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Smart manufacturing — Reference architecture model industry 4.0 (RAMI4.0)

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FOREWORD

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The text of this PAS is based on the following document:	This PAS was approved for publication by the P-members of the committee concerned as indicated in the following document
Draft PAS	**Report on voting**
65/645/PAS	65/655/RVDPAS

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INTRODUCTION

Background

Industry requires constant attention on optimization, cost efficiency, energy efficiency, environmental concerns, quality, security, safety, time-to-market, inventory reduction, simulation, ease of maintenance, etc. Customers also want to satisfy new requirements and address new use cases now reachable given the availability of new technologies. Addressing these challenges, several projects in different countries were issued with similar names and aims, e.g. in Germany “Industrie 4.0”, in France “Industrie du Futur”, in China “Intelligent Manufacturing”, in Japan etc.

Manufacturers, customers, service providers are working in a more and more global market. The need of interoperability of products, open interfaces, etc. can only be achieved with International Standards. To cover these needs, IEC and ISO have activities related to Smart Manufacturing.

Objective

This specification defines a Reference Architecture Model to identify, structure, and illustrate the different areas where standards exist or standards are required. It allows setting standards in relation to different aspects, hierarchies and life cycles.

Life cycles are relevant to products, to assets in the factory or plant, to orders from planning to cash and to the supply chain covering the process from source to delivery.

In addition, this specification defines term and definitions generally for Smart Manufacturing. As Smart Manufacturing is covering different domains (batch, continuous, discrete, etc.), terms need to be harmonized and globally accepted.

The fundamental purpose of Industry 4.0 is to facilitate cooperation and collaboration between technical objects, which means they have to be virtually represented and connected. In this context, a technical object is an object that is of value to an organization, which therefore not only means physically tangible objects, but also intangible objects such as ideas, archives and software. The concept of Industry 4.0 is intended to create digital description rules for a technical object throughout its entire lifetime, and for the associated changes in value, in the form of the Reference Architecture Model for Industry 4.0 “RAMI4.0”. The purpose of this model is to represent the technical object and all aspects relevant to it, from its development, production and use right through to its disposal. The Industry 4.0 component provides a digital description of the object, making it possible to represent that object virtually.

Technical objects are intentionally manufactured in order to fulfil a specific purpose. They possess common characteristics in terms of their lifetime and the associated changes in value. Technical objects for which a “change in value” or an “owner” are important aspects are also referred to as “technical assets”. Because this is almost always the case, the terms “technical object” and “technical asset” can be regarded as synonymous. In this document, the term “technical asset”, or simply “asset” is used.

This document describes two fundamental reference models for the Industry 4.0 concept:

– The reference architecture model RAMI4.0 is a reference model of Industry 4.0 reference architecture and gives a structured description of fundamental ideas. See Clause 5.
– The I4.0 component reference model provides digital access to this description. See Clause 6.

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The central concept of Industry 4.0 is that assets can be combined in any way, and these assets are formally described in sufficient detail for use in the digital world. This methodology not only enables sufficient generic descriptions of a configuration, but through an increasing degree of detail also allows for very specific descriptions. This is a core concept regardless of the way in which the asset is used.

To virtually represent configurations of assets and the connections between them, the “principle of recursive description of assets” is used to characterize an asset as follows:

– the structural description is compliant with RAMI4.0;
– a configuration of two or more assets collectively forms a new asset, which is described using RAMI4.0;
– components of an asset can themselves represent separate assets that are described with RAMI4.0;
– the asset description is provided as structured information in the administration shell of the I4.0 component that acts as a virtual representation of an asset.

This means that any configuration can be digitally represented to any degree of granularity by describing structured assets, and combinations thereof, using RAMI4.0.

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SMART MANUFACTURING – REFERENCE ARCHITECTURE MODEL INDUSTRY 4.0 (RAMI4.0)

1 Scope

This document, which is a PAS, describes a reference architecture model in the form of a cubic layer model, which shows technical objects (assets) in the form of layers, and allows them to be described, tracked over their entire lifetime (or "vita") and assigned to technical and/or organizational hierarchies.

It also describes the structure and function of Industry 4.0 components as essential parts of the virtual representation of assets.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61360-1, *Standard data element types with associated classification scheme for electric components – Part 1: Definitions – Principles and methods*

IEC 61360-2, *Standard data element types with associated classification scheme for electric components – Part 2: EXPRESS dictionary schema*

IEC TR 62794[1], *Industrial-process measurement, control and automation – Reference model for representation of production facilities (digital factory)*

IEC TS 62832-1, *Industrial-process measurement, control and automation – Digital factory framework – Part 1: General principles*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
administration shell
virtual digital and active representation of an I4.0 component in the I4.0 system

Note 1 to entry: An administration shell contains the manifest and the component manager.

