Functional Viewpoint of Application Scenario Value-Based Service

DISCUSSION PAPER

In collaboration with

ロボット革命イニシアティブ協議会
Robot Revolution Initiative

STANDARDIZATION COUNCIL INDUSTRIE 4.0

VDI/VDE Society Measurement and Automatic Control

Functional Viewpoint of Application Scenario Value-Based Service

1. Introduction

1.1 Background

In the context of Industrie 4.0 and Connected Industries for some time now, the recognition is aware that – in addition to a technologically driven bottom-up approach – one must complement the topic of digitization in manufacturing industries also by a top-down driven approach. In such a top-down approach the starting point are possible future business scenarios, from which more technically use case descriptions are derived. These use cases are the basis to derive new products, solutions, and services as well as standardization requirements.

It is recognized that the application scenarios of Plattform Industrie 4.0, see [1], provide a representative overview of the new business opportunities in the context of the digitization in manufacturing industries. Therefore, need for action from a methodological point of view is less at the level of the business scenarios, but to now concretize these business scenarios from a technical point of view.

The separate document "Usage Viewpoint of Application Scenario Value-Based Service" developed by VDI/VDE-GMA, Robot Revolution Initiative and Standardization Council Industrie 4.0 see [2], shows some usage views of that particular scenario as examples of the concretization. In order to express how technically a system for such usage cases can be designed, even still in an abstract level, and to identify what technology and/or standards can be used, one more breaking down analysis with functional views is required.

1.2 Objectives

Our goal is to describe on a technical level in the form of use cases the interplay of actors with a technical system. We have set the scope of our consideration according to the application scenario of Plattform Industrie 4.0 "Value-Based Service", see [3], and to usage activities described in "Usage Viewpoint of Application Scenario Value-Based Service" [2].

The first target audience of this document is system designers who want to draw system architecture, function to work and information to share in the system, and necessary interactions between them for Value-Based Service application. Use case descriptions in Clause 3 in this document can be references to those engineers as a design guide, although described steps are not in implementation level.

The second target audience is standard developers who support building, operation and maintenance of such system by providing enhanced and/or newly developed standards. Standard developers may want to promote currently available standards to Value-Based Service business players when their roles are implemented in same scenarios as use cases. Standard developers can also find some requirements for new standardization work out of these use cases, once use case scenarios, or part of the scenarios, seem to be supported by standards which do not exist now.

The Germany-Japan cooperation team works on this requirement analysis together with IEC TC65 Smart Manufacturing standardization activities.

2. Additional Information

2.1 Introduction to IIRA

The Industrial Internet Reference Architecture (IIRA), see [4], provides guidance and assistance in the development, documentation, communication, and deployment of IIoT systems. The corresponding document is primarily for IIoT system architects, which can use the IIRA systematically as an architectural template to define their unique IIoT system requirements and design concrete architectures to address them.

At the core of the IIRA are the so called IIRA viewpoints, see Figure 1:

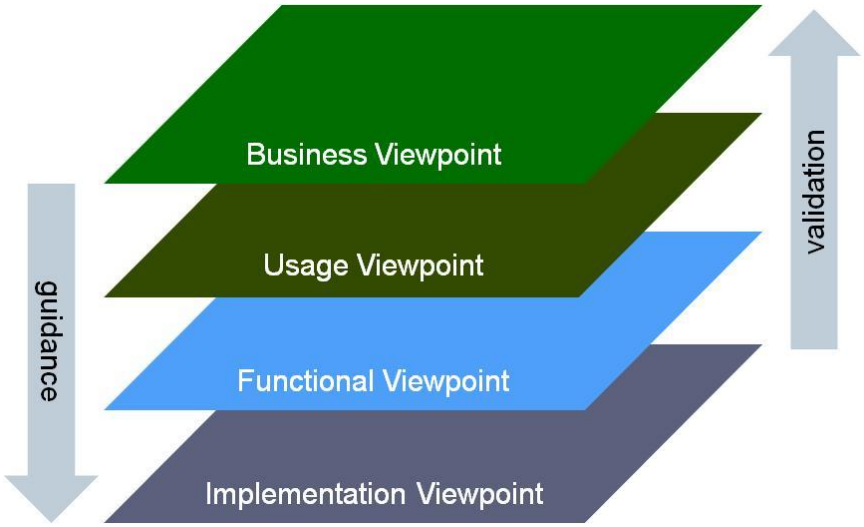


Figure 1: Industrial Internet Architecture Viewpoints (according to [4])

- Business viewpoint – attends to identification of stakeholders and their business vision, values, and objectives in establishing an IIoT system in its business and regulatory context.
- Usage viewpoint – addresses expected system usage. It is typically represented as sequences of activities involving human or logical users that deliver intended functionality to ultimately achieve the fundamental system capabilities.
- Functional viewpoint – focuses on the functional components in an IIoT system, their structure and interrelation, the interfaces and interactions between them, and the relationships and interactions of the system with external elements in the environment, to support the usages and activities of the overall system.
- Implementation viewpoint – deals with the technologies needed to implement functional components, their communication schemes, and their lifecycle procedures. These elements are coordinated by activities (usage viewpoint) and support the system capabilities (business viewpoint).

There are cause and effect dependencies between the viewpoints. Typically a viewpoint guides the design of the viewpoint below and a viewpoint serves for validation of the viewpoint above.

We will use this framework for our description.

2.2 Introduction to Application Scenario Value-Based Service

Today typically a product provider delivers a product to a customer and does not have any feedback from the usage of his product by the customer. The application scenario Value-Based Service is based on the innovation hypothesis that in the future delivered products will be connected to a so-called service platform, data from the usage of the product by the customer will be fed to the service platform, and based on the usage data a service provider can offer (data-driven) value-added services to the customer. Figure 2 illustrates the participating stakeholders, the underlying value network, and the new information flow from the customer to the service platform as the basis for new data-driven services.

