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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Smart Machine-to-Machine communications (SmartM2M).

Modal verbs terminology

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1 Scope

The present document specifies the requirements for an initial semantic model for industry and manufacturing domains based on a limited set of use cases and from available existing data model. It includes deployment and related services aspects. The present document is developed in close collaboration with AIOTI, the H2020 Large Scale Pilots and with ETSI activities in this domain. Further extensions are envisaged in the future to cover entirely the industry and manufacturing domains. The associated ETSI TS 103 410-5 [i.9] will define the extension (i.e. the semantic model) for the industry and manufacturing domains based on the requirements and use cases specified in the present document.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] European Commission and TNO: "Smart Appliances REFerence ontology (SAREF)", April 2015.

NOTE: Available at http://ontology.tno.nl/saref.

[i.2] European Commission and TNO: "D-S4 Final Report - SMART 2013-0077 - Study on Semantic Assets for Smart Appliances Interoperability", March 2015.

NOTE: Available at https://sites.google.com/site/smartappliancesproject/documents.

[i.3] ETSI TS 103 264 (V2.1.1) (03-2017): "SmartM2M; Smart Appliances; Reference Ontology and oneM2M Mapping".

[i.4] ETSI TR 103 411 (V1.1.1) (02-2017): "SmartM2M; Smart Appliances; SAREF extension investigation".

[i.5] ETSI TS 103 410-1: "SmartM2M; Smart Appliances Extension to SAREF; Part 1: Energy Domain".

[i.6] ETSI TS 103 410-2: "SmartM2M; Smart Appliances Extension to SAREF; Part 2: Environment Domain".

[i.7] ETSI TS 103 410-3: "SmartM2M; Smart Appliances Extension to SAREF; Part 3: Building Domain".

[i.8] Adolphs P., Epple U., et al.: "Status Report Reference Architecture Model Industrie 4.0 (RAMI4.0)". Düsseldorf, Frankfurt 2015. VDI - The Association of German Engineers, ZVEI - German Electrical and Electronic Manufacturers' Association.

[i.9] ETSI TS 103 410-5: "SmartM2M; Extension to SAREF; Part 5: extension to Industry and Manufacturing Domains".

[i.10] ETSI TS 103 410 series: "SmartM2M; Extension to SAREF".

[i.11] IEC 62794:2012: "Industrial-process measurement, control and automation - Reference model for representation of production facilities (digital factory)".

[i.12] IEC 62832: "Industrial-process measurement, control and automation - Digital factory framework".

[i.13] VDMA 24582: "Fieldbus Neutral Reference Architecture for Condition Monitoring in Factory Automation".

NOTE: Available at https://www.vdma.org/.

[i.14] ISO/IEC 20140: "Automation systems and integration - Evaluating energy efficiency and other factors of manufacturing systems that influence the environment".

[i.15] IEC 61804: "Function blocks (FB) for process control and electronic device description language (EDDL)".

[i.16] IEC 62453: "Field device tool (FDT) interface specification".

[i.17] ISO/IEC 27000:2018: "Information technology -- Security techniques -- Information security management systems -- Overview and vocabulary".

[i.18] IEC 62443: "Security for industrial automation and control systems".

[i.19] eCl@ss specification.

NOTE: Available at https://www.eclass.eu/.

[i.20] GTIN Management standard, 1.0. June 2016.

[i.21] IEC 62264: "Enterprise-control system integration".

[i.22] IEC 61512: "Batch control".

[i.23] IEC 62541: "OPC Unified Architecture".

[i.24] DIN SPEC 16592: "Combining OPC Unified Architecture and Automation Markup Language".

NOTE: Available at https://www.din.de/en/wdc-beuth:din21:265597431.

[i.25] IEC 61784: "Industrial communication networks - Profiles".

[i.26] Industrial Data Space: "Reference Architecture Model 2017".

NOTE: Available at https://www.internationaldataspaces.org/.

[i.27] IEC 62890: "Life cycle status".

[i.28] ISO 13849: "Safety of machinery -- Safety-related parts of control systems".

[i.29] IEC 62061:2005: "Safety of machinery - Functional safety of safety-related electrical, electronic and programmable electronic control systems".

[i.30] IEC 61511: "Functional safety - Safety instrumented systems for the process industry sector".

[i.31] IEC 61508: "Functional safety of electrical/electronic/programmable electronic safety-related systems".

[i.32] IEC 61360: "Standard data element types with associated classification scheme".