[1] Withdrawn.

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3.2
architecture
fundamental concepts or properties of a system in its environment embodied in its elements, relationships, and in the principles of its design and evolution

[SOURCE: ISO/IEC/IEEE 42010:2011, 3.2]

3.3
archive world
all the information in the digital world which is no longer valid or up-to-date and which therefore can no longer be changed

Note 1 to entry: Information which is no longer valid or up-to-date is transferred to the archive world.

Note 2 to entry: No statement is made on when the information is transferred from the model world or state world to the archive world.

3.4
asset
object which has a value for an organization

3.5
service
separate scope of functions offered by an entity or organization via interfaces

Note 1 to entry: This definition is not the same as the definition of services by the OASIS-RM ("Services are the mechanism by which needs and capabilities are brought together").

3.6
entity
uniquely identifiable object which is administered in the information world due to its importance

3.7
information world
digital world or cyber world
ideas, concepts, algorithms, models and entirety of representations of physical objects and people in the virtual environment

Note 1 to entry: The framework for considering each entirety needs to be defined.

Note 2 to entry: The elements of the information world can be semantically related to each other.

3.8
component manager
organizer of autonomous administration and access to resources of the relevant I4.0 component, such as the I4.0 component itself, object, technical functionality, virtual representation

Note 1 to entry: In many documents, the component manager is referred to as the resource manager, but this should be called the component manager in future.

3.9
manifest
externally accessible, defined set of meta-information on the functional and non-functional properties of the relevant I4.0 component

Note 1 to entry: The manifest can be regarded as similar to the manifest in information technology.

3.10
physical world
all actually existing objects and people

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Note 1 to entry: The real world is the same as the physical world.

Note 2 to entry: Loaded or stored software is part of the physical world.

Note 3 to entry: The framework for considering each entirety needs to be defined.

3.11
reference architecture
model for an architecture description (for I4.0) which is generally used and recognized as being suitable (has reference character)

Note 1 to entry: A reference architecture can be defined on the basis of a reference model.

3.12
reference model
model that is generally used and recognized as being suitable (has recommendation character) for deriving specific models

3.13
value-added chain
sequence of processes that add value (linear or hierarchical, which formally means acyclically aligned)

Note 1 to entry: Company boundaries are not necessarily relevant for a value-added chain or value chain.

3.14
value-added system
network or system of value-added chains that can include connections and dependencies between them

3.15
value-added process
process during which a commodity can be created which is valuable for a customer

Note 1 to entry: The commodity does not have to be tangible (such as a raw material or manufactured product), but can also be intangible (such as knowledge, information or a service).

Note 2 to entry: The determination of the value or price is not considered here.

Note 3 to entry: Value-added processes are value activities according to Porter.

4 Assets in Industry 4.0

4.1 The object world

Figure 1 shows the structure of the object worlds. In the object world of Industry 4.0, assets from the information world and the physical world are considered. Besides these assets, people (the human world) also play an important part. The information world is divided into the model world, the state world and the archive world. The model world contains objects such as meta-documents, models, concepts, technical documentation, production plans and procedural descriptions. The state world describes the current state. The archive world contains the recorded state and life cycle information of processes that have taken place. These can be production processes, development processes, maintenance processes and so on.

The physical world includes all physical products, installations, resources, IT systems, loaded programs, etc. When classifying software, it should be noted that the algorithm itself belongs to the information world, but the executable program loaded to a system is part of the physical world. People are part of the physical world and participate in the information world. Because of their intelligence and freedom to make decisions, human beings have a special status.