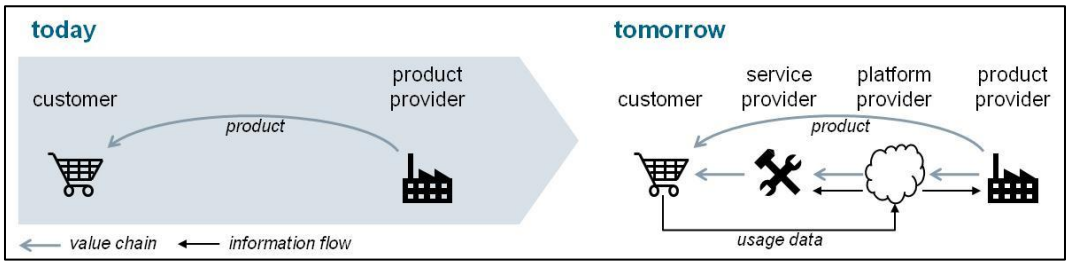


Figure 2: Value-network of application scenario Value-Based Service (Plattform Industrie 4.0)

2.3 Overview of Usage Viewpoint of Application Scenario Value-Based Service

Since the discussions are ongoing we will give a short introduction to the business viewpoint of the application scenario Value-Based Service to keep this document consistent and self explanatory. Figure 3 illustrates how we apply the application scenario Value-Based Service as shown in Figure 2. The product under consideration is a machine. We distinguish two different business stakeholders indicated by the two different colors: the supplier of the machine (green) and the operator of the machine (orange).

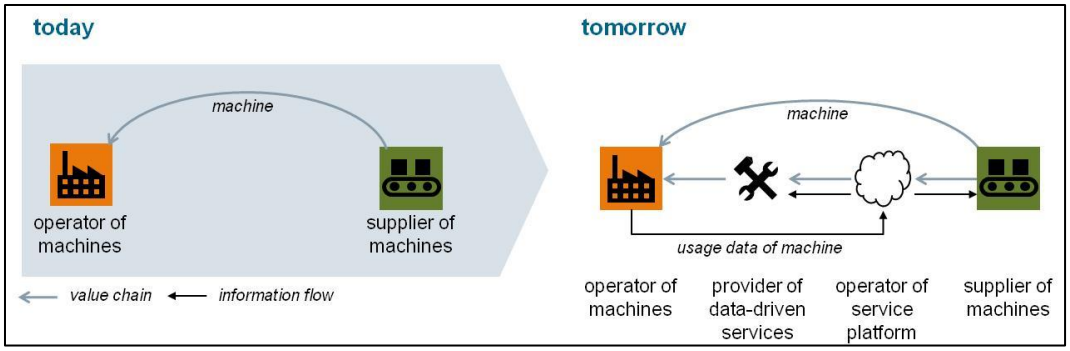


Figure 3: Usage of application scenario Value-Based Service (according to [3])

The application scenario introduces two additional business roles: the operator of the service platform and the provider of data-driven services. Now it has to be discussed who will implement these additional business roles in the future. It would be possible that the existing business stakeholders, namely the supplier of the machine or the operator of the machine, implement these roles, but it is also conceivable that other business stakeholders will do this.

As described in [5] a variety of different business setups is possible. For each business setup there are other value-networks and value propositions. Figure 4 illustrates some of the possible business setups. In this figure same colors indicate that the respective roles are implemented by the same business stakeholder.