[i.33] ISO 13584: " Industrial automation systems and integration -- Parts library".

[i.34] IEC 62424:2016: "Representation of process control engineering - Requests in P&I diagrams and data exchange between P&ID tools and PCE-CAE tools".

[i.35] IEC 62714: "Engineering data exchange format for use in industrial automation systems engineering - Automation markup language".

[i.36] ISO/PAS 17506:2012: "Industrial automation systems and integration -- COLLADA digital asset schema specification for 3D visualization of industrial data".

[i.37] IEC 61131: "Programmable controllers".

[i.38] IEC 61987: "Industrial-process measurement and control - Data structures and elements in process equipment catalogues".

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

ontology: formal specification of a conceptualization, used to explicit capture the semantics of a certain reality

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AIOTI	Alliance for the Internet of Things Innovation
AML	Automation ML
DIN	Deutsches Institut für Normung
EDD	Electronic Device Description
EDDL	Electronic Device Description Language
FDT	Field Device Tool
GTIN	Global Trade Item Number
HTTP	HyperText Transfer Protocol
INMA	Industry and Manufacturing
IoT	Internet of Things
ISMS	Information Security Management System
IT	Information Technology
OPC	Object linking and embedding for Process Control
RAMI 4.0	Reference Architectural Model Industrie 4.0
SAREF	Smart Appliances REFerence ontology
SAREF4INMA	SAREF extension for the Industry & Manufacturing domain
STF	Specialists Task Force
TNO	Netherlands Organization for Applied Scientific Research
TR	Technical Report
TS	Technical Specification
UA	Unified Architecture
URI	Uniform Resource Identifier
VDMA	Verband Deutscher Maschinen- und Anlagenbau
XML	Extensible Markup Language

4 SAREF extension for the Industry and Manufacturing domain

SAREF [i.1] is a reference ontology for IoT created in close interaction with the industry during a study requested by the European Commission in 2015 [i.2] and subsequently transferred into an ETSI TS 103 264 [i.3]. SAREF contains core concepts that are common to several IoT domains and, to be able to handle specific data elements for a certain domain, dedicated extensions of SAREF can be created. Each domain can have one or more extensions, depending on the complexity of the domain. As a reference ontology, SAREF serves as the means to connect the extensions in different domains. The earlier document ETSI TR 103 411 [i.4] specifies the rationale and methodology used to create, publish and maintain the SAREF extensions.

The present document specifies the requirements for an initial SAREF extension for the industry and manufacturing domain based on a limited set of use cases and from available existing data models. The present document has been developed in the context of the STF 534 (https://portal.etsi.org/STF/STFs/STFHomePages/STF534.aspx), which was established with the goal to create SAREF extensions for the domains of Smart Cities, Smart Industry & Manufacturing, and Smart AgriFood. The STF 534 follows the outcomes of the earlier STF 513, which developed an updated SAREF specification [i.3], and the first extensions of SAREF in the energy [i.5], environment [i.6] and building [i.7] domains.

The STF 534 consists of the following two main tasks:

1) gather requirements, collect use cases and identify existing sources (e.g. standards, data models, ontologies, etc.) from the domains of interest (i.e. Smart Cities, Smart Industry & Manufacturing, and Smart AgriFood); and

2) produce extensions of SAREF for each domain based on these requirements.

The present document focuses on the extension of SAREF for the Smart Industry and Manufacturing domain, which will result in a new ontology, called SAREF4INMA, to be published in the companion ETSI TS 103 410-5 [i.9] as part of the SAREF extensions series ETSI TS 103 410 [i.10].

5 Related initiatives

5.1 Introduction

In this clause, some of the main related initiatives in terms of modelling and standardization in the smart industry and manufacturing domain are reviewed. Existing efforts range from national or international standardization initiatives, to specific European projects related to these initiatives and standards/data models used in the domain.

5.2 Standardization initiatives and associations

5.2.1 Industry 4.0 initiatives

There are various national initiatives to support digitalization in manufacturing. These include for instance:

- The platform Industry 4.0 in Germany.
- The Smart Industry initiative in the Netherlands.
- Industria 4.0 in Italy.
- Industrie du future initiative in France.

These initiatives typically focus on the following different aspects:

- Cyberphysical systems: the usage of robots and advanced T-capabilities (sensors, data analytics) in a production environment.
- Digital manufacturing technologies: new manufacturing technologies such as 3D printing, requiring a high level of digital input (e.g. digital designs/digital twins).
- New business models and propositions: lot size one-manufacturing, servitization of manufacturing, maintenance and other new business propositions leading to changes in the way businesses and their networks are structured.

