VDI VDE VDI/VDE-Gesellschaft
Mess- und Automatisierungstechnik

ZVEI: Die Elektroindustrie

Status Report

Industrie 4.0 – Technical Assets

Basic terminology concepts, life cycles and administration models

March 2016

Preamble

This status report presents basic concepts for modeling technical assets, their life cycle and their administration in the information world. The results are based on work conducted by the VDI/VDE GMA technical committee FA7.21. This technical committee is engaged in terminology, reference models and architectures for a future Industrie 4.0 system design. This report presents results of a work package which addresses reference models in the content of technical assets. The reference models are discussed in detail including demonstrations of how these models can be combined to an integrated conceptual model framework. Essential suggestions from other working groups especially from the ZVEI (SG2) have been incorporated in these results.

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Düsseldorf, March 2016

Content

1 Motivation

“Industrie 4.0” describes a future scenario of industrial production [1, 3]. As defined by the “Plattform Industrie 4.0” [2], the scenario is characterized by three main aspects.

- a new level of organizing and controlling the entire value chain with the life cycle of products
- the availability of all relevant information in real time which is achieved by interconnecting all instances that participate in the value creation processes
- the creation of dynamic, real-time optimized and self-organizing cross-company value networks by interconnecting humans, objects and systems, and their abilities

In this context, automation technology faces the challenge of integrating the control and organization of these value creation networks into the environment of industrial automation. This integration has two sides: On the one hand, the functionalities of industrial automation systems must be available for use by the overriding management systems. On the other hand, value creation management functions must have the capability of being integrated into the systems of industrial automation. These tasks and challenges lay out the demands concerning the design of future industrial automation systems. Any future reference architecture must take these demands into account.

1.1 Reference models and architectures

To promote a systematic and sustainable development process, it is of essential interest to build the system architectures on a set of stable, consensus-based and standardized reference models. In the last year, extensive efforts have been made to define and establish a set of basic reference models. An overview of the models discussed in the technical committee FA7.21 is depicted in Figure 1.

Many of these concepts are not new, since they already appear in existing standards, guidelines and in industrial practice. However, they have to be revised, generalized and precisely formulated.

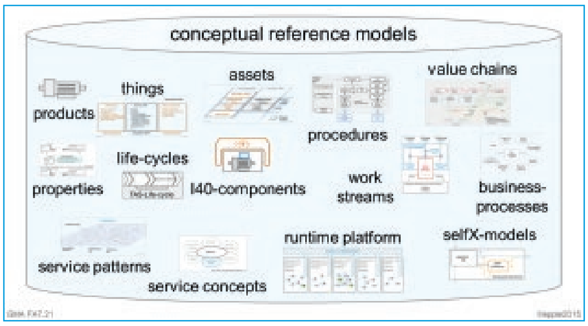

Figure 1. Conceptual reference models

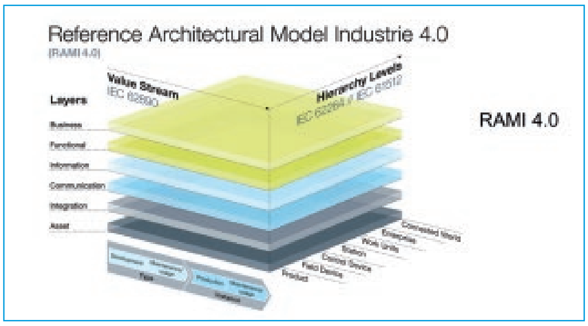

Figure 2. The RAMI4.0 reference architecture [7]

Within the framework of I4.0, reference architectures are required in addition to the afore-mentioned reference models. Reference architectures establish a framework for the conceptual construction of systems, while the reference models provide building concepts within the architecture. The RAMI4.0 model (Figure 2) provides a basic reference architecture for an I4.0 system. It will be published as DIN SPEC [7].

1.2 Content of this report

This report focuses on the modeling of assets and their administration in the digital IT-system. Reference models of assets are very important. They provide the basis for the modeling of many other reference models including the modeling of life cycles, value chains and product tracking. In the same manner, the administrated assets in the digital IT-system build a platform for the information models on higher levels.

2 Technical assets

In “I4.0” many different types of subject matter and resources must be considered: humans, technical items, natural resources, legal entities etc. Despite the importance of all of these entities, this article refers to the technical items only.

Defined as followed: A technical item is an artefact produced especially to fulfill a role within a system.

Due to this definition, technical item are characterized by a common life-cycle-schema and a common value course. If aspects like “value course” or “owner” play an important role, technical items can also be denominated as “technical assets”. The denominations technical item and technical asset can be used synonymously. Consequently, the choice of denomination rests with the user and his specific focus or preference. This report, we will either employ the term “technical asset” or simply “asset”.

Common life-cycle schema

Figure 3 shows the common life-cycle schema for all technical assets.

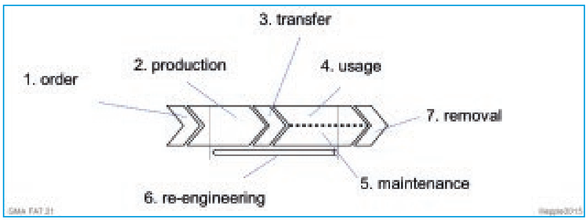

Figure 3. Technical asset standard life cycle

Every technical asset has to be generated by a production process. Generation can mean: development (of a type), engineering (of a plant), measurement (of status information), construction (of a plant) or manufacturing (of a product). After production, the asset is existent but still not ready to use. The provisioning phase comprises all processes in between the finished production and the ready-to-use state of the product within an application. In this phase, an asset is shipped, transported, mounted, parametrized, approved, enabled, downloaded etc. After the provisioning phase, the asset is ready to fulfill its role as technical equipment within the application system. In the usage phase, two different views have to be considered: the usage view and the maintenance view. The usage view perceives the asset as equipment that fulfills a technical task. The maintenance view still perceives the asset as a product which has to be maintained. The maintenance can be realized by the user, the manufacturer or a third party service provider. Maintenance processes can be processed on site, remotely or after disassembly in a workshop. Specific maintenance processes have to be interpreted as partial rebuild actions and need a consecutive provisional phase. For future business value chains, the organization of maintenance processes will be one of the most important topics. Remote digital access of external service suppliers to the asset and the responsibility for the functionality and integrity of the asset will also be critical points.

Applied to the life-cycle schema, technical assets show a similar value course (Figure 4).

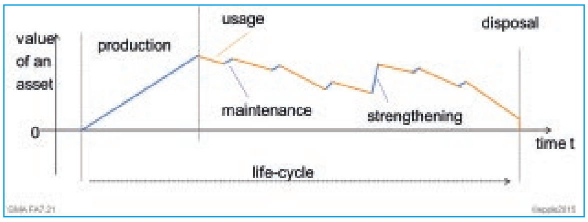

Figure 4. Typical value course of a technical asset

Within the production phase, the substance value of the asset increases. Within the provisioning phase, the utility value for the user increases even further. Through continuous usage and passing time, the value typically decreases due to degeneration or aging effects. In this phase, the value can be increased by maintenance, optimization, strengthening or reengineering.