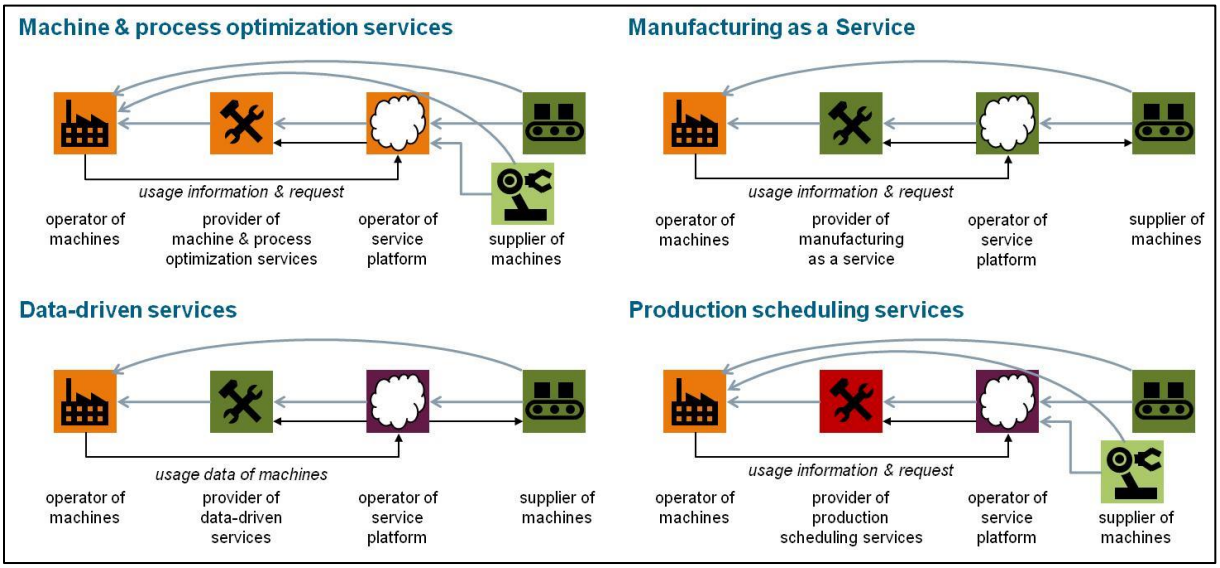
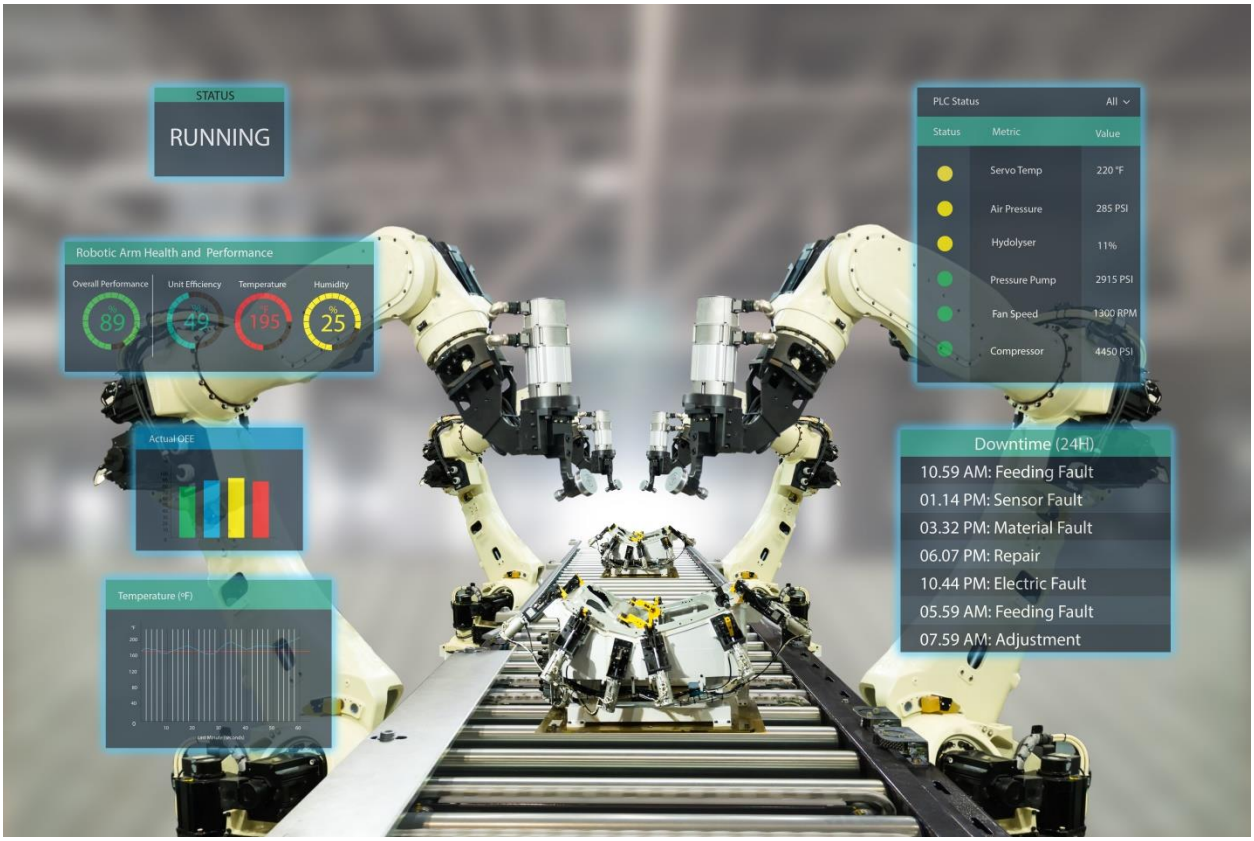


Figure 4: Examples for variety of different business setups (based on [5])



3. Functional Viewpoint of Application Scenario Value-Based Service

3.1 Introduction

In Clause 3, the functional viewpoint of application scenario Value-Based Service is introduced. From this viewpoint, the functional requirements of an IIoT system designed for the application scenario are analyzed regarding each element of the IIoT system, and interactions of actors with the IIoT system are also analyzed in terms of information exchanged.

Figure 5 shows correspondences between the concepts used in the functional viewpoint and relevant concepts appeared in the references such as the usage viewpoint and functional viewpoint of IIRA [4], the usage viewpoint of application scenario Value-Based Service [2], and IEC 62559-2 [6]. How the concepts used in this functional viewpoint are related to (and comparable with) the concepts appeared in the references is summarized below, although each concept is explained in detail later.

- Elements of IIoT system: Elements of IIoT system are crucial in realizing communication and interaction among actors. Similar to the usage viewpoint of application scenario Value-Based Service, the meaning of IIoT system elements are adopted from the IIRA. They are similar to system actors in IEC 62559-2. Their functional requirements are specified in the functional viewpoint presented in this clause.
- Actors: Following the definition in IEC 62559-2, actors are entities that communicate and interact. Actors in the functional viewpoint here are more specifically business actors (e.g., people) and distinguished from system actors (e.g., devices and applications). Actors in the functional viewpoint are also similar to roles in the usage viewpoint of application scenario Value-Based Service. Roles in the usage viewpoint are given in specific scenarios and assumed by parties, which are strongly depending on the business setup and the internal organization of a company involved.

- Scenarios: A scenario describes sequences of activities/processes about interactions among actors. Scenarios in the functional viewpoint mostly correspond to the activities in the usage viewpoint of application scenario Value-Based Service, but some scenarios are extended so that the scenarios can naturally derive some functional requirements of an IIoT system discussed among the authors. The description format of scenarios in the functional viewpoint partly follows the use case template in IEC 62559-2. In particular, requirements regarding functions of the IIoT system and interactions of actors with the IIoT system in terms of information exchanged, are analyzed following the template. In relation to the usage viewpoint and functional viewpoint of IIRA, mapping from scenarios to functional requirements in the functional viewpoint corresponds to mapping from activities to functional components in the IIRA. (Implementation map to implementation components is not considered in the functional viewpoint presented here.)
- Information exchanged: Since application scenario Value-Based Service is concerned with how information obtained from assets in the use stage is utilized for value creation for users and operators of an IIoT system, information exchanged among the actors interacting with the IIoT system is explicitly described. The description format of information exchanged follows the information exchanged in the use case template of ICE 62559-2.
- Requirements: Functional requirements of an IIoT system in context of application scenario Value-Based Service are described regarding each element of the IIoT system. The description format of a functional requirement follows the use case template in IEC 62559-2. These requirements are further mapped to the functional domains introduced in the functional viewpoint of IIRA. Furthermore, some crucial properties of information exchanged (see below) are organized as information requirements.