The Industry 4.0 initiatives focus on aspects such as standardization (which standards to use or to extend), the development of new digital technologies (e.g. 5G wireless connectivity for manufacturing) and 'soft' aspects such as business model innovation and skills. Through so-called 'digital innovation hubs' collaborations between manufacturing companies, their service provides (including IT-companies), (potential) customers and research organizations have been established. The Industry 4.0 initiatives can provide input to the SAREF extension for smart industry and manufacturing in terms of key use cases and the standards used in this domain.

5.2.2 Reference Architecture Model for Industry 4.0 (RAMI)

Figure 1 shows an overview of the Reference Architecture Model for Industry 4.0 (RAMI) [i.7] and [i.8]. This model is used for the alignment of several standards used in the aforementioned Industry 4.0 initiatives. These standards are grouped according to the topics they deal with that, in turn, are related to three key elements in the industry environment, i.e. factory, product and process.

The standards related to the factory describe the organization, communication, structure and involvement in the development process of the machinery. The standards related to the product explain the hierarchy of the different products in the factory and both the communication between the different products and their relation with the machinery. Finally, the standards related to the process show the life-cycle of the products and the machinery. It is worth highlighting that there are topics related to two or more elements in the industry environment.

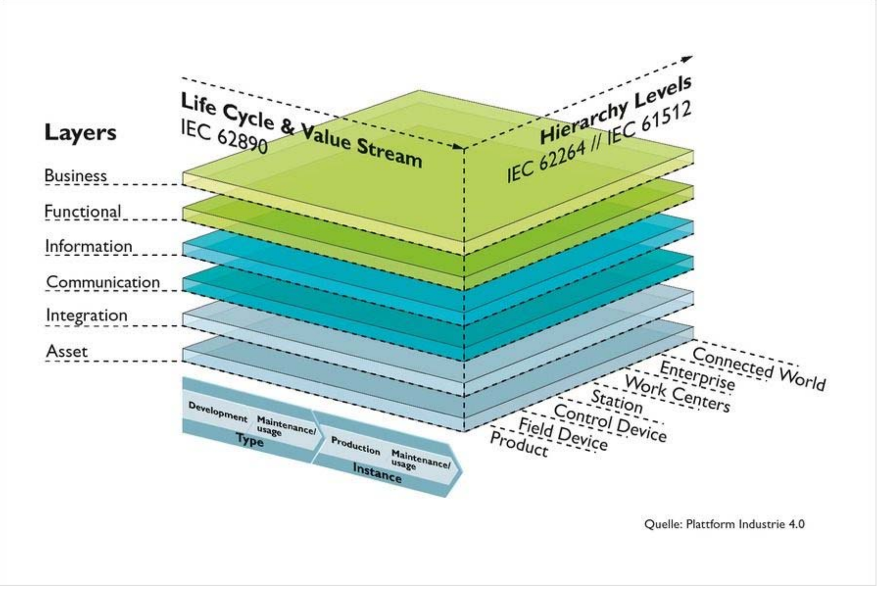

Figure 1: Reference Architecture Model for Industry 4.0

5.2.3 AIOTI

The Alliance for Internet of Things Innovation (https://aioti.eu/), founded by the European Commission in 2015, consists on thirteen working groups. The WG03 on IoT standardization is a horizontal working group that addresses, amongst other, the issue of semantic interoperability in the IoT that is especially relevant to SAREF. The WG11 on Smart Manufacturing is a vertical working group dedicated to IoT solutions that can bring together information, technology and human ingenuity to achieve a rapid revolution in the development and application of manufacturing intelligence to every aspect of business.

5.3 Standards

Figure 2 shows an (initial) overview of existing standards in the industry and manufacturing domain. These standards are grouped based on their scope (e.g. digitalization, communication, engineering, life-cycle, etc.) and the topic they cover (i.e. factory, product, process).