Categories of technical assets

In I4.0 there are many different kinds of technical assets. It is helpful to divide them into five categories as shown in Figure 5.

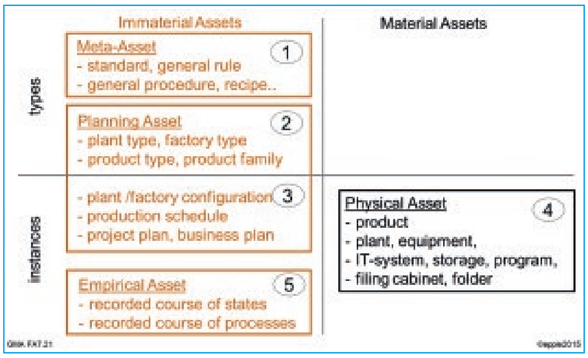

Figure 5. Categories of technical assets

Technical assets can either be part of the physical world or the information world. Assets of the physical world are material assets like work pieces, pipes, motors, pumps, production plants, computers, storage units, filing cabinets, and so on.

Assets of the information world are immaterial assets like concepts, models, plans, standards, and so on.

Meta models are assets with no direct instantiation in the physical world. Standards, general rules, methods, technologies, common procedures are typical examples.

Class models are assets which describe a solution that shall be instantiated in the physical world, for example, the complete documentation of a product type, a software version, a product family or the complete planning documents of a production plant.

Instance models are planning assets which only relate to a specific instance, for example, a specific production schedule, a configuration set for a specific role, or the description of an individual system. Although these assets are instance assets, they are still part of the information world.

The last category contains the empirical data models. In many cases, these objects are not regarded as assets, which does not alter the fact that they still are assets. Information about the state of a process variable has to be generated explicitly (by measurement) and can then be used for process control and analysis. If we apply these considerations to big data applications, it becomes obvious that validated datasets develop into valuable assets.

Figure 5 additionally separates the immaterial assets into “types” and “instances”. An immaterial asset is not the item itself, but the description of an item. The described item can either be an abstract object or an individual object (in the semantic of ISO15926 [16] this corresponds to an AbstractObject or a Possible-Individual). The used denominations “types” and “instances” are taken from the RAMI4.0 model. They shall indicate whether the description refers to an abstract object or an individual object. This is just a very rough classification but it helps to separate the development and life-cycle management of product types (product families) from the production and life-cycle management of the individual products [5].

Value chains

In technical systems, different assets are linked in complex networks. Any asset within the network keeps its own identity and own life cycle. However, complex interdependencies between the life-cycle states of the involved assets are established due to the network integration. In this context, two typical examples are presented

- Aggregation of technical assets

The concept of technical assets is not restricted to a special size or complexity of the subject matter. One of the most popular concepts to build new assets is the construction principle. It is wide-spread in all categories. According to the construction principle, a new asset is generated by constructing a system that uses less complex assets than parts. The schema can be applied repeatedly.

- Dependencies between type and instances

In the industrial environment, plants and products are planned first. Every physical asset can be seen as an instance which is constructed according to the plans described in the type. The type itself is a planning asset. This dependency highlights the fact that constructing an instance is a “usage” of the type asset. The type asset has to be in the usage phase when the production of an instance is initiated.

An example is provided in Figure 6: A supplier A wants to offer a new part type AX. The type is constructed and released. The release contains a catalog library element for external use that describes the properties of the new part type AX (brown arrows) and the complete documentation needed for the construction of the element instances (black arrows). The Machine supplier B is expected to construct a new machine BY. He searches through the parts catalogs and selects the new Part AX. He integrates the functionality of AX into his construction plans.

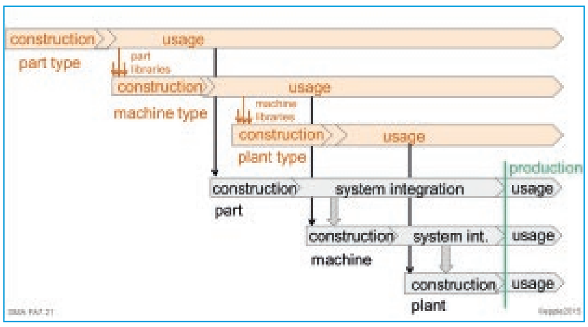

Figure 6. Coupled life-cycle pro-cesses

The plant manufacturer C designs the plant CW using the functionality of the machine BY which he obtains from the type description of B. Within this sequence, all assets and processes belong to the information world (in reality, the development comprises the building of prototypes, test exemplars, 0-series, etc., and the boundary between development and instance production is not really sharp). The grey swim lanes show the life cycles of the material assets. The black arcs represent the knowledge of "how to construct the asset" described in the type asset. The grey arcs represent the physical components which are used as physical construction elements. As illustrated on the right side, the startup of the usage stage of a new element is typically linked to the startup of the usage phase of its aggregate.

This is a simple example which is used to demonstrate the linkage between the life cycles of types and instances of aggregates. More detailed models can be found in IEC 62890[5] and [9].

In the environment of operative production processes, the value chains of the assets

- product type,
- process- and plant type,
- product (physical instance), and
- technical plant (physical instance)

are linked together by their artefacts and establish a characteristic production pattern of the involved life-cycle processes (Figure 7).

Classical and future production structures differ significantly with regard to the design of production chains, the tailoring of responsibilities and legal competences, the control and organization of individual value creation processes and the interconnection of organization- and information flows. An example of a traditional "big" manufacturer is illustrated in Figure 8. The manufacturer (grey box) has its own product development and process- and plant engineering division.

This situation is typical for big suppliers in the manufacturing industry and in the process industry.

It is important to mention that the meta model in Figure 7 is a framework which allows all kinds of business organizations surrouding an industrial production process. An example of an individualized production is given in Figure 9. In this example, the production is realized by a 3D printing service company (grey box). This company owns 3D print service machines. The production engineering only involves the placing of these machines onto the shop floor. The production type development is individualized to the users need. It can be realized by a specialized design company or by the user itself (yellow box).

