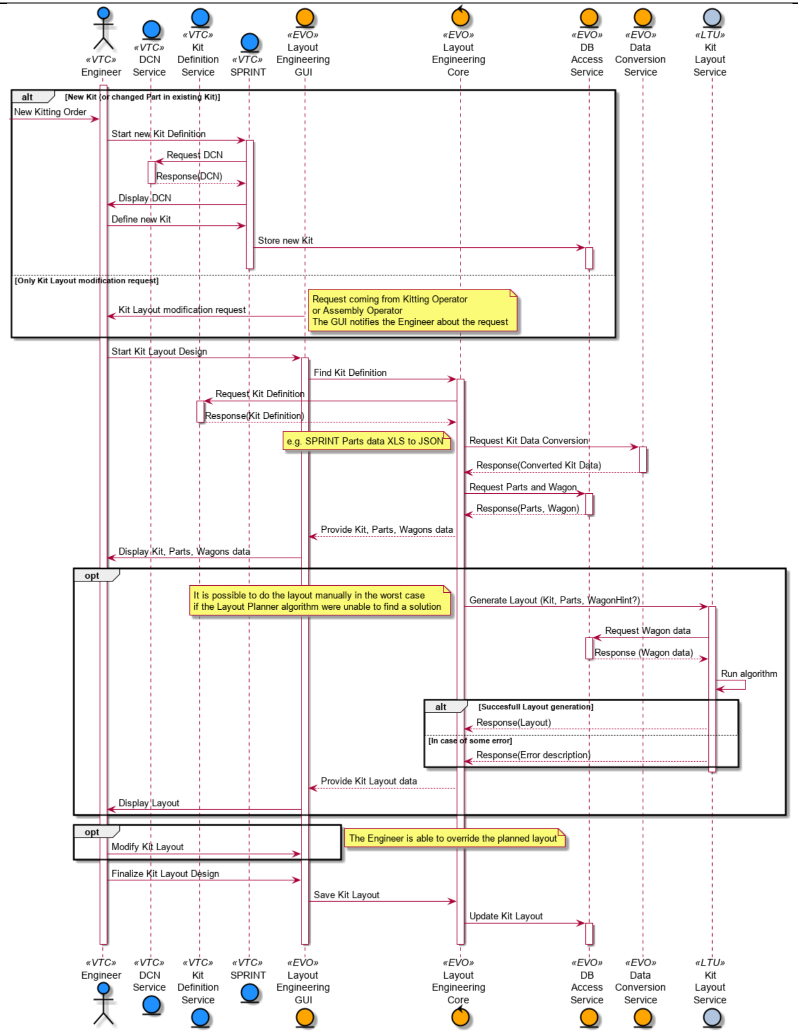
<tr><td></td><td colspan="2">
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<tr><td>Standardisation Requirements</td><td><u>AS-IS</u>

<u>System and Software Standards</u>
• -

<u>Information and Representation Standards</u>
• -

<u>Semantic and Language Standards</u>
• -

<u>Communication Standards</u>
• -

<u>Cybersecurity and Safety Standards</u>
• -</td><td><u>TO-BE</u>

<u>System and Software Standards</u>
• REST

<u>Information and Representation Standards</u>
• UML

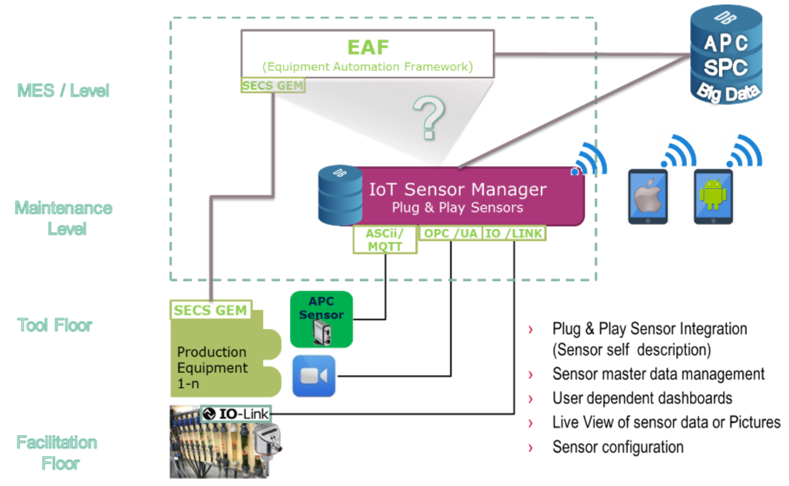
<u>Semantic and Language Standards</u>
• JSON, XML, CSV