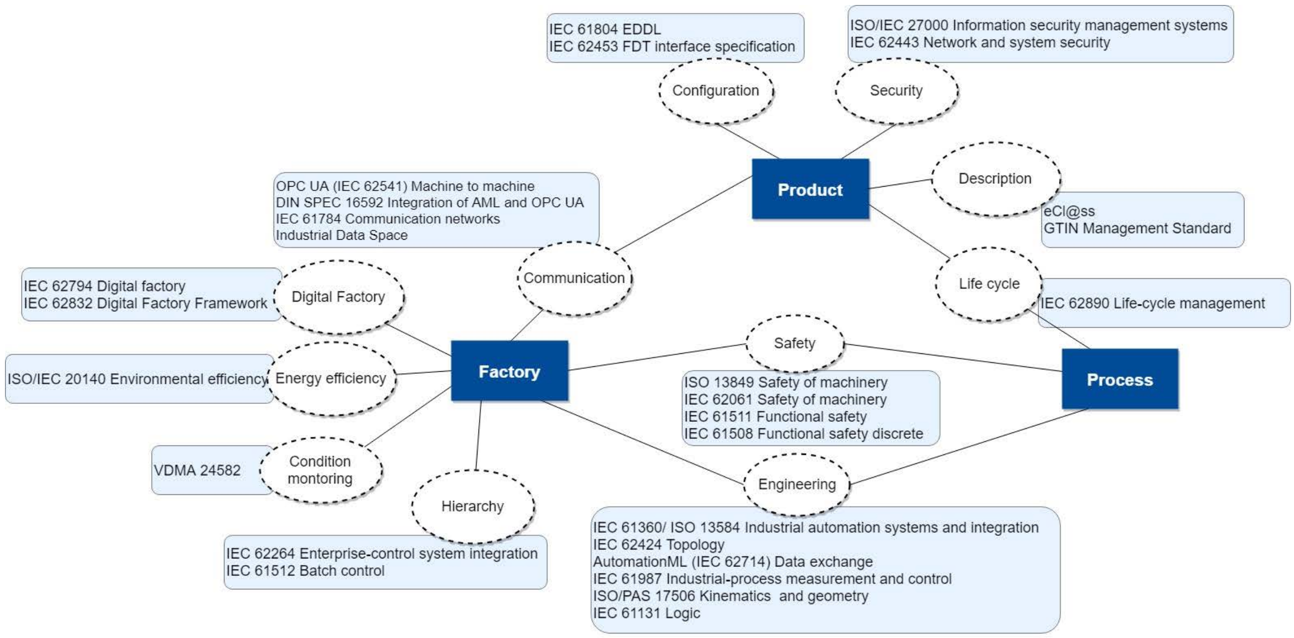

Figure 2: Relevant standards in Industry and Manufacturing

The next paragraphs describe in more detail each of the standards included in Figure 2 grouped according to the scope and the topic each one deals with.

The standards related to the *factory* are:

- Concerning digital factory:
  - **IEC 62794 [i.11] Digital Factory:** This specification describes a reference model which comprises the abstract description for automation assets and structural and operational relationships. This reference model supports the electronic representation of certain aspects of a plant. It covers the systems used to make products, although it does not cover raw production material, work pieces in process nor end products.
  - **IEC 62832 [i.12] Digital Factory Framework:** This specification defines the general principles of the Digital Factory framework, which is a set of model elements and rules for modelling production systems. This standard is built upon the IEC 62794 **[**i.11**]** standard.
- Concerning condition monitoring:
  - **VDMA 24582 [i.13]:** This specification presents the reference architecture of condition monitoring systems in production automation. It is the basis for the creation of communication profiles for condition monitoring and the integration of condition monitoring into engineering tools within automation systems.
- Concerning energy efficiency:
  - **ISO/IEC 20140 [i.14] Environment efficiency:** This specification specifies a method for evaluating the energy efficiency of a manufacturing system and other factors such as energy consumption, waste and release that influence the environment. The evaluation method provides guidelines to analyse the usage of energy by the manufacturing system and its effects on the environment.

The standards related to the *product* are:

- Concerning configuration:
  - **IEC 61804 [i.15] EDDL:** This standard specifies electronic device description (EDD) interpretation for EDD applications and EDDs to support EDD interoperability. It is intended to ensure that field device developers use the EDD language constructs consistently and that EDD applications interpret in the same way the EDD.

- **IEC 62453 [i.16] FDT interface specification:** This specification provides an interface specification for developers of FDT (Field Device Tool) components to support function control and data access in a client/server architecture.

- Concerning security:

  - **ISO/IEC 27000 [i.17] Information security management systems:** This specification provides recommendations on information security management within the context of an Information Security Management System (ISMS). This standard covers privacy, confidentiality and IT, technical or cybersecurity issues.

  - **IEC 62443 [i.18] Network and system security:** The goal of this specification is to provide a framework that facilitates addressing current and future vulnerabilities in industrial automation and control system and applying necessary mitigations. This standard is built upon the ISO/IEC 27000 **[**i.17**]** standard.