New production concepts can substantially change the complexity of the different process steps, while

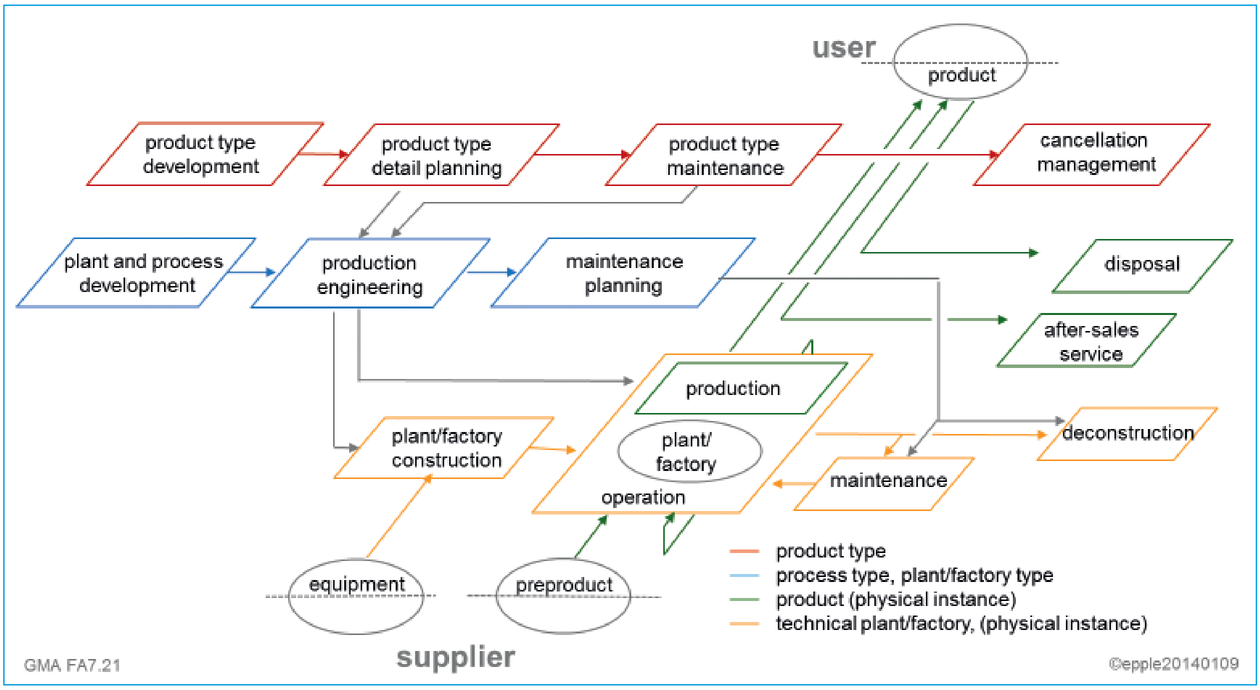

Bild 7. Life-cycle processes – production pattern [11]

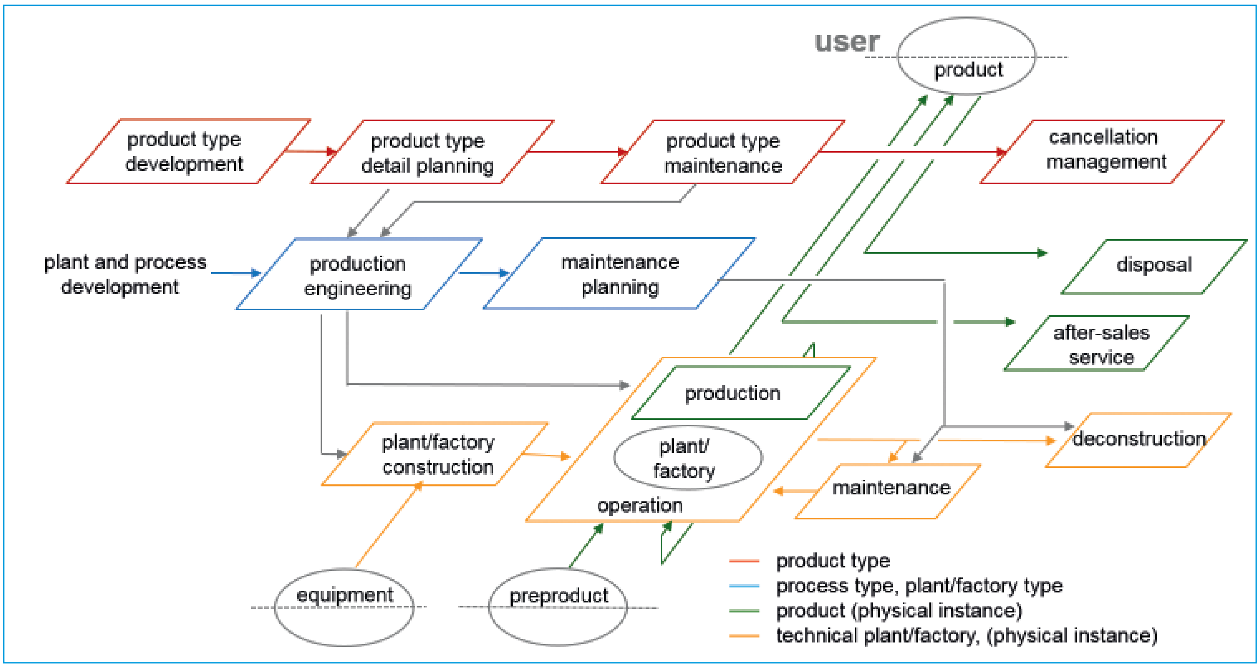

Figure 8. Example: classical manufacturer [11]

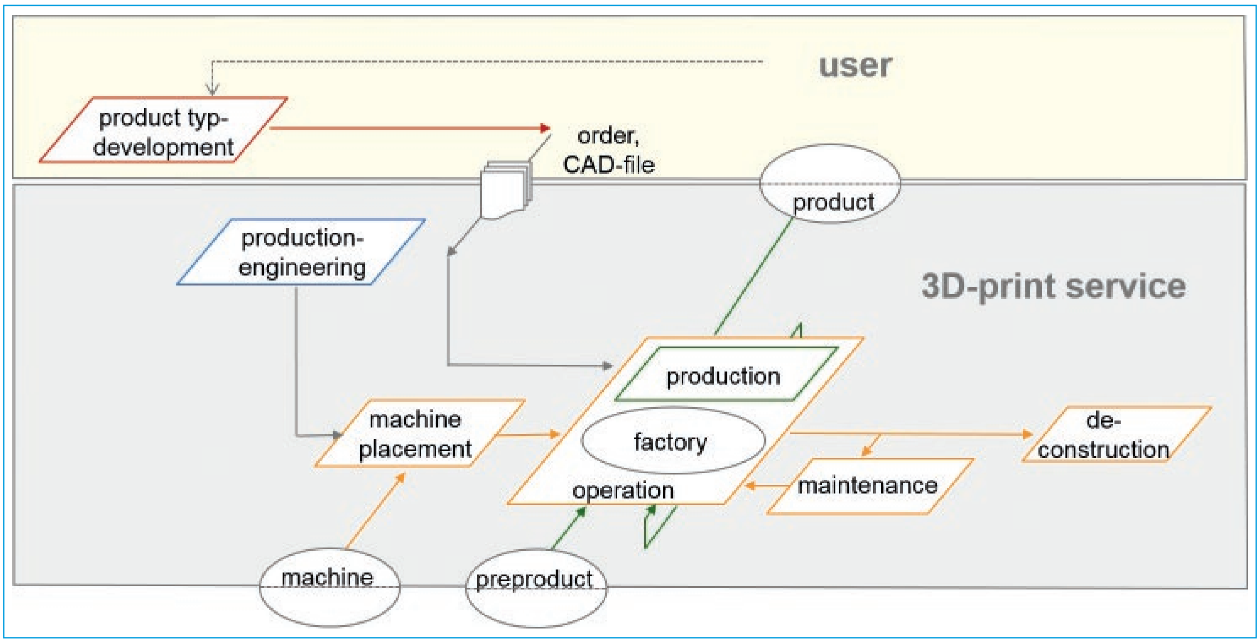

Figure 9. Example: 3D print service [11]

new business concepts can change the assignment of the steps to new types of suppliers. To be prepared for these changes, the processes in the value chain should be modularized and linked by standardized interfaces. Important aspects for the linkage of processes along the value chains, besides the states of the assets, are, for example, the control flow, the cost flow and the documentation flow.