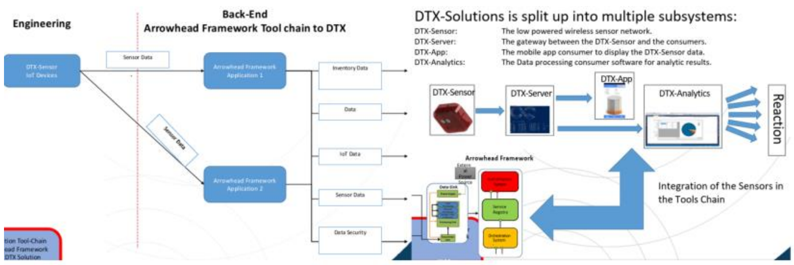
<u>Communication Standards</u>
• Ethernet or WiFi
• IPv4 or IPv6
• TCP</td></tr>
</table>

	Reference Model Standards • - **Domain-Specific Standards** • - **Framework Development and Specific Applications for development** • -	• TLS • HTTP **Cybersecurity and Safety Standards** • - **Reference Model Standards** • - **Domain-Specific Standards** • - **Framework Development and Specific Applications for development** • Visual Studio Code • vim • Java, JavaScript • SQL, • CSS

Table 19: Use Case 15 - Smart Kitting to Manage High Diversity

Use Case 16	**Production Support, Energy Efficiency, Task Management, Data Analytics and Smart Maintenance**
Use Case Objective	Automatic machine diagnostic approach for reactive maintenance.
Smart Manufacturing Benefit	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.
Life Cycle Phase	Operation and Management, Maintenance

<table>
<tr>
<td>Diagram/ Architecture</td>
<td colspan="2">




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<td>Standardisation Requirements</td>
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<u>AS-IS</u>

<u>System and Software Standards</u>
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<u>Information and Representation Standards</u>

<u>Semantic and Language Standards</u>
• -

<u>Communication Standards</u>
• -

<u>Cybersecurity and Safety Standards</u>
• -
</td>
<td>
<u>TO-BE</u>

<u>System and Software Standards</u>
• VDI3832 Measurement of structure-borne sound of rolling element bearings in machines and plants for evaluation of condition

<u>Information and Representation Standards</u>
• Product data representation and exchange
• Framework for object-oriented information exchange

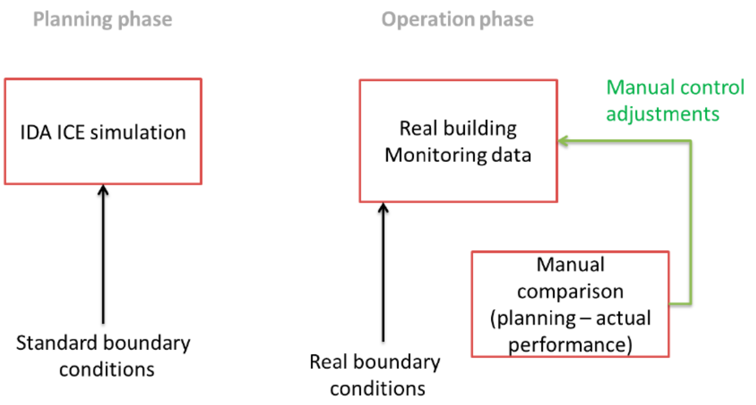
<u>Semantic and Language Standards</u>
• -
</td>
</tr>
</table>

	Reference Model Standards • - **Domain-Specific Standards** • - **Framework Development and Specific Applications for development** • -	**Communication Standards** • - **Cybersecurity and Safety Standards** • **Reference Model Standards** • RAMI, IIRA, ASS, NIST • Digital Factory **Domain-Specific Standards** • VDI 3832 • VDI 3839 • DIN 1311 • ISO 2954 • ISO18431 • ISO 13373 • ISO 13374 • ISO 13379 • VDI 3836 • ISO 10816 • ISO 15242 **Framework Development and Specific Applications for development** • -