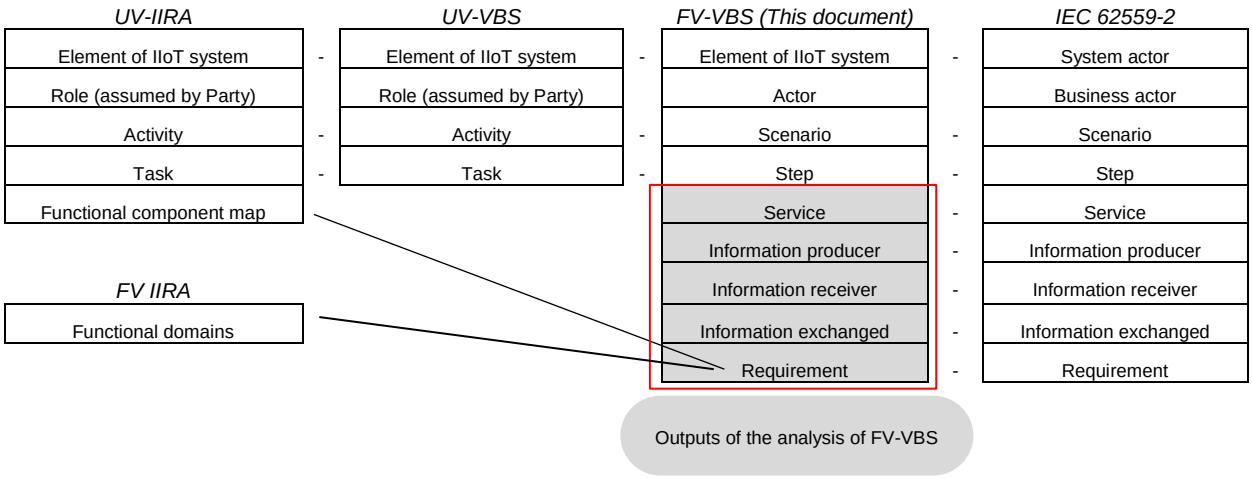


Figure 5: The concepts used in the functional viewpoint analyzed in this document and their relations to part of the usage viewpoint of IIRA (UV-IIRA), the functional viewpoint of IIRA (FV-IIRA), the usage viewpoint of application scenario Value-Based Service (UV-VBS), and the use case template in IEC 62559-2.

In summary, as sub-clause 3.5 and 3.6 in this document show, the main outputs of the analysis of the functional viewpoint are the functional requirements mapped on the functional viewpoint of IIRA and information exchanged using the use case template of IEC 62559-2.

3.2 Elements of IIoT system

Functional requirements of an IIoT system, which are identified and analyzed in the document, are organized regarding each element of the IIoT system. The elements of an IIoT system are consistent with those introduced in the usage viewpoints of application scenario Value-Based Service, namely, connected asset, service platform, and application (See. Figure 6). Selection of these elements does not indicate the architecture of an IIoT system for application scenario Value-Based Service. Various architectures satisfying the functional requirements can be proposed. Nevertheless, the organization of functional re-

quirements with these three elements can be mapped to the three tier IIoT system architecture described in the implementation viewpoint of IIRA [4]. The architecture is composed of the edge tear (i.e., edge nodes such as machines and gateways), the platform tear managing data flow and control flows, and the enterprise tear implementing domain specific applications for end-users of the IIoT system.

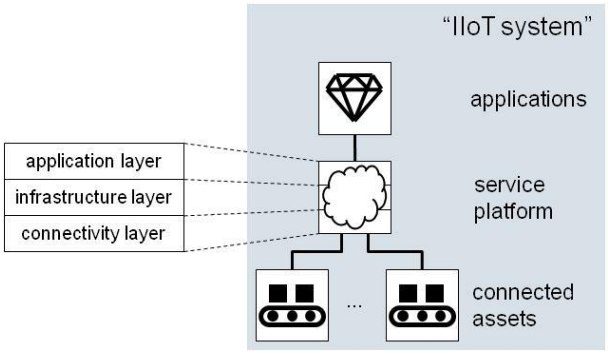


Figure 6:.Elements of an IIoT System for Usage Viewpoint of application scenario Value-Based Service (according to [2])

In practice, there are a number of instances of these elements of an IIoT system (i.e., various types of connected assets and applications with diverse functionality). The description of three elements described here is type (class) description rather than instance description (Service platform can be regarded as a singleton).

Each element of an IIoT system is specified by name and description. It is briefly explained below following the description in the usage viewpoint of application scenario Value-Based Service, and function requirements of each element identified and analyzed in this document are summarized later.

Element name	Description
Connected asset	An integral part of a production system (synonymously factory or plant). The production system has been designed to manufacture (or produce) a product. In addition to this role the production system may be connected to a service platform in order to improve the usage of the asset based on the analysis of usage data of the asset.
Service platform	The center of the logical structure is a so-called *service platform* organized in three layers: • Connectivity layer: This layer offers the capabilities to connect assets distributed all over the world and to collect usage data from the connected assets. We assume that the connection of assets requires similar capabilities as the integration of assets into a technological process, e.g. the integration of machines into a production system. • Infrastructure layer: This layer offers the capabilities to manage and analyze data collected from the connected assets and provides the necessary computing execution capabilities, e.g. cloud infrastructure (public, private, or on-premise). The capabilities for managing and analyzing the data will be offered in form of function blocks to be used by applications. The infrastructure layer offers development capabilities to create such function blocks and to embed function blocks developed outside of the service platform. The creation of such function blocks requires in particular programming and data analytics skills. In addition, the infra-

	structure layer will offer capabilities to configure applications. • Application layer: This layer comprises the various applications. These applications can be configured based on the capabilities provided by the infrastructure layer; furthermore, the applications can be executed based on the execution and computing capabilities of the infrastructure layer. The applications can make use of the data collected from the assets and the data analysis capabilities offered by the function blocks provided by the infrastructure layer. We assume that no specific programming skills are necessary to engineer these applications, i.e. the applications can be created by configuration of the function blocks offered in libraries and it is not necessary to program new function blocks.
Application	The basis from a technical perspective in order to offer data-driven services as described in the business viewpoint.