3 Assets as a basis of the RAMI4.0 architecture

The first and basic layer of the RAMI4.0 architecture (Figure 2) comprises the assets themselves [7, 8]. All assets, that is, material as well as immaterial assets can be found at this basic layer. This is a characteristic feature of the RAMI4.0 architecture. Additionally, the RAMI4.0 architecture proposes a schema on how the assets can be ordered. The ordering is based on fundamental and general principles. Unfortunately, these principles are not quite obvious in the axis-description of Figure 2. The basic ideas of the RAMI4.0 axis ordering will be presented in this section.

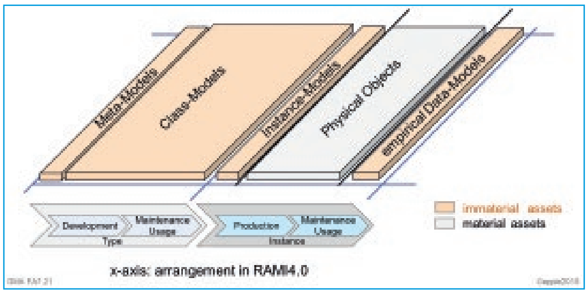

Figure 10. Mapping the asset cate-gories to the x-axis of the RAMI4.0 architecture

3.1 x-axis: ordering by asset categories

In the RAMI4.0 architecture, the assets are sorted by their categories along the x-axis. The presentation distinguishes between "instances" and "types". This denomination is a result of the history of the RAMI4.0 model development. It was one of the main design decisions of the RAMI4.0 architecture to model type descriptions as individual assets (with own life cycles) which are independent from specific products. To highlight this fact, the assets are divided along the x-axis into "types" (type descriptions) and "instances" (specific products).More detailed classification as presented in Figure 5 is used.

As illustrated in Figure 10, these extended asset categories can be mapped directly to the basic types/instances structure of the RAMI4.0 x-axis.

The arcs indicate two different facts.

- Regardless of its category, every asset has its own life cycle (corresponds to Figure 3).
- The life cycle of types and instances are typically linked (corresponds to Figure 6)

It is difficult to show these facts within one axis notation. The explanations given in Chapter 2 help to understand the general idea.

The ordering of the categories along the x-axis follows the main dependencies in the value chains as shown for example in Figure 6 and Figure 7. However, it must be pointed out that the ordering and the shown arcs have nothing to do with the individual life cycle of an asset. Every asset changes its life cycle state dynamically, but it keeps its category and its position on the x-axis unchanged over its whole life cycle.

3.2 y-axis: ordering by roles

An asset belongs to a specific category throughout its entire life cyle but it can play different roles in different technical environments. Roles can change within the life cycle. In a technical environment, there are two basic roles an asset can assume: as equipment as part of a technical system or as a product (or user) of a technical system. This differentiation is a fundamental one, since it follows the basic characteristics of a "technical system" [6] Every intentional system is a technical system. It provides a technical environment in which a technical process can be realized. The goal of the process is to produce, transform, transport or change a product or to serve a user. Within a technical process, users and products have the same role. They are not part of the technical system (plant), but are the objects to which the intended process goals are related. A user uses the system actively by himself, while a product is passive as it is processed by an external client. A cyber physical system (CPS) as an "intelligent" asset can be denominated as product which is processed with the help of its own intelligence, or as user as well.

In the RAMI4.0 model, the assets are ordered along the y-axis with respect to the role they play in the respective environment.

In a first step, they are divided into two parts: The first part contains assets in the role of "products" (or "users"); the second part contains assets in the role of an "equipment". This general classification of the roles is applicable to every kind of technical system: production systems, development systems, buildings, logistic systems and so on. The focus of the RAMI4.0 architecture is the application within industrial production. In this case, the role "equipment" can be classified into more specific units such as "field devices, control devices, stations, work units, enterprises and connected world".

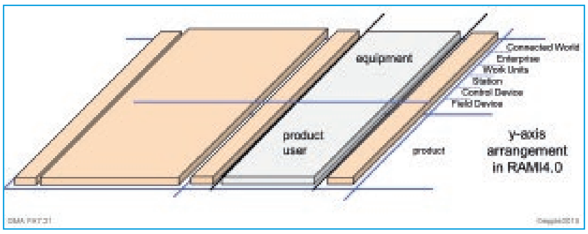

Figure 11. Role-specific arrange-ment of the assets on the y-axis of the RAMI4.0 architecture

Note: The role arrangement schema of the y-axis is primarily relevant for the material assets. Assets of the other categories can only be partly assigned to the slots. This is, for example, not the case for meta models.

All in all, the ordering schema along the y-axis is just a presentation help for fostering an intuitive understanding of the architecture. In case the terms or aggregation steps do not fit into the respective domains, they can easily be readjusted.

3.3 Individual RAMI4.0 instances

RAMI4.0 is an architectural model which can be individually applied in every organizational environment. Every organizational environment has its own RAMI4.0 instance. The asset layer of every RAMI4.0 instance especially contains those assets that are relevant in the specific environment. It can happen that the same item appears as an asset in different RAMI4.0 instances. Figure 12 shows a coffee machine as an example.

The figure shows three organizational environments: the "manufacturer", the "logistic service provider" and "a household". In all three cases the coffee machine is an asset taking part in the technical processes. Therefore, the coffee machine is shown in all three RAMI4.0 instances. The coffee machine is a physical object in each case (categories are unchangeable characteristics) and this determines its position on the x-axis in all three RAMI4.0 instances. In the organization environment of the manufacturer, the coffee machine has the role of a product in the life cycle "production". For the logistic service provider, the coffee machine is just a good that has to be conveyed (cargo). For a logistic service provider, trucks, streets, forklift, platforms are part of the technical system. This system offers transport processes for its products, which are the goods that have to be conveyed. In the organizational environment of the logistics service provider, the coffee machine has the role of a product. The coffee machine is in the life cycle phase "provisioning". After delivery, the coffee machine becomes an asset of "a household". The kitchen can be seen as a technical system (to support cooking processes) and the coffee machine will become a part of it. In this environment, the coffee machine has the role of a system-equipment. It can be seen as a "field device". After the provisioning processes "unpacking", "installation" and "startup", it enters the state "usage".