Table 20: Use Case 16 - Production Support, Energy Efficiency, Task Management, Data Analytics and Smart Maintenance

Use Case 17	**Linking a Building Simulator to a Physical Building in Real-Time**
Use Case Objective	Optimize the performance of a building – including its skin, the HVAC system and controls – in an automated way during operation, and even if the building use or user behavior changes.
Smart Manufacturing Benefit	A newly developed building tracking system (which replaces the monitoring campaign) will be applied in the new R&D building of Infineon Austria in Villach (IFAT). The new tool is the missing link between real building and system simulation

<table>
<tr><td></td><td colspan="2">software that is often applied in the design phase, and the building management system that is used during operation.

The demonstration building will be equipped with measurement sensors to record the weather data on site, the status of doors, windows and shading devices. In addition, the energy consumption for heating, ventilation and air conditioning as well as temperature, humidity and CO2 levels in the building will be measured.</td></tr>
<tr><td>Life Cycle Phase</td><td colspan="2">Operation and Management</td></tr>
<tr><td>Diagram/ Architecture</td><td colspan="2">
</td></tr>
<tr><td>Standardisation Requirements</td><td><u>AS-IS</u>
<u>System and Software Standards</u>
• -
<u>Information and Representation Standards</u>
• -
<u>Semantic and Language Standards</u>
• -
<u>Communication Standards</u>
• -
<u>Cybersecurity and Safety Standards</u>
• -
<u>Reference Model Standards</u>
• -
<u>Domain-Specific Standards</u></td><td><u>TO-BE</u>
<u>System and Software Standards</u>
• -
<u>Information and Representation Standards</u>
• -
<u>Semantic and Language Standards</u>
• JSON
<u>Communication Standards</u>
• OPC-UA, BACnet, Modbus, Https, TCP/IP, UDP,
<u>Cybersecurity and Safety Standards</u>
• IEC 62443
<u>Reference Model Standards</u>
• RAMI 4.0
<u>Domain-Specific Standards</u></td></tr>
</table>

	• - **Framework Development and Specific Applications for development** • -	• - **Framework Development and Specific Applications for development** • Allegro CL and Visual Studio 2019 for software development in the languages Lisp, C , C++ and Fortran.

Table 21: Use Case 17 - Linking a Building Simulator to a Physical Building in Real-Time

Use Case 18	**Secure sharing of IoT generated data with partner ecosystem**	
Use Case Objective	Main purpose of this activity is to enable Boliden to have a secure way to make relevant data in mining industry available via an open platform approach (does not have to be Boliden internal) to securely share data within the partner ecosystem including tracking use rights, traceability of usage and possibility to invalidate data	
Smart Manufacturing Benefit	- Potential legal issues arise. - Concept for data tagging is not available as standard - Possibility to trace where Boliden data is going and possibility of invalidation is not existing today	
Life Cycle Phase	Operation and Management	
Diagram/ Architecture	-	
Standardisation Requirements	**AS-IS** **System and Software Standards** • - **Information and Representation Standards** • - **Semantic and Language Standards** • - **Communication Standards** • - **Cybersecurity and Safety Standards**	**TO-BE** **System and Software Standards** • - **Information and Representation Standards** • SysML **Semantic and Language Standards** • XML, JSON, , Sparql, RDF, **Communication Standards** • Ethernet or WiFi • IPv4 or IPv6 • TCP

	• - **Reference Model Standards** • - **Domain-Specific Standards** • - **Framework Development and Specific Applications for development** • -	• TLS • HTTP & HTTPS • OPC-UA, MQTT, Ethernet, LoRaWAN, or NB-IoT **Cybersecurity and Safety Standards** X.509 Certificates **Reference Model Standards** • Fiware, RAMI 4.0, IIC **Domain-Specific Standards** • - **Framework Development and Specific Applications for development** • Visual Studio • Eclipse • VIM • JAVA, JavaScript, .Net

Table 22: Use Case 18 - Secure sharing of IoT generated data with partner ecosystem

Use Case 19	**Deployment and configuration**
Use Case Objective	The main purpose is monitor the 6.000 commercial solar power plants which 3E carry out through software-as-a-service platform, called SynaptiQ
Smart Manufacturing Benefit	SynaptiQ performs data enrichment and data aggregation on top of the incoming data streams in order to provide real-time analytical services. Moreover, it is the trusted B2B performance monitoring solution of key reference players, steadily growing in connected capacity with a CAGR +30%. Others advantages will be improve reconfiguration engineering
Life Cycle Phase	Operation and Management