3.3 Actors

Actors are entities that communicate and interact. Actors are specified by name and description.

- Actor name: It is a unique identifier of each actor. Actor name is also consistently used across all scenarios in this document.
- Actor description: Description of each actor specifying concrete roles, and required qualifications and skills.

It is preferred that actors are commonly used in diverse use cases, as long as their assumed roles are similar. Nevertheless, new actors can be introduced in describing a use case when an actor with appropriate role for the use case are not found in the list of existing actors. (In IEC 62559-2, actors are maintained across diverse use cases in the form of an actor list referred to by diverse use cases.)

Actors can be classified into groups in order to provide a better overview of actors.

- Grouping: Classification of actors
- Group description: Description of each group

The actors used in the functional viewpoint are those used in the usage viewpoint of application scenario Value-Based Service. Similar to the description in the usage viewpoint, the actors are classified into three groups (the term *group* is used in IEC 62559-2, but the term *cluster* is used in the usage viewpoint). Actors in the first group are concerned with the usage of assets (asset is an element (class) of IIoT system explained later). They include operator of an asset, production manager, supplier of an asset, and asset integrator. Actors in the second group are related to the infrastructure layer of the service platform and concerned with the usage of the service platform. They include developer of a function block, operator of the service platform, and computing resource. Actors in the third group are related to the application. Here, asset usage advisor is an actor belonging to the third group.

Actors

Grouping	Group description
Asset usage-related roles	Actors concerned with usage of assets.

Actor name	Actor description

Operator of an asset	This is the operator of an asset, typically a machine or the entire plant. He uses the asset according to a given usage profile and schedule provided by the production manager, monitors the actual process-data related to the asset, guarantees quality assurance with respect to the manufactured product, he executes service and maintenance tasks related to the asset and needs support in case of anomalies (e.g. unplanned events, trends, etc.).
Production manager (of the manufacturing company)	He manages the overall manufacturing process (planning and scheduling of the production), he plans and initiates maintenance activities to keep the assets up to date, he designs and initiates major asset reconfiguration activities triggered by business considerations (e.g. changing the capacity of the plant because of market demands, offering other products to the market, etc.), and finally he decides on and initiates the implementation of recommendations provided by the role “asset usage advisor”.
Supplier of an asset	He is the supplier of the physical asset and is an expert of the (technical) capabilities of the asset.
Asset integrator	He is able to connect an asset to a service platform using the capabilities offered by the connectivity layer of the service platform. The connection is developed based on the specific requirements delivered by some stakeholder, mainly by the production manager. As already mentioned in the description of the connectivity layer of the service platform we assume that the connection of assets re-quires similar capabilities as the integration of assets into a technological process, e.g. the integration of machines into a production system.

Grouping	Group description
Platform-related roles	Actors related to the infrastructure layer of the service platform and concerned with the usage of the service platform

Actor name	Actor description
Developer of a function block	He is able to design, implement, test, and improve a function block using the development capabilities offered by the infrastructure layer of the service platform. He has to combine data analytics skills (analyzing the usage data of the connected assets) and domain knowledge (typically delivered by the supplier and operator of an asset and/or the asset usage advisor) with computer sciences and modeling skills to develop algorithms and integrate the algorithms into a function block.
Operator of the service platform	He manages and operates all capabilities provided by a service platform. This includes support and consulting activities for the usage of the different layers of a service platform.
Computing resource	A computer used to execute applications in an automatic way in order to provide the necessary computing execution capabilities of the service platform.

Grouping	Group description
Application-specific roles	Actors specific to applications

Actor name	Actor description
Asset usage	This is an expert role, who transforms the insights of the technical analysis of the

advisor	usage data of connected assets into some recommendations offered as a service to the operator of the asset. He is involved based on schedule or spontaneously on request. A combination of various expertise is requested, but especially assessment skills are necessary. He has to turn information about an asset into actionable recommendations for the operator of an asset including explaining the benefits and risks of his recommendations. He will be supported by appropriate applications. These applications will be configured by the expert himself using the libraries of function blocks and configuration tools offered by the infrastructure layer of the service platform.

3.4 Scenarios

Scenario consists of several steps indicating interactions (or works) of actors with elements of IIoT system. Each step represents the finest-grained description level of interaction. The concept and description level of scenario and step are consistent with activity and task described in the usage viewpoint of application scenario Value-Based Service as explained below. Functional requirements of an IIoT system, whose usage is described in the usage viewpoint, are clarified through describing and analyzing scenarios.

A scenario is described with Scenario ID and short description. A scenario is described in detail in the steps belonging to each scenario.

- Scenario ID: It is a unique identifier given to each scenario. In this document, Scenario ID is defined by SCN**, where ** is two decimal digits. The number does not specify causality or order of execution.
- Scenario name: It summarizes the interactions of actors with the IIoT system occurred to in this scenario. Scenario name starts with a verb.

The description of scenarios is based on the description of the activities in the usage viewpoint of application scenario Value-Based Service. The correspondence between these descriptions is shown below. The scenarios from SCN01 to SCN05 belong to the setup (configuration) stage, and the scenarios from SCN06 to SCN13 belong to the use (operation and maintenance) stage as introduced in the usage viewpoint. In order to describe some functional requirements of an IIoT system discussed in the author team, the following modifications have been made. .

- Activity “Collection and analysis of usage data of an asset” has been divided to SCN06 and SCN07
- A scenario SCN13 has been introduced.
- SCN11 and SCN12 have been extended.