The example shows that the same item can appear as asset in different RAMI4.0 instances in different roles and different life cycle phases. It demonstrates that the application of the RAMI4.0 architecture can be extended to all organizational environments which use a technical system to fulfill a technical process task. In these cases the wording to denominate the roles and the equipment hierarchy can be adapted to the domain specific usage.

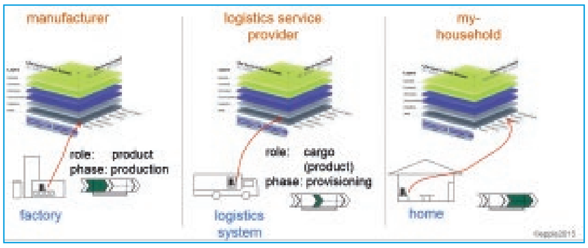

Figure 12. Different RAMI4.0 instances in the coffee machine example.

4 The information world

Within the RAMI4.0 architecture, the physical world is completely allocated in the basic asset layer. All other layers contain immaterial objects of the information world only. The functionality of the layers is described in [7]. This chapter references the asset layer, the integration layer, the communication layer and the information layer. The integration layer describes the different views with regard to the assets in the basic layer. This chapter, for example, uses the views "asset administration" and "asset usage as carrier of information objects". The communication layer links the physical components to the information platform and the information layer comprises all aspects concerning the storage, exchange and processing of information. The information layer contains meta models, models of different abstraction levels and of course the information instances themselves.

4.1 Physical carrier

It should be noted that every immaterial item and thus each "information" needs a physical representation on a physical medium as carrier. Such a medium can be for example a sheet of paper, the brain of a human, a digital mass storage or the core of a computer system (Figure 13).

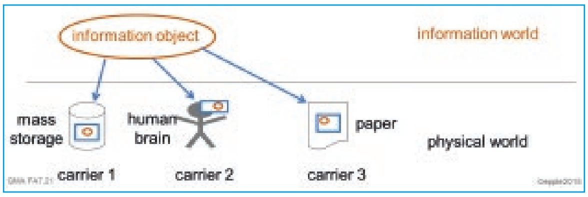

Figure 13. Information object and physical carrier

The character of the physical carrier does not change the content of the information object. For instance, a plan can be stored in the memory of a human being, on a computer as an XML or PDF file, or as a printed version on a piece of paper. However, the information content remains the same in each case. Objects in the information world cannot exist without a physical carrier. The deletion of the carrier would also delete all information that is stored on the carrier. In order to prevent the loss of information, equivalent object images can be stored on multiple different carriers. In that occurrence, this still concerns one information identity. The question of how to store and administrate information on carriers is an important aspect of the information concept.

As shown in Figure 14, humans and computers are able to store, exchange and process information. Other media, like paper are just able to store information.

From an abstract point of view, a general information concept can be used and the technical mapping to the carriers be hidden. However, if we go one step further and search for efficient information models which can be used in the industrial production environment, we have to take into account the principle type of technological system that realizes the physical carriers. The organization and management can be handled by a specific virtualization functionality.

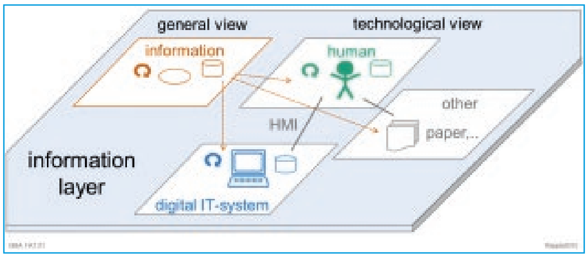

Figure 14. General and technological basis of the information layer

4.2 Digital IT system

Up to this point, no assumptions are made on how the information world is structured and technically realized. All discussed concepts are independent of this structure and realization.

An important focus of I4.0 is the management of information within a digital IT system. In this context, a digital IT system is understood as a system that is formed by the interaction of all information objects within a carrier system which is interconnected via a digital communication system. Within the digital IT system, every information can be accessed at any time (if not restricted by organizational or security reasons). As shown in Figure 12, the digital IT system is only one part of the information world, but, in an I4.0 environment of course a very important part. In the following technological concepts, only information managed within the digital IT system will be considered. In this environment no storage on paper or other non-digitally accessible media is allowed. All information is held in the digital IT system.

5 Administration of assets in the information world

Assets exist by themselves and also have an intrinsic life cycle. This is true for all types of assets and especially physical objects. Both, the existence of the physical assets and their identities, including their states and life cycle, are initially unknown to the information system. Thus, it is a central question of system design to what extent this information is made known to the information system. In Figure 15 the situation is illustrated with respect to the RAMI4.0 layer model.

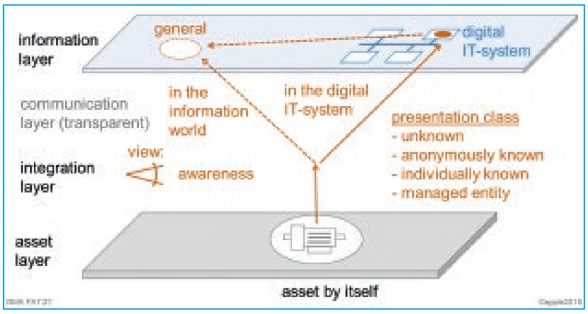

Figure 15. Classifying the awareness of assets by means of presentation classes

The question can be formulated in a general form: “Which information about an asset is known anywhere in the information world?”, or in a specific form: “Which information about an asset is known within a specific subsystem of the information world?” Without loss of generality, we will restrict our considerations to the specific question: “Which information about an asset is known within the digital IT system?” This is an important question in the environment of I4.0.

5.1 Presentation classes of assets in the digital IT system

As shown in Figure 15, the awareness of assets in the digital IT system can be classified into four presentation classes:

- unknown
- anonymously known
- individually known
- managed entity

In an I4.0 environment, it is assumed that immaterial technical assets are per se information objects within the digital IT system (no plans on paper). Therefore, immaterial technical assets are per se at least individually known. Additional administration objects only have to be added for managed entities. For the presentation and awareness of physical assets, special objects have to be added in any case.

5.1.1 Unknown assets

Unknown assets are not known to the information world.

5.1.2 Anonymously known assets

In the case of anonymously but not individually known assets, one can only recognize that an asset of a certain type exists in a certain place within the information world. An example would be a screw in a container. Even if the number of screws in the container is known, no individual properties apart from the general type attributes can be assigned to an individual screw in the container. If an asset that cannot be individually identified is installed in a system, then it will become indirectly identifiable because of its mounting position. When a screw is installed in a certain position within the plant, one can identify whether or not the screw has corroded and needs to be replaced. However, this is only possible as long as the screw is integrated into the plant.

5.1.3 Individually known assets

Individually identifiable assets have an unequivocal name that is known throughout the system. The name is also known in the information world. The system has an identification process at its disposal by means of which the asset can be identified in the physical world and assigned to the corresponding name object. The technology used for the identification process is entirely insignificant for this concept. Thus, the identification may occur by means of an HID code that is physically attached to the object, through the analysis of characteristic physical properties (fingerprints, etc.) or via a systematic and deterministic tracking strategy in the system (coil, batch, etc.). In each case, the detected asset can be clearly assigned to the respective name object in the information world.