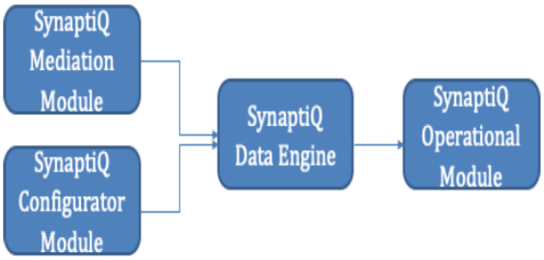
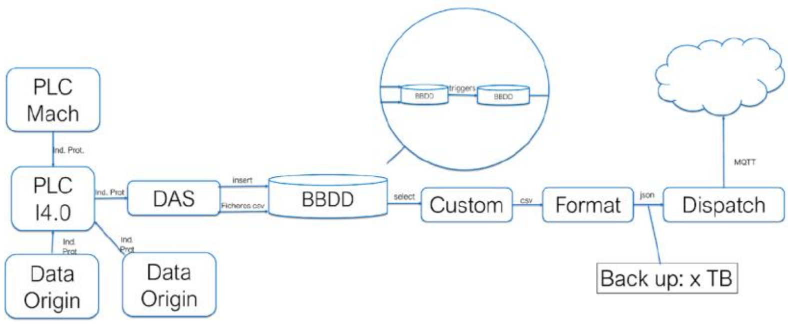
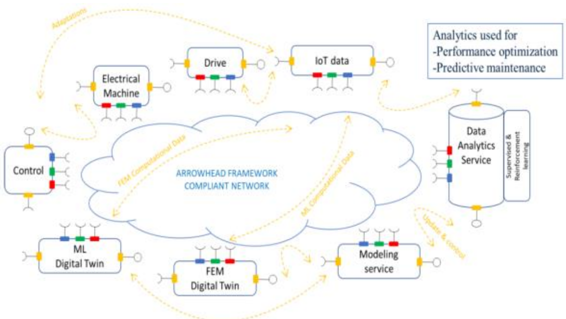
<table>
<tr><td>Diagram/ Architecture</td><td colspan="2">
</td></tr>
<tr><td>Standardisation Requirements</td><td><u>AS-IS</u>
<u>System and Software Standards</u>
• -
<u>Information and Representation Standards</u>
• -
<u>Semantic and Language Standards</u>
• -
<u>Communication Standards</u>
• -
<u>Cybersecurity and Safety Standards</u>
• -
<u>Reference Model Standards</u>
• -
<u>Domain-Specific Standards</u>
• -
<u>Framework Development and Specific Applications for development</u>
• -</td><td><u>TO-BE</u>
<u>System and Software Standards</u>
• REST API
<u>Information and Representation Standards</u>
• -
<u>Semantic and Language Standards</u>
• JSON
<u>Communication Standards</u>
• Interoperability protocol
<u>Cybersecurity and Safety Standards</u>
• -
<u>Reference Model Standards</u>
• -
<u>Domain-Specific Standards</u>
• -
<u>Framework Development and Specific Applications for development</u>
• Java, MySQL</td></tr>
</table>

Table 23: Use Case 19 - Deployment and configuration

<table>
<tr><th>Use Case 20</th><th colspan="2">Elastic Data Acquisition System</th></tr>
<tr><td>Use Case Objective</td><td colspan="2">Develop an Elastic Data Acquisition System that implements different services for the Presses and Stamping Systems.</td></tr>
<tr><td>Smart Manufacturing Benefit</td><td colspan="2">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 start monitoring those variables and these ones are 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.</td></tr>
<tr><td>Life Cycle Phase</td><td colspan="2">Maintenance</td></tr>
<tr><td>Diagram/ Architecture</td><td colspan="2">
</td></tr>
<tr><td rowspan="2">Standardisation Requirements</td><td><u>AS-IS</u></td><td><u>TO-BE</u></td></tr>
<tr><td><u>System and Software Standards</u>
• -
<u>Information and Representation Standards</u>
• -
<u>Semantic and Language Standards</u>
• -
<u>Communication Standards</u>
• MQTT
• HTTP
• COAP</td><td><u>System and Software Standards</u>
• -
<u>Information and Representation Standards</u>
• Working on that
<u>Semantic and Language Standards</u>
• CSV,
• JOSN
<u>Communication Standards</u>
• OPC-UA
• UMATI</td></tr>
</table>