Activity name appeared in the usage viewpoint of Value-Based Service [2]
Connection of an asset
Reconfiguration of an asset
Configuration of an application
Development of a library of function blocks
Development of a service platform
Collection and analysis of usage data of an asset
Recording additional data on spontaneous request
Operation and maintenance of a service platform
Generation of recommendations resp. requests for action
Execution of recommendation resp. request for action
Benchmarking of assets

Scenario ID	Scenario name
SCN01	Connection of an asset
SCN02	Reconfiguration of an asset
SCN03	Configuration of an application
SCN04	Development of a library of function blocks
SCN05	Development of a service platform
SCN06	Collection of usage data of an asset
SCN07	Analysis of usage data of an asset
SCN08	Recording additional data on spontaneous request
SCN09	Operation and maintenance of a service platform
SCN10	Generation of recommendations resp. requests for action
SCN11	Execution of recommendation resp. request for action
SCN12	Benchmarking of assets
SCN13	Continuous update of an asset model for improving usage data analysis of assets

The contents of each step in a scenario are Step ID, Name, Description, Actors, Requirements, Information producer, Information receiver, and Information exchanged. The contents Name, Description, Requirements, Information producer, Information receiver and Information exchanged correspond are used in the use case template of IEC 62559-2. The content Actors correspond to Roles in each task of activities in the usage viewpoint of application scenario Value-Based Service.

- Step ID: It is a unique identifier given to each step. In this document, Step ID is defined by SCN**-x, where SCN** is the Scenario ID and x is a decimal digit. Unless specified, the digit indicates the natural order of execution of steps in a scenario. The corresponding content in the use case template of IEC 62559-2 is Step No.
- Name: Label that would appear in, for instance, a diagram. Unique label should be assigned to each step in all scenarios considered.
- Description: This describes what action takes place in this step. The focus should be on the behavior of actors and elements of IIoT system, and interactions and information exchanged among them.
- Actors: Name of the actors that interact with other actors (or elements of IIoT system) in this step. The overall role and other characteristics of each actor should be mentioned in the actor list described in Sub-clause 3.3.
- Requirement IDs: IDs of the functional requirements of elements of IIoT system (functional requirements are described in Sub-clause 3.6). Multiple requirements can be given in each step (comma separated in case of multiple requirements). Requirements can be empty in some steps, because interactions among the actors are described in these steps and they do not refer to elements of IIoT system and thus their functional requirements.
- Service: This column identifies the characteristics of the information originated, transferred, or processed in each step in terms of the type of Service. The types of service are introduced in IEC 62559-2 as shown below [6], which is partly derived from IEC 61968-100:2013, 6.2.2 (Service can be empty in case information exchanged is not observed in the corresponding step).
    - CREATE means that an information object is to be created at the Information producer.
    - GET (this is the default value if none is populated) means that the Information receiver requests information from the Information Producer (default).
    - CHANGE means that information is to be updated. The information producer updates the Information receiver's information.
    - EXECUTE is used when a complex transaction is being conveyed using a service, which potentially contains more than one verb.
    - REPORT is used to represent transferral of unsolicited information or asynchronous information flows. Producer provides information to the Receiver.
- Information producer: The value of this column in each step is one of the actors or elements of IIoT system. The role of information producer is specified by the type of service (see above). It can be empty in case Service in the step is not specified.
- Information receiver: See the description in Information producer.
- Information exchanged IDs: This briefly describes information to be exchanged between the two actors – information producer and information receiver. Information exchanged is specified by its ID. The detail of information exchanged is described in Sub-clause 3.5. It is allowed to list several information exchanged in one step, comma separated. The value can be empty in case Service in the step is empty.

SCN01 – Connection of an asset

Step ID	Name	Description	Actors	Requirement IDs	Service	Information producer	Information receiver	Information exchanged IDs
SCN 01-1	Define data to be transferred	Define data to be transferred to service platform (including transfer protocol) based on the requirements of the production manager	asset integrator & supplier of asset	FRca-1, FRca-2	CREATE	Asset integrator (*1)	Asset	InfEx-2, InfEx-3
SCN 01-2	Connect asset to service platform	Connect asset to service platform (including providing configuration capabilities to manage a virtual representation of the asset over its lifecycle in the service platform)	asset integrator	FRca-3, FRca-4	GET	Asset	Service platform	InfEx-1, InfEx-3
SCN 01-3	Provide access to usage data	Provide access to usage data of asset	operator of service platform	FRca-2, FRsp-2	CREATE	Operator of service platform	Service platform	InfEx-3
SCN 01-4	Validate connection	Validate connection of asset	asset integrator & operator of service platform & supplier of asset	FRsp-1	GET	Service platform (*2)	Asset integrator	InfEx-3
SCN 01-5	Accept connection	Acceptance of connection of an asset	asset integrator & production manager	(*3)	GET	Asset integrator	Production manager (*4)	InfEx-3

(*1) Asset integrator receives the requirement from production manager, and transforms the requirement to asset-specific data definition (with help of supplier of asset) in advance.

(*2) Asset communicates with service platform and then asset integrator checks the results of communication (i.e., whether communication is successful or failed).

(*3) In some steps, information is exchanged between actors without involvement of the IIoT system. Function requirements of the IIoT system are not specified in such steps.

(*4) Production manager confirms and accepts the connection of the asset with service platform based on the requirement.