5.1.4 Assets as managed entities

Entities are assets which have assigned their own objects in the information world for their administration [6;10]. The administration functionality can provide, for example, functions for the tracking of the asset, the recording of life-cycle information, the operative control of the assets production process and automated monitoring and quality control. Whether or not an object is regarded as an entity is determined by design decisions [6]. As shown in Figure 16, both, assets of the physical world and assets of the information world can be regarded as entities.

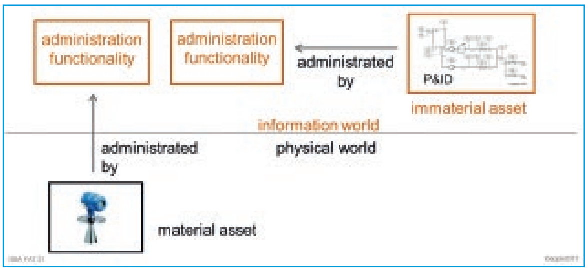

Figure 16. Assets as managed entities

The lefthand side depicts the documentation of a radar probe's life cycle. The radar probe is regarded as an entity and has its own administration functionality. In contrast, the righthand side shows the documentation of the life cycle of a P&I diagram. In the presented case, the P&I diagramm is transformed into an entity and also receives its own administration functionality. In the model pursued, the asset as item is conceptually differentiated from its administration.

5.2 Asset administration shell

The asset administration shell (AAS) is a concept that was designed to organize the administration of assets within the digital IT system [9].

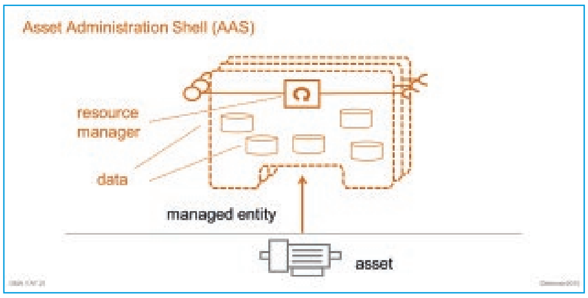

Figure 17. The asset administration shell

The AAS concept (Figure 17) is characterized by the following properties:

- For every asset (see Figure 17), one or more AAS exist.
- Every AAS has exactly one resource manager.
- The resource manager provides services to integrate the AAS into the I4.0 service system.
- The resource manager can be realized on any node in the network.
- An AAS contains a set of information objects which are owned and administrated by the AAS. These information objects can be distributed in the network.
- An AAS can provide active components.
- An AAS can provide links to external information objects.

Typically, a technical item is an asset for different clients, such as the producer, a logistic partner, the user, the service provider and others. Every interested party wants to be in possession of its own administration information about the asset. Of course, some of the data will be exchanged but other data will be held back. The AAS concept allows every interested party to use an own AAS. The principles of information management, service oriented information exchange and the synchronization with the state of the asset can be standardized while the amount of information exchange between the AAS is captured by the specific business model.

6 Physical assets as information carriers

Physical assets are real world resources. They provide abilities to realize real world processes for storage and transportation, or to process material, energy and information. Every physical asset has its special set of abilities. Some of them have the ability to store, process and exchange digital information.

Communication ability

To become part of the digital IT system, these assets must have digital communication abilities and need to be connected to the digital communication network. Figure 18 illustrates this aspect.

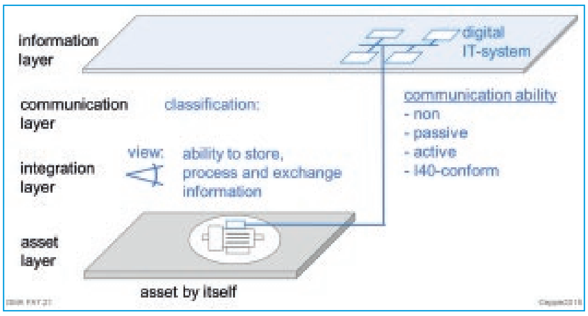

Figure 18. Classification of the communication ability

The communication ability here only refers to the communication in a digital communication system. It can be classified into the communication classes:

- not
- passive
- active
- I4.0-conform

6.1.1 Not able to communicate

A physical unit is not able to communicate in case it does not have any information carrier functionality (screw, conductor, tank, etc.), or in case it does indeed have an information carrier functionality but no digital interface (intelligent conventional washing machine, intelligent (4...20) mA-field device without HART, etc.)

6.1.2 Passive communication ability

A physical unit has passive communication ability in case it has an information carrier that can be read out via system interfaces. Although the information carrier itself is passive, it does allow the extraction of its data and by this mean it also allows, e. g., the identification of objects (RFID, bar code, etc.).

6.1.3 Active communication ability

A physical unit that has the ability to actively participate in network communication can be regarded as a basic component from the perspective of digital communication. The component identifies itself actively upon network contact and also registers itself as a participant of communication traffic.

6.1.4 I4.0-conform communication ability

Assets which provide all abilities of an I40 service system participant are regarded as having I4.0-conform communication ability. This means the following:

- can be identified by a unique name,
- support the generic I4.0 standard-services and states
- provide an adequate protection for data and functions,
- its robustness and availability is suitable for its task
- offers the required real time ability
- supports the standardized I4.0 semantic

7 Assets as parts of the digital IT system

7.1 CP-Classification

The method of administration and thus the presentation class of an object within the information system is independent from its communication ability. Therefore, an important apparatus of the system, like an engine, can be managed as an entity even though it is not able to communicate. The tracing and registration of its life-cycle states must then either occur via external measurement or identification systems, or be realized personally by the involved humans. Naturally, it is advantageous for the administration of an entity when the entity object is at least able to communicate passively (signal interfaces, RFID). However, this is not a necessary prerequisite. The degree of familiarity of an object within the information system can be selected freely for each object and is determined by design decisions. The communication ability supports object administration but is not a requirement for object administration. Contrariwise, a certain level of communication ability does require a sufficient identifiability of the object, or, in other words, a certain degree of familiarity within the information system.

Due to the importance of the communication ability and degree of familiarity, the affiliation of an element with the different classes can be expressed by means of a combined CP-number notation. The acronym CP stands for communication and presentation. This type of notation has proven itself useful e.g. in the domain of IP-protection classes. The structure of the CP-number notation is illustrated in Figure 19.

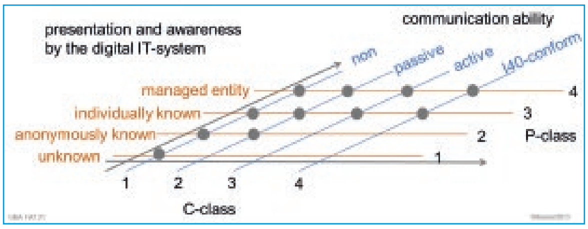

Figure 19. CP-Classification

Hence, the notation CP33 denotes e.g. an individually known component that is able to communicate actively like a classical fieldbus device. A containment that is managed and maintained in its life cycle but has no communication ability whatsoever would receive the CP class "CP14".