- Concerning product description:

  - **eClass [i.19]:** This specification describes a hierarchy for grouping materials, products and services according to a logical structure. This grouping describes product-specific properties that can be described using norm-conforming properties.

  - **GTIN Management standard [i.20]:** This specification defines how to identify elements that may be priced, or ordered, or invoiced at any point in the supply chain.

The standards related to both *product* and *factory* are:

- Concerning hierarchy:

  - **IEC 62264 [i.21] Enterprise-control system integration:** This specification describes the manufacturing operations management domain and its activities. This description enables integration between the manufacturing operations and the control and the enterprise domains.

  - **IEC 61512 [i.22] Batch control:** This specification defines reference models for batch control as used in the process industries and terminology that helps to explain the relationships between these models and the terms.

- Concerning communication:

  - **OPC UA (IEC 62541 [i.23]) Machine to machine:** This specification defines the OPC UA Architecture, which is a machine to machine communication protocol for industrial automation.

  - **DIN SPEC 16592 [i.24] Integration of AML and OPC UA:** This specification describes the combination of AML engineering data with OPC Unified Architecture online information such as process data and diagnostic information.

  - **IEC 61784 [i.25] Communication networks:** This specification defines a set of protocol-specific communication profiles to be used in the design of devices involved in communications in factory manufacturing and process control.

  - **Industrial Data Space [i.26]:** This specification defines the data exchange in business ecosystems, with the aim of guaranteeing secure and trusted communication.

The standards related to both *process* and *product* are:

- Concerning life-cycle:

  - **IEC 62890 [i.27] Life-cycle management:** This specification describes the lifecycle management for systems and products used in industrial process measurement, control and automation.

The standards related to both *process* and *factory* are:

- Concerning safety:
  - **ISO 13849 [i.28] Safety of machinery:** This standard provides safety requirements and guidance on the principles for the design and integration of safety-related parts of control systems, including the design of software.
  - **IEC 62061 [i.29] Safety of machinery:** This specification defines requirements and recommendations for the design, integration and validation of safety-related electrical, electronic and programmable electronic control systems for machines.
  - **IEC 61511 [i.30] Functional safety:** This standard gives requirements for the specification, design, installation, operation and maintenance of a safety instrumented system, so that it can be confidently entrusted to achieve and maintain a safe state of the process
  - **IEC 61508 [i.31] Functional safety discrete:** This standard sets out the requirements for ensuring that systems are designed, implemented, operated and maintained to provide the required safety integrity level.
- Concerning engineering:
  - **IEC 61360 [i.32]/ISO 13584 [i.33] Industrial automation systems and integration:** This standard specifies a general-purpose dictionary of technical terms covering the field of electro technology, electronics and related domains.
  - **IEC 62424 [i.34] Topology:** This standard defines procedures and specifications for the exchange of Process Control Engineering relevant data provided by the Piping and Instrumentation Diagram (P&ID) tool.
  - **AutomationML (IEC 62714 [i.35]) Data exchange:** This standard describes a data exchange solution based on an XML schema focusing on the domain of automation engineering. This standard integrates IEC 61131 [i.37], IEC 62424 [i.34] and ISO/PAS 17506 [i.36].
  - **IEC 61987 [i.38] Industrial-process measurement and control:** This standard defines a generic structure and its content for industrial-process measuring and control equipment.
  - **ISO/PAS 17506 [i.36] Kinematics and geometry:** The aim of this standard is to provide a specification for the COLLADA schema in sufficient detail to enable software developers to create tools to process COLLADA resources.
  - **IEC 61131 [i.37] Logic:** This standard defines the characteristics of programmable controller systems. It applies to programmable controllers and their associated peripherals which are intended to control and command the machines and industrial processes.

5.4 European project Productive 4.0

Productive 4.0 (https://productive40.eu/) is a European co-funded innovation and lighthouse program that aims to create a user platform across value chains and industries, thus promoting the digital networking of manufacturing companies, production machines and products. Productive 4.0 counts on a consortium of more than 100 partners from 19 European countries that examine methods, concepts and technologies for service-oriented architectures as well as for components and infrastructure in the Internet of Things.

The project addresses several areas of digitalization; in each area interoperability is required between systems and solutions of various providers. These areas include:

- IoT-enabling of products and manufacturing environments: the integration of sensors in smart products and production equipment.
- Service-oriented platforms for manufacturing data: the exchange of data within a manufacturing environment using smart manufacturing equipment. This data can be used for monitoring and controlling the production process.