	Cybersecurity and Safety Standards • - **Reference Model Standards** • - **Domain-Specific Standards** • - **Framework Development and Specific Applications for development** • .NET • SQL_SERVER	• PPMP **Cybersecurity and Safety Standards** • - **Reference Model Standards** • - **Domain-Specific Standards** • - **Framework Development and Specific Applications for development** • .NET • SQL_SERVER

Table 24: Use Case 20 - Elastic Data Acquisition System

Use Case 21	**Data-based digital twin for electrical machine condition monitoring**	
Use Case Objective	The use case will develop data-based digital twin for electrical machine condition monitoring	
Smart Manufacturing Benefit	- Electrical motor performance optimizatio - Predictive maintenance - Integration of different parts	
Life Cycle Phase	Evolution, Requirements, Operation & Management	
Diagram/ Architecture		
Standardisation Requirements	**AS-IS**	**TO-BE**

	System and Software Standards • - **Information and Representation Standards** • - **Semantic and Language Standards** • - **Communication Standards** • - **Cybersecurity and Safety Standards** • - **Reference Model Standards** • - **Domain-Specific Standards** • - **Framework Development and Specific Applications for development** •	**System and Software Standards** • REST **Information and Representation Standards** • Common Data Model (MIMOSA) **Semantic and Language Standards** • JSON **Communication Standards** • HTTP, MQTT **Cybersecurity and Safety Standards** • - **Reference Model Standards** • OSA-EAI **Domain-Specific Standards** • - **Framework Development and Specific Applications for development** • -

Table 25: Use Case 21 - Data-based Digital Twin for electrical machine condition monitoring

Use Case 22	**Arrowhead Framework training tool**
Use Case Objective	The use case provides a definition of the targeted process to be supported by the Arrowhead Tools framework for the educational use case.
Smart Manufacturing Benefit	The outcome of this task is a pilot training/educational program that can be easily customised to other specific needs of other training programs and their objectives.

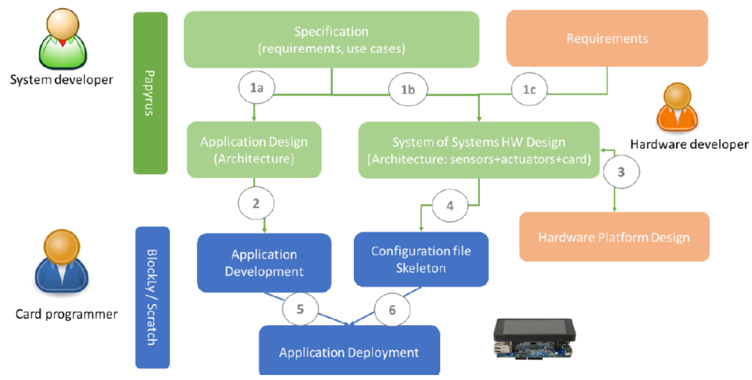
<table>
<tr><td>Life Cycle Phase</td><td colspan="2">Training</td></tr>
<tr><td>Diagram/ Architecture</td><td colspan="2">
</td></tr>
<tr><td rowspan="1">Standardisation Requirements</td>
<td><u>AS-IS</u>
<u>System and Software Standards</u>
• -
<u>Information and Representation Standards</u>
• -
<u>Semantic and Language Standards</u>
• -
<u>Communication Standards</u>
• -
<u>Cybersecurity and Safety Standards</u>
• -
<u>Reference Model Standards</u>
• -
<u>Domain-Specific Standards</u>
• -
<u>Framework Development and Specific Applications for development</u>
•</td>
<td><u>TO-BE</u>
<u>System and Software Standards</u>
• -
<u>Information and Representation Standards</u>
• -
<u>Semantic and Language Standards</u>
• -
<u>Communication Standards</u>
• -
<u>Cybersecurity and Safety Standards</u>
• -
<u>Reference Model Standards</u>
• -
<u>Domain-Specific Standards</u>
• -
<u>Framework Development and Specific Applications for development</u>
• Blockly</td></tr>
</table>