7.2 I4.0 component

If an AAS and its asset are connected by the digital communication system, they will together form an I4.0 component. A structural precondition is the classification of the asset as a CP24, CP34 or CP44 device. It must be designed as an entity with an AAS and has to be able to at least join the digital communication as a passive component. As shown in Figure 20, I4.0 components can be built on the basis of material assets as well as on the basis of immaterial assets.

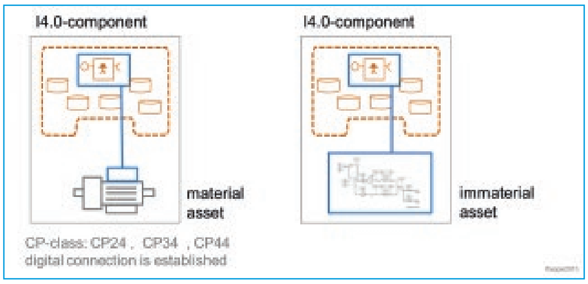

Figure 20. I4.0 components

An extensive description of I4.0 components and their properties can be in [9].

7.3 Onboard resource manager

If the information storage and processing capacity of an asset is strong and flexible enough, then the resource manager can be deployed onto the asset itself.

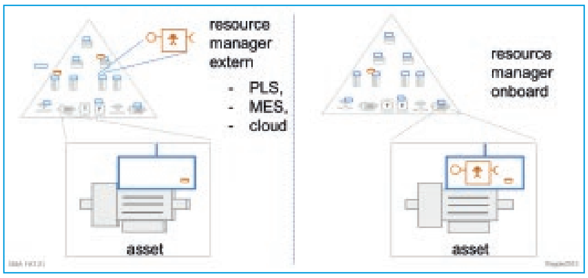

Bild 21. Onboard resource manager

In this case, the AAS can be realized onboard (Figure 21) completely, or split into two parts with one part being realized onboard and another part in the network. Onboard resource managers enable a self-administration functionality and are the basis for CPS and IoT concepts [12; 13].

8 Conclusion

Technical assets are the basic subject matter of I4.0 systems. Reference models describing the characteristics of technical assets seem to be a good starting point for creating the reference model landscape. Even though the technical assets belong to completely different categories in terms of subject matter (Figure 5), they show common characteristic life cycles and can be administrated according to the same meta concepts. If the principle was understood, that a pump can be administrated in the same way as a standard, an electric wiring diagram or a measured data set, the complexity of life cycle management would be significantly reduced and become highly intuitive for us human beings. Although this is just a starting point for an I4.0 system, it is nevertheless urgently required. The stringent differentiation between assets as items by themselves and their presentation in the information world, the separation of presentation in the digital IT system and communication abilities are simple concepts but very helpful to clarify the discussion.

In this report, we focused on technical assets and the digital IT system as carriers of information. Humans, within their role as workers, can be integrated into this technical system as special "material assets". Due to their intelligence and flexibility, they play a special role [4], but in their worker role, they can principally be integrated into a generalized asset concept. Of course, this contemplation does not meet the singularity of human beings at all. As stated in [1; 2] and especially [15], humans play a comprehensive role in the I4.0 vision. I4.0 will change the entire working environment to a significant degree. This affects the processes in development, production, aftersales services and business services, the way we deal with products as users and our approaches to life as well as our social structures. We do not know what the future will bring. From a technical point of view, it seems to be important to keep the systems understandable and controllable by humans. Standardized reference models are very helpful to enforce this understanding. Furthermore, if reference models are implemented in such a way that they remain explicitly visible within the runtime solutions, then they offer the possibility of implementing automated model-based engineering and management functions due to their formal or semi-formal description. This is a starting point for an automated administration of technical assets which will significantly reduce the overall complexity and expenditure.

9 Terminology

Standardization is often referred to as one of the challenges of I4.0. It always begins with the terminology used. Within the framework of I4.0, the languages and terminology of production and ICT (information and communication technology) are merging. There are however historically-based differences and ambiguities in important terms related to I4.0.

The “Terminology” working group of GMA FA 7.21 headed by Dr.-Ing. Miriam Schleipen of the Fraunhofer IOSB is working on putting together a common “basis” (terminology) for I4.0 in the sense of linguistic and conceptual constructs.

Members of the work group are part of FA 7.21; in addition there are other people who – as part of the group – actively contribute terms to the work centred on I4.0 terms. These include representatives of industry and research who are active in the fields of production and ICT.

In many cases, those involved recognize terms as already allocated in their own fields or as evoking certain associations in their minds. These could be definitions which denote different items in the fields of production and ICT, such as the term “services”. Equally prevalent, however, are definitions having different meanings within one of the two domains, such as the term “component”. The corresponding subtleties must be identified and reconciled.

In addition, there are many terms which first arise in connection with the topic of I4.0, such as I4.0 component, I4.0 system or I4.0 platform.

Terms brought in from outside and previously little used in the technical field of automation are also becoming important, such as ecosystem or value network. These are, however, essential in the I4.0 environment and, thus, need to be formulated such that everyone can work with them.

Discussion about terminology is usually a balancing act between a very detailed definition of the topic and an over-generalized and non-specific definition of a term.

Term definitions are, therefore, compiled on the basis of existing norms and standards (IEC, ISO, for example) in the fields of ICT and production. But frequently cited technical publications in relevant fields are also taken into consideration. Definitions are always checked against the relevant dictionaries (such as Duden) in order to rule out misinterpretations as far as possible. Last but not least, contact is made with the corresponding working groups in the various fields, for example, with regard to topics such as security, human-machine interaction or cyber-physical systems (CPS).

Furthermore, definitions of terms should not include a specification of the topic but only a replacement definition of the term itself and be kept as short as possible (no more than 255 characters).

Terms to which reference is made in the definitions and which are not universally applicable will also be included in the terms list.

Proposals for term definitions are drawn up in the working group, and, upon reaching a certain degree of maturity, are passed on to the FA 7.21 for harmonization. A decision is made here whether the term definition should be published or requires revision. Should comments and suggestions be received via the web site after publication, terms will be revised as appropriate. In this way, account can also be taken of feedback from, for example, the ZVEI or the working groups of the platform Industry 4.0.

From time to time, the definitions are checked against glossaries from Switzerland, the USA, Austria, and so on, in order to take current international work in the I4.0 field into consideration as well.

The first 42 term definitions have passed through various stages of development and quality levels and have been approved for publication. Overall a list of approximately 150 terms has been drawn up as a work plan. This list already contains the German terms and their English translation together with a classification under one of the topic areas as well as a prioritization in order to keep work on definitions in compliance with the FA 7.21 work plan.