- Production control: real-time data collection and data analytics to enable production control, e.g. for zero defect manufacturing.
- Process virtualization: creating a 'digital twin' of a production environment using configuration data and measurements enabling analytics to find possible improvements and simulation of proposed changes.
- Product lifecycle management: the capturing of design and usage data of products along the entire lifecycle and supply chain of a product.

The Productive 4.0 project contains several use cases addressing one or more of these areas, providing possible input for extending SAREF.

6 Use cases

6.1 Use case 1: Zero defect manufacturing

The competitiveness of a manufacturing process is often defined by its ability to be flexible, i.e. quickly change from one product to the other, and have a manufacturing process with as little yield loss as possible. Zero defect manufacturing focuses on reducing the yield loss to zero, often combined with an increase in flexibility. To that end, a combination of precision manufacturing technology, data collection and process control is needed.

Two cycles are especially needed in the zero defect manufacturing use case, i.e. a real-time loop and a data-collection-and-analysis loop, which are shown in Figure 3 (in red and blue color, respectively):

- The first cycle is a **real-time loop** that focuses on the immediate collection of data from sensors in or around a production equipment (e.g. a stamping machine that takes a metal sheet as raw material and produces a certain metal object as a result). These data consist of the machine settings and states, its measurements (e.g. temperature, pressure, force measured by the machine during production) and units of measure, but also characteristics of the resulting product (e.g. properties of the metal object produced by the machine). Based on these data, a controller component can decide to change the settings of the production equipment in real-time to avoid errors that could possibly lead to defects in the final product. This loop often takes place within and in the surrounding of the production equipment (e.g. through edge computing concepts) given its real-time nature.
- The second cycle is a **data collection and analysis loop** needed to achieve a continuous process analysis and improvement. Also this loop includes smart sensors, but it has a longer timespan compared to the real-time loop. It can measure the characteristics of the incoming (raw) material to update the production settings accordingly in a later moment. Similarly, it can detect feedback parameters to predict the quality of the end-product and provide feedback to the production process. Over a longer period of time, these parameters are fed to a self-learning framework which can be used to detect patterns leading to errors and/or areas for further improvement.

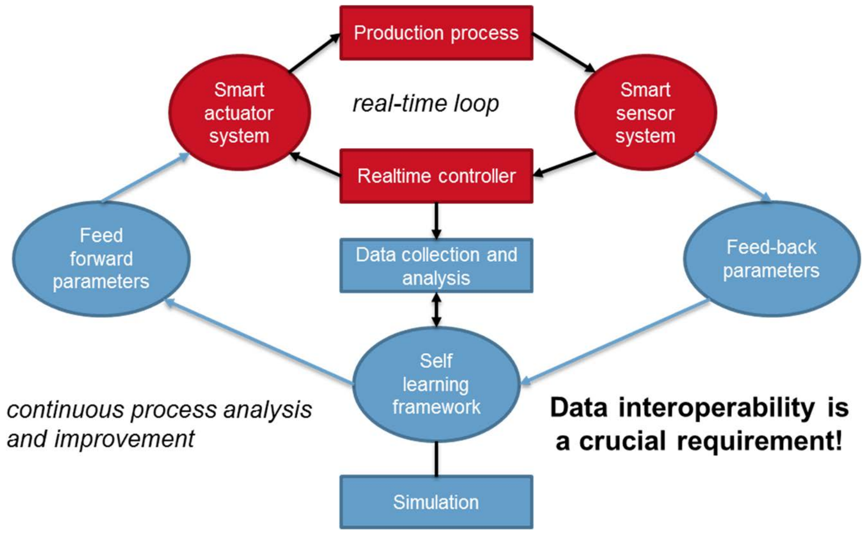

Figure 3: Zero defect manufacturing

In the zero defect manufacturing use case, interoperability is especially required between sensors, production equipment and the data collection environment for the data collection and analysis loop (second cycle). The Productive 4.0 innovation and lighthouse program (https://productive40.eu/) provides us with several concrete examples of this use case relating to the stamping of metal objects and chatter control in milling.