SCN02– Reconfiguration of an asset

Step ID	Name	Description	Actors	Require-ment IDs	Ser-vice	Infor-mation producer	Infor-mation receiver	Information exchanged IDs
SCN 02-1	Identify asset mod-el in ser-vice plat-form	Identify the virtual representation of the asset in the service platform to be reconfigured	Asset integrator (or operator of asset)	FRca-5, FRsp-4	GET	Service platform	Asset integrator (*1)	InfEx-3
SCN 02-2	Reconfig-ure asset	Reconfigure the asset, i.e. execute necessary work to be done with the asset, this includes work in the physical world as well as in the digi-tal world, but no activities related to the service platform	Asset integrator (or operator of asset)	FRca-6, FRca-7	CHA NGE	Asset integrator (*1)	Asset	InfEx-1
SCN 02-3	Update reconfig-ured asset model	Update the virtual representation of the asset in the service platform according to the reconfigu-ration of the asset according to SCN02-2 (in order to be able to deliver the data-driven ser-vices)	Asset integrator (or operator of asset)	FRca-8, FRca-9, FRsp-3, FRsp-4	CHA NGE	Asset integrator (*1)	Service platform	InfEx-1
SCN 02-4	Acknowled ge recon-figuration	Acknowledge the reconfiguration of the asset	Production man-ager (or operator of asset)		GET	Asset integrator (*1)	Produc-tion manager (*1)	InfEx-3

(*1) According to the type of reconfiguration, operator of asset may be able to perform and acknowledge reconfiguration.

SCN03 – Configuration of an application

Step ID	Name	Description	Actors	Require-ment IDs	Ser-vice	Infor-mation producer	Infor-mation receiver	Information exchanged IDs
SCN 03-1	Design application	Design a concept for an application based on the business requirements (traditional design task)	asset usage ad-visor	FRca-1, FRsp-6 (*1)	CRE ATE (*2)	Asset usage advisor	-	InfEx-7, InfEx-8,
SCN 03-2	Configure application	Configure the application using the configuration capabilities offered by the infrastructure layer of the service platform	asset usage ad-visor	FRsp-4,	CHA NGE	Asset usage advisor	Service platform	InfEx-9,
SCN 03-3	Deploy and test appli-cation	Deploy and test the application using the capa-bilities provided by the service platform	asset usage ad-visor	FRsp-4, FRsp-7	GET	Service platform	Asset usage advisor	InfEx-9
SCN 03-4	Improve application	Continuous improvement of the application based on the gained experiences and evolving business requirements (traditional improvement task)	asset usage ad-visor	FRsp-4, FRapp-1	CHA NGE	Asset usage advisor	Service platform	InfEx-7, InfEx-8

(*1) If an application is designed for specific service platform or asset, the specifications of the service platform or asset are necessary in the design process and they should be available to asset usage advisor.

(*2) A design process can be interpreted following the definition of a service type CREATE as “information exchanged (i.e., design concept of an application in this case) is created at (the place of) asset usage advisor”. Same interpretation is used in SCN04-1 and SCN05-01

SCN04 – Development of a library of function blocks

Step ID.	Name	Description	Actors	Require-ment IDs	Ser-vice	Infor-mation producer	Infor-mation receiver	Information exchanged IDs
SCN 04-1	Design function blocks	Design a concept for a library of function blocks based on the business requirements and tech-nological opportunities (traditional design task)	developer of function block	FRapp-2, FRsp-8	CRE ATE	Develop-er of function block	-	InfEx-11, InfEx-12
SCN 04-2	Develop and embed function blocks	Develop the function blocks (or embed function blocks developed outside of the service plat-form) using the development capabilities offered by the infrastructure layer of the service platform	developer of function block	FRsp-4, FRsp-9	CHA NGE	Develop-er of function block	Service platform	InfEx-13
SCN 04-3	Deploy and test func-tion blocks	Deploy and test the library of function blocks based on the capabilities provided by the ser-vice plat-form	developer of function block	FRsp-4, FRsp-9	GET	Service platform	Develop-er of function block	InfEx-13
SCN 04-4	Improve function blocks	Continuous improvement of the library of func-tion blocks based on the gained experiences, new technological opportunities, and evolving business requirements (traditional improvement task)	developer of function block	FRsp-4, FRsp-10	CHA NGE	Develop-er of function block	Service platform	InfEx-11, InfEx-12,

SCN05 – Development of a service platform

Step ID	Name	Description	Actors	Requirement IDs	Service	Information producer	Information receiver	Information exchanged IDs
SCN 05-1	Design service platform	Design a concept for a service platform based on the business requirements and technological opportunities (traditional design task)	Operator of service platform		CREATE	Operator of service platform		InfEx-14, InfEx-15,
SCN 05-2	Develop and implement service platform	Develop the layers of the service platform and implement all required capabilities	Operator of service platform	FRsp-11	CREATE	Operator of service platform	Service platform	InfEx-16
SCN 05-3	Deploy and test service platform	Deploy and test the service platform	Operator of service platform	FRsp-11	GET	Service platform	Operator of service platform	InfEx-16
SCN 05-4	Improve service platform	Continuous improvement of the service platform based on the gained experiences, new technological opportunities, and evolving business requirements (traditional improvement task)	Operator of service platform	FRsp-11, FRsp-12	CHANGE	Operator of service platform	Service platform	InfEx-14, InfEx-15

SCN06 – Collection of usage data of an asset

Step No.	Name	Description	Actors	Requirement IDs	Service	Information producer	Information receiver	Information exchanged IDs
SCN 06-1	Collect usage data by asset	Asset monitors and records its own state (including results of operations performed by operator of asset)	Asset	FRca-6, FRca-10, FRca-11	GET (*1)	Asset	Asset	InfEx-4
SCN 06-2	Collect usage data by operator of asset	Operator of asset records and observes the data of asset (without assuming specific application)	Asset and Operator of asset	FRca-12	GET	Asset	Operator of asset	InfEx-4, InfEx-5
SCN 06-3	Collect usage data by service platform	Asset upload its data to service platform (by scheduled execution of the associated applications such as a data-collection algorithm)	Asset, Service platform and Computing resource	FRca-3, FRca-13, FRsp-13, FRsp-14, FRsp-15, FRapp-3 , FRapp-4, FRapp-5 FRapp-6	GET	Asset	Service platform	InfEx-4

(*1) Collection of usage data of asset by itself is interpreted following the definition of a service type GET that “Asset (as the information receiver) requests information from Asset (as the information producer)

(*2) This step assumes that some assets may not have function to collect its usage data and transfer the data.