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The current status (externally communicated, in preparation, awaiting definition) of all terms is continuously updated:

http://i40.iosb.fraunhofer.de/

Sources are cited here and also references to sources from which terms have been derived.

administration shell

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

architecture

combination of elements of a model based on principles and rules for the purpose of its construction, development and utilization

archive world

totality of all information in the information world whose validity or up-to-dateness has expired and which can, thus, no longer be changed

Note 1: Information losing its validity or up-to-dateness is transferred to the archive world.

Note 2: No statement is made regarding the time at which information is transferred from the model world or state world to the archive world.

asset

item which has a value for an organization

choreography between services

(self-organizing) interaction between service users in the context of higher-level specificationscClassification of communication & presentation (CP classification)

classification of communication and identification capability

Note: Because the capability to communicate and the degree of familiarity recognized are so important (communication and presentation-CP), the membership of an element in its respective class can be expressed by a combined CP/numeric notation. A notation of this kind has proved itself useful in the field of IP protection classes, for example.

Example: CP33, for example, corresponds to an individually known component actively capable of communication – in other words, for example, a classic Profibus field device. A safety container which is monitored and managed throughout its life cycle but has no ability to communicate would come under CP class CP14.

cyber-physical system

system which links real (physical) objects and processes with information-processing (virtual) objects and processes via open, in some cases global, and constantly interconnected information networks

Note: A CPS optionally uses services available locally or remotely, has human-machine interfaces, and offers the possibility of dynamic adaptation of the system at runtime.

component manager

the organizer of self-management and of access to the resources of the I4.0 component, for example, I4.0 component, item, technical functionality, virtual representation

Note: In many documents, component manager is referred to as resource manager, but the term component manager should be used in future.

core model

reference model of basic concepts and contexts which concern a general aspect of systems

CPS platform

implementation of a communication and system infrastructure with necessary management and production services and defined QoS (quality of service) characteristics for the efficient construction and integration of CPS for an application domain

cyber-physical production system (CPPS)

CPS which is used in production

entity

uniquely identifiable item which is managed on account of its importance in the information world

horizontal integration

integration within a functional/organizational hierarchical level across system boundaries

human-machine interaction

collaboration between users and technology, such as computers, machines or CPS

Note 1: Implemented by human- and task-oriented technical systems at the interface between users and technology.

Note 2: Includes the analysis, design and evaluation of such systems.

I4.0 component

globally uniquely identifiable participant with communication capability consisting of administration shell and asset (corresponds to CP24, CP34 or CP44) within an I4.0 system which there offers services with defined QoS (quality of qervice) characteristics

Note 1: For its services and data, the I4.0 component offers protection commensurate with the task.

Note 2: An I4.0 component can represent a production system, a single machine or station, or even an assembly within a machine.

I4.0 platform

implementation of a (standardized) communication and system infrastructure with the necessary management and production services and defined QoS (quality of service) characteristics as a basis for the efficient construction and integration of I4.0 systems in an application domain.

Note 1: To ensure interoperability, an I4.0 platform must be based on a reference architecture.

Note 2: An I4.0 platform must define a relation to the I4.0 system.

I4.0 system

system, consisting of I4.0 components and components of a lower CP classification, which serves a specific purpose, has defined properties, and supports standardized services and states

Note 1: A system may be present as a component in a further I4.0 system.

Note 2: An I4.0 system must define a relation to the I4.0 platform.

individual concept

term which represents or designates an individual item or instance

information world (digital world, cyber world)

ideas, thought constructs, algorithms, models, and the totality of representations of physical objects and people in a virtual environment

Note 1: The frame of reference of the totality in question must be defined.

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

interoperability

ability of different components, systems, technologies, or organizations to actively work together for a specific purpose

Note: Interoperation is collaboration put into practice.

item

unit which exists objectively, is demarcated and identifiable

Note 1: An item can be virtual or physical in nature.

Note 2: An item can be a device, subsystem, software program, plan, living organism, organization or the like.

Note 3: An item has a life cycle.

manifest

externally accessible defined set of meta-information, which provides information about the functional and non-functional properties of the I4.0 component

Note: The manifest can be regarded as similar to the manifest in computer science.

model

coherent, sufficiently detailed abstraction of aspects within a field of application

model world

totality of all metadocuments, plans and descriptions in the information world

orchestration of services

flexible connection of individual services for a defined purpose

Note: This can be done during the planning phase and/or at runtime.

physical world

The totality of all actually existing items and individuals

Note 1: The real world corresponds to the physical world.

Note 2: Software loaded or in memory is part of the physical world.

Note 3: The frame of reference of the totality in question must be defined.

plug & work

setting up, modification or termination of interoperation between two or more involved parties with minimal effort

Note 1: The interoperability of those involved is assumed.

Note 2: The minimum effort can vary depending on the state of the art.

Note 3: Plug & play and plug & produce are synonyms or similar terms.

reference architecture

model for a description of the architecture (for I4.0) which is used generally and is recognized as appropriate (with the character of a reference)

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

reference model

model which is used generally and is recognized as appropriate (with the character of a recommendation) in order to derive specific models

security

state which in the technical context covers among other items functional safety, reliability and IT security

Note 1: The German term "Sicherheit" translates to either "security" or "safety" in English.

Note 2: Due to the breadth of this subject area, this term definition will not be treated in greater detail.

service

demarcated scope of functionality which is offered by an entity or organization via interfaces

Note: This definition is not identical to the definition of services provided by the OASIS RM ("services are the mechanism by which needs and capabilities are brought together").

service orientation

paradigm which enables the straightforward exchange, addition or removal of loosely coupled services

smart factory

factory whose degree of integration has reached a level which makes self-organizing functions possible in production and in all business processes relating to production

Note: The virtual representation of the factory makes intelligent decisions possible. The aim is to increase efficiency, effectiveness, flexibility and/or adaptability.

smart product

produced or manufactured (intermediate) product which in a smart factory delivers the (outward) communication capability to network and to interact intelligently with other production participants

Note 1: The product is a produced or manufactured article or semi-finished product.

Note 2: A digital image is part of the product intelligence and can be localized on the product itself but also spatially separate from it.

Note 3: Unique identification and product-related information makes it possible for the product to be linked to the smart factory.

smart production

dialogue between smart factory and smart product

state world

totality of information currently collected in the information world

term

conceptual unit formed by abstraction from a set of items by determining the common properties of these items [DIN 2342-1]

value-added chain

sequence of value-creation processes (linear or hierarchical, formally this means directed acyclically)

Note: Corporate boundaries are not necessarily relevant to a value-creation chain or value chain.

value-added process

process from which goods valuable to customers arise

Note 1: The goods in question may be not only physical in nature (such as raw materials, products) but even intangible (such as knowledge, data, services).

Note 2: Value assessment and pricing are not considered here.

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

value-added system

network or system consisting of value-creation chains or value chains which can include not only cross-connections but also dependencies between them

vertical integration

integration within a system which crosses functional/organizational hierarchy levels

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

Authors

The status report present results of the discussions in the GMA technical committee “Industrie 4.0”. This committee currently focuses on the following aspects: terminology, concepts and reference models for I4.0. The major emphasis is put on consensus-based standardization.

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