Table 26: Use Case 22 - Arrowhead Framework training tool

9. Appendix 2 – Use Cases and Standards Relationship

		Use cases																						
Standard Group	**Specific Standard**	**1**	**2**	**3**	**4**	**5**	**7**	**8.1**	**8.3**	**8.4**	**9**	**10**	**11**	**12**	**13**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**Total**
Semantic and Language	JSON		■	■		■	■		■	■		■	■			■		■	■	■	■	■		14
Communication	HTTP/HTTPS		■	■	■	■						■				■		■	■		■	■		10
Semantic and Language	XML		■	■	■	■	■			■		■	■			■			■					10
Communication	OPC-UA		■				■											■	■		■			5
Communication	MQTT		■							■					■				■			■		5
Communication	WiFi		■									■	■			■			■					5
Communication	ETHERNET		■									■	■			■			■					5
Framework development	.NET			■		■					■								■		■			5
Framework development	Microsoft SQL														■	■			■	■	■			5
Systems and Software	REST APIs												■		■	■				■		■		5
Framework development	Java					■										■			■	■				4
Semantic and Language	CSV					■										■			■		■			4
Information and Representation	UML 2		■	■	■											■								4
Information and Representation	SysML		■	■	■														■					4
Semantic and Language	RDF 1.1		■	■		■													■					4

		Use cases																						
Standard Group	**Specific Standard**	**1**	**2**	**3**	**4**	**5**	**7**	**8.1**	**8.3**	**8.4**	**9**	**10**	**11**	**12**	**13**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**Total**
Communication	Lora																							3
Communication	TCP																							3
Information and Representation	XML																							3
Reference model	RAMI																							3
Systems and Software	ISO 15288																							3
Systems and Software	ISO 12207																							3
Communication	CanOpen																							2
Communication	UMATI																							2
Communication	SigFox																							2
Communication	Sercos2																							2
Communication	NFC																							2
Communication	SMTP																							2
Communication	UDP																							2
Communication	NB-IoT																							2
Communication	IPv4																							2
Communication	IPv6																							2
Communication	TLS																							2
Cybersecurity and Safety	IEC 61508																							2
Cybersecurity and Safety	X.509																							2
Framework development	C++																							2
Framework development	Swagger																							2

		Use cases																						
Standard Group	**Specific Standard**	**1**	**2**	**3**	**4**	**5**	**7**	**8.1**	**8.3**	**8.4**	**9**	**10**	**11**	**12**	**13**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**Total**
Framework development	CAKE API																							2
Framework development	OSLC4Net																							2
Framework development	CSS																							2
Framework development	Eclipse Kura																							2
Framework development	Visual																							2
Framework development	Vim																							2
Information and Representation	ISO 10303																							2
Information and Representation	SRL																							2
Reference model	IIRA																							2
Reference model	ASS																							2
Reference model	NIST																							2
Reference model	Digital Factory																							2
Semantic and Language	SKOS 2																							2
Semantic and Language	OSLC KM 2																							2
Semantic and Language	GCODE																							2
Semantic and Language	SPARQL																							2

		Use cases																						
Standard Group	**Specific Standard**	**1**	**2**	**3**	**4**	**5**	**7**	**8.1**	**8.3**	**8.4**	**9**	**10**	**11**	**12**	**13**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**Total**
Arrowhead Framework trianing tool	Google Blockly																						■	1
Communication	ETHERCAT						■																	1
Communication	Sercos III						■																	1
Communication	MTCOnnect						■																	1
Communication	LoraWan							■																1
Communication	OMG-DDS								■															1
Communication	CanBus										■													1
Communication	I2C/SPI/UART/RS232											■												1
Communication	GPRS												■											1
Communication	LTE-M												■											1
Communication	Bluetooth												■											1
Communication	FTP														■									1
Communication	IMAP														■									1
Communication	Rabbit MQ														■									1
Communication	BACnet																	■						1
Communication	Modbus																	■						1
Communication	PPMP																				■			1
Communication	OneM2M																		■					1
Communication	COAP																				■			1
Communication	RFID		■																					1
Cybersecurity and Safety	EDXL							■																1
Cybersecurity and Safety	IEC 62443																	■						1