SCN07 – Analysis of usage data of an asset

Step ID	Name	Description	Actors	Require-ment IDs	Ser-vice	Infor-mation producer	Infor-mation receiver	Information exchanged IDs
SCN 07-1	Analyze usage data by asset	Asset analyzes its usage data by itself			EX-ECU TE	Asset		InfEx-4
SCN 07-2	Generate an alarm by asset	Asset generates special notification in a case that some threshold is passed (with monitoring and alarm generation applications installed on asset)	Operator of asset or asset usage advisor	FRca-11, FRca-14, FRapp-7,	RE-POR T	Asset	Operator of asset or asset usage advisor	InfEx-6, InfEx-10,
SCN 07-3	Analyze usage data by operator of asset	Operator of asset analyzes the usage data of an asset locally	Operator of asset	FRca-6, FRca-11, FRca-14	EX-ECU TE	Operator of asset		InfEx-4
SCN 07-4	Request analysis of usage data of asset	Operator of asset requests asset usage advisor to analyze asset	Operator of asset & asset usage advisor		RE-POR T	Operator of asset	Asset usage advisor	InfEx-23
SCN 07-5	Generate an alarm by service platform	Service platform generates an alarm in the case that some threshold is passed (with monitoring and alarm generation applications installed on platform)	Computing re-source & asset usage advisor	FRsp-5, FRsp-13, FRsp-15, FRapp-7,	RE-POR T	Service platform	Asset usage advisor	InfEx-10, InfEx-18
SCN 07-6	Analyze usage data by asset usage ad-visor	Asset usage advisor analyzes the usage data of an asset on service platform	Asset usage ad-visor & compu-ting resources	FRsp-4, FRsp-13, FRapp-6	EX-ECU TE	Asset usage advisor		InfEx-4

SCN08 – Recording additional data on spontaneous request

Step ID	Name	Description	Actors	Requirement IDs	Service	Information producer	Information receiver	Information exchanged IDs
SCN 08-1	Request additional data	Request for specific data	Asset usage advisor		REPORT	Asset usage advisor	Operator of asset	InfEx-23
SCN 08-2	Select sensors	Select suitable sensor(s)	Operator of asset	FRca-1				
SCN 08-3	Connect sensors	Connect sensor(s) to asset	Operator of asset	FRca-5				
SCN 08-4	Record additional data	Record required data	Computing resource	FRca-10	GET	Asset (*1)	Computing resource	InfEx-4
SCN 08-5	Provide additional data	Provide recorded data to asset usage advisor	Computing resource	FRsp-15	GET	Computing resource	Asset usage advisor	InfEx-4
SCN 08-6	Disconnect sensors	Disconnect sensor(s) from asset	Operator of asset	FRca-5				
SCN 08-7	Analyze additional data by asset usage advisor	Analyze the additional data (this may require the configuration of appropriate applications)	Asset usage advisor	FRsp-4, FRsp-13, FRapp-6	EXECUTE	Asset usage advisor		InfEx-4

(*1) Additional sensor collects usage data of asset, and the data is eventually sent to computing resource connected with service platform.

SCN09 – Operation and maintenance of a service platform

Step ID	Name	Description	Actors	Require-ment IDs	Ser-vice	Infor-mation producer	Infor-mation receiver	Information exchanged IDs
SCN 09-1	Measure perfor-mance of service platform	Perform measures to guarantee requested ser-vice level of service platform	Operator of ser-vice platform	FRsp-13, FRsp-16	GET	Service platform	Operator of service platform	InfEx-17

SCN10 – Generation of recommendations resp. requests for action

Step ID	Name	Description	Actors	Requirement IDs	Service	Information producer	Information receiver	Information exchanged IDs
SCN 10-1	Generate recommendation	Transforming specific events into a recommendation for resp. request for action by the operator of the asset	Computing resource & asset usage advisor	FRsp-5, FRapp-5, FRapp-7	REPORT	Computing resource	Asset usage advisor	InfEx-18
SCN 10-2	Provide recommendation	Provision of recommendation to production manager or operator of the asset	Asset usage advisor	FRapp-3 (*2)	GET	Asset usage advisor	Production manager (*1)	InfEx-24
SCN 10-3	Discuss recommendation	Discussion of recommendation with production manager or operator of the asset	Asset usage advisor & production manager or operator of asset	FRapp-3 (*2)	GET	Production manager (*1)	Asset usage advisor	InfEx-25
SCN 10-4	Do accounting of recommendation service	Accounting of delivered service	Asset usage advisor & production manager		GET	Production manager	Asset usage advisor	InfEx-29

(*1) Operator of asset may be able to receive and discuss recommendation

(*2) Application run on service platform visualizes recommendations

SCN11 – Execution of recommendation resp. request for action

Step ID.	Name	Description	Actors	Requirement IDs	Service	Information producer	Information receiver	Information exchanged IDs
SCN 11-1	Scheduling execution of actions	Rescheduling of actions of relevant assets following given recommendation (e.g., production scheduling and maintenance scheduling)	Production manager	FRca-13, FRsp-17, FRsp-18	CHANGE	Production manager	Asset (*1)	InfEx-26
SCN 11-2	Request of information for execution of actions	Request of information regarding execution of actions of relevant assets following the given recommendation (e.g., maintenance instruction).	Operator of asset	FRca-13,	GET	Asset	Operator of asset (*2)	InfEx-27
SCN 11-3	Execution of actions	Execution of actions of relevant assets following the given recommendation (e.g., isolation and maintenance of asset)	Operator of asset	FRca-7	EXECUTE	Operator of asset	Asset	(*3)
SCN 11-4	Acknowledgment of execution of actions	Acknowledge execution with respect to asset usage advisor	Production manager or operator of asset	FRapp-3	GET	Production manager	Asset usage adviser	InfEx-28

(*1) Execution schedules of actions of assets may be rescheduled via service platform.(*2) Requested information may be obtained via service platform.(*3) Execution of actions