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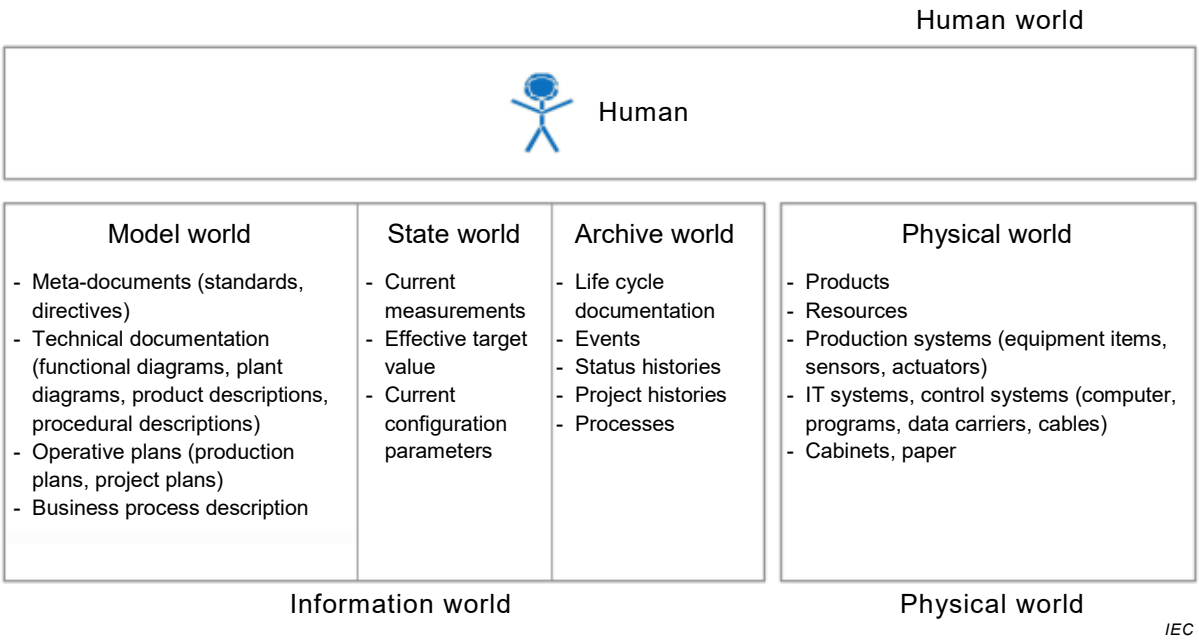

Figure 1 – Structure of the object worlds with examples

4.2 Information carriers

Figure 2 shows examples of various carriers of information. A plan, for example, can be stored as an xml or pdf file on a computer. It can also be inside somebody's head or printed out on a piece of paper. In each case, the information asset "plan" is the same. The character of the physical carrier does not alter the information asset. If the carrier is destroyed, so is all the information stored on it. To prevent information from being lost, copies of it can be made on multiple carriers. However, they are all still the same asset.

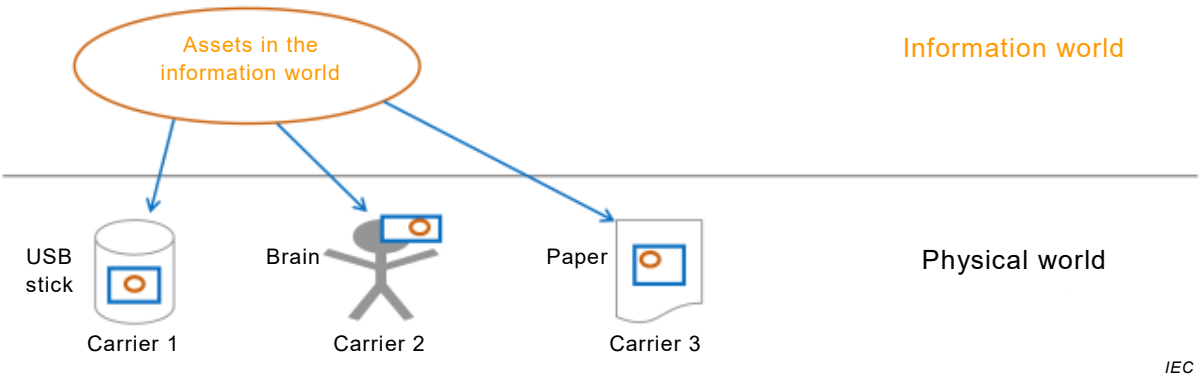

Figure 2 – Assets in the information world and their physical carriers

4.3 Assets and the information world

Every asset has a value for an organization. It represents an artefact that is specifically intended to perform a particular role in a particular system. Assets are intentionally manufactured in order to fulfil a specific purpose. They possess a common "vita", or lifetime, and the associated change in value. See Figure 3. Assets for which a "change in value" or an "owner" are important aspects are also referred to as "technical assets".

The key task in Industry 4.0 is to take technical assets from the physical world and virtually represent them in the information world. The physical world is to be understood to mean the entirety of all real assets and people.

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