6.2 Use case 2: Smart services for product in use

Business models increasingly shift from products to services. Through servitization, manufacturing companies remain responsible for the proper functioning of the product during its entire lifecycle. Data can be collected using IoT-technologies on several aspects:

- The functioning of parts of the product (energy consumption, performance of an engine, etc.) and derived characteristics (wear and tear, need for replacement of parts). This data is used for servicing the equipment.
- The usage of the product: how often is a product used and under which conditions. This can be used to optimize the service usage (e.g. by giving recommendations) or as feedback to a design-department for future versions of the product. It can also be used as an input for additional value-added services (e.g. app-enabled products).

6.3 Use case 3: Smart product lifecycle

To a greater extent, businesses are organized in value chains. Non-core tasks are outsourced to other partners, allowing for manufacturing specialization. These suppliers are not only responsible for the production of a certain part but increasingly also for the design and maintenance of the product. Complex products (e.g. manufacturing equipment) often have a long lifespan which can include updates and revisions.

Data interoperability is required for several aspects:

- Between the original design and production data
- For the usage of the product
- The responsibilities of the organizations involved (manufacturer, user, servicing organization, parts supplier, etc.)

Some of the data are relatively static, whilst other data can change over time because of changes in ownership and contractual roles. Over time a digital footprint of the product needs to be established to allow for the management of the product during its entire lifecycle. In this way, this use case is linked to the other two use cases.

7 Requirements

The requirements presented in this clause have been derived from the zero defect manufacturing use case. Competency questions that have been extracted from this use case as the basis to create SAREF4INMA include the following:

- List of requirements for the zero defect manufacturing use case provided by the Productive 4.0 project.
- List of requirements provided by standards, specifically from: OPC UA in order to define interoperability between devices; eCl@ss in order to classify items; IEC 61512 [i.22] in order to identify production batches; IEC 62264 [i.21] in order to identify the structure of the factory; IEC 62890 [i.27] in order to define the product life-cycle; and GTIN in order to identify each element in the factory.

Different types of data can be taken into account in the various phases of the production process, namely related to:

1) machine/production equipment;
2) materials (incoming and outcoming);
3) products; and
4) factory.

The associated requirements are presented from Table 1 to Table 4. Due to the fact that some requirements are extracted from the use case and other requirements are extracted from the standard specifications, these requirements can be defined either as competency questions with answers or as statements.

Table 1: Requirements for Machine/Production Equipment

Id	Competency Question/Statement	Possible answer
INMA-1	What sort of production equipment is used in the factory?	Milling machine, stamping machine, moulding machine.
INMA-2	What type of stamping machine is used in the factory?	Schäfer ABS1200.
INMA-3	What type of capabilities exist for stamping machines?	High-pressure stamping, high-volume stamping.
INMA-4	What are the capabilities of the Schäfer ABS1200 stamping machine?	High-volume stamping.
INMA-5	Which configuration parameters does the Schäfer ABS1200 have?	Pressure, amount.
INMA-6	Which units of measure exist for the pressure parameter of the stamping machine?	Number of kilotons.
INMA-7	What type of sensors exist?	Measurement devices (which just measure a certain value), edge computing devices (which also perform analytics and provide a complex/aggregated result).
INMA-8	Which sensors are used in the production process?	Temperature reader, form validation optical sensor.
INMA-9	Which actuators are used in the production process?	Product feed machine, product flow switch, etc.
INMA-10	Which machine states exist for the Schäfer ABS1200 stamping machine?	Operational, temperature, actual pressure, power consumption.
INMA-11	What is a machine state composed of?	A time-stamp and a reading.
INMA-12	What is the actual value of the operational-machine state of the Schäfer ABS1200?	At t=11:30:30 the operational state is true.
INMA-13	What production batch is the machine working on?	At t=12:30:30 the machine was working on batch 12345AB.
INMA-14	A production equipment can be composed by sensors and actuators	
INMA-15	Each production equipment can have a method to execute an action	
INMA-16	Each production equipment has a machine information, configuration parameters and status	
INMA-17	Every production equipment needs to be uniquely identifiable	
INMA-18	What are the attributes of the production equipment?	Identifier, browse name, display name, description, class.
INMA-19	Every production equipment can be composed of variables	
INMA-20	A variable is a component of the production equipment representing the data of objects, e.g. measurement	
INMA-21	AnalogItemType is a type of variable	
INMA-22	Variables can be defined using properties	
INMA-23	Which are the attributes of a variable?	Value, datatype, value rank, array dimensions, access level, user access level, minimum simple interval, historizing.
INMA-24	A production equipment can contain other production equipment	
INMA-25	A moulding machine has injection units	
INMA-26	Which are the statuses of the injection units?	In production, present.
INMA-27	Each production batch is identified by a GTIN	
INMA-28	What attributes has a moulding machine?	Supplier, brand, gtin, type of device, manufacturer.
INMA-29	What attributes has an injection system?	Supplier, brand, gtin, type of device, manufacturer.
INMA-30	What is a batch?	The material that is being produced or that has been produced by a single execution of a batch process.
INMA-31	What types of batches are in a factory?	Material batch, Production batch.
INMA-32	What attributes has a production batch?	Identifier, size, needed equipment, product, raw material.