		Use cases																					
Standard Group	**Specific Standard**	**1**	**2**	**3**	**4**	**5**	**7**	**8.1**	**8.3**	**8.4**	**9**	**10**	**11**	**12**	**13**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**Total**
Cybersecurity and Safety	ISO 27001		■																					1
Cybersecurity and Safety	IEC 62443		■																					1
Cybersecurity and Safety	OWASP		■																					1
Cybersecurity and Safety	Firewall		■																					1
Domain-Specific	VDI 3839																■							1
Domain-Specific	DIN 1311																■							1
Domain-Specific	ISO 2954																■							1
Domain-Specific	ISO 18431																■							1
Domain-Specific	ISO 13373																■							1
Domain-Specific	ISO 13374																■							1
Domain-Specific	ISO 13379																■							1
Domain-Specific	VDI 3836																■							1
Domain-Specific	ISO 10816																■							1
Domain-Specific	ISO 15242																■							1
Framework development	VORTO							■																1
Framework development	Node JS												■											1
Framework development	Azure														■									1
Framework development	Files														■									1
Framework development	MongoDB														■									1

		Use cases																						
Standard Group	**Specific Standard**	**1**	**2**	**3**	**4**	**5**	**7**	**8.1**	**8.3**	**8.4**	**9**	**10**	**11**	**12**	**13**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**Total**
Framework development	JavaScript																							1
Framework development	Python																							1
Framework development	Matlab																							1
Framework development	R																							1
Framework development	ISO 14963																							1
Framework development	ISO 18649																							1
Framework development	ISO 16587																							1
Framework development	CEN/WS063																							1
Framework development	ISO 55000																							1
Framework development	CEN DS/CWA 15740																							1
Framework development	SEMI MS1-0812																							1
Framework development	SEMI MS2-1113																							1
Framework development	SEMI MS23-0915																							1
Framework development	SEMI MS4-0416																							1
Framework development	SEMI MS5-0813																							1

		Use cases																						
Standard Group	**Specific Standard**	**1**	**2**	**3**	**4**	**5**	**7**	**8.1**	**8.3**	**8.4**	**9**	**10**	**11**	**12**	**13**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**Total**
Framework development	SEMI MS6-0308								■															1
Framework development	SEMI MS7-0708								■															1
Framework development	SEMI MS8-0309								■															1
Framework development	SEMI MS9-0611								■															1
Framework development	SEMI MS10-0912								■															1
Framework development	JESD22								■															1
Framework development	QC 080000								■															1
Framework development	ISO 50001								■															1
Framework development	ISO 14001								■															1
Framework development	ISO 14015								■															1
Information and Representation	ReqIF			■																				1
Information and Representation	MSExcel			■																				1
Information and Representation	IBM Doors			■																				1
Information and Representation	VORTO							■																1
Information and Representation	ISO 15143										■													1

		Use cases																						
Standard Group	**Specific Standard**	**1**	**2**	**3**	**4**	**5**	**7**	**8.1**	**8.3**	**8.4**	**9**	**10**	**11**	**12**	**13**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**Total**
Information and Representation	MIMOSA																							1
Information and Representation	FMU/FMI																							1
Information and Representation	W3C RDF																							1
Information and Representation	ISO 17369																							1
Information and Representation	OSLC EMS																							1
Information and Representation	XMI																							1
Reference model	FIWARE																							1
Reference model	IIC																							1
Reference model	SAREF																							1
Reference model	SOSA																							1
Reference model	NDE4.0																							1
Reference model	AAS																							1
Reference model	OSA-EAI																							1
Semantic and Language	BSHM																							1
Semantic and Language	PLC																							1
Semantic and Language	eCl@ss																							1
Semantic and Language	OWL2																							1

		Use cases																					
Standard Group	**Specific Standard**	**1**	**2**	**3**	**4**	**5**	**7**	**8.1**	**8.3**	**8.4**	**9**	**10**	**11**	**12**	**13**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**Total**
Semantic and Language	STEP																							1
Systems and Software	ISO 16262																							1
Systems and Software	OSLC RM/AM/TCR																							1
Systems and Software	SOA																							1
Systems and Software	VDI 3832																							1
Systems and Software	FMU/FMI																							1