Table 2: Requirements for Material

Id	Competency Question/Statement	Answer
INMA-33	What kind of incoming material is used in the machine?	An individual item, a sub-assembly composed of different items or a volume of raw material.
INMA-34	Is the incoming material considered to be a batch?	A volume of raw material can be part of a batch or part of a supply-stock (in which case raw material from multiple sources get mixed) Individual items, sub-assemblies and volumes of raw materials can be part of a batch.
INMA-35	When can data be attributed to incoming material?	When the material is an item, a sub-assembly or a batch. When the material is a supply-stock only actual values can be measured (e.g. a sensor reading at a certain timestamp, see production equipment).
INMA-36	Does the data relate to the material as whole?	Data can be related to a batch, item or sub-assembly. When the material is a volume of raw materials data can be related to a specific position on the material.

Table 3: Requirements for Product

Id	Competency Question/Statement	Answer
INMA-37	Which parts does the product consists of?	The product consists of item 1, 2 and 3. *and/or* The product consists of sub-assembly A (composed of item 1 and 2), B (composed of item 3 and 4) and C (composed of item 5 and 6). *and/or* The product was made of material from batch XYZ123.
INMA-38	When was the product manufactured?	The product was manufactured during production batch ABC123. The product was manufactured on June 12th 2016 at 8:05am.
INMA-39	Which machines were involved in manufacturing the product?	The Schäfer ABS1200.
INMA-40	A product shall have an identifier.	
INMA-41	Products can be distinguished in categories	
INMA-42	A shaver is a type of product.	
INMA-43	What attributes has a shaver?	Supplier, brand, gtin, type of device, manufacturer, URI.
INMA-44	Any new product requires the assignment of a new GTIN.	
INMA-45	GTINs can be 8, 12, 13, or 14 digits in length	
INMA-46	How is GTIN constructed?	Indicator digit, GS1 Company Prefix, Item Reference, Check Digit.
INMA-47	A GTIN may be encoded in EAN/UPC, ITF-14, GS1-128, GS1 DataBar, and GS1 DataMatrix symbols or EPCs.	
INMA-48	Each product and machine has its correspondents updates and upgrades.	
INMA-49	A product is divided into the type and the instance.	

Table 4: Requirements for Factory

Id	Competency Question/Statement	Answer
INMA-50	A process cell is located in a certain area of a factory	
INMA-51	Each area belongs to a site	
INMA-52	A site is located in a factory	
INMA-53	Each area contains process cells	
INMA-54	Each process cell can contain units	
INMA-55	Each unit contains equipment module	
INMA-56	Production equipment are located in the equipment modules	
INMA-57	Equipment modules can contain control modules	
INMA-58	Control modules are equipment in the physical model that can carry out basic control	

8 Conclusions

The present document describes the use cases considered as relevant for the development of the SAREF4INMA extension, namely:

1) zero defect manufacturing;
2) smart services for product in use; and
3) smart product lifecycle.

The present document further defines the final requirements in terms of competency questions or statemens to be implemented in an initial SAREF4INMA extension (58 requirements in total), which have been extracted from the zero defect manufacturing use case and from existing standards. Validation of these requirements is expected to be carried out while creating the SAREF4INMA extension, leveraging the related initiatives identified in the present document.

Note that in addition to the zero defect manufacturing use case, also the smart services for product in use and smart product lifecycle use cases are acknowledged in the present document as especially relevant, as they present semantic interoperability issues that could be supported by the SAREF4INMA extension. However, there is a limited number of use cases that can be considered within the timeframe and resources available in the STF 534. It is therefore recommended to take into account these use cases in future versions of the SAREF4INMA extension.

Annex A: Bibliography

- ETSI TS 103 267: "SmartM2M; Smart Appliances; Communication Framework".
- ETSI TS 118 101: "oneM2M; Functional Architecture (oneM2M TS-0001)".
- ETSI TS 118 102: "oneM2M; Requirements (oneM2M TS-0002)".
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History

Document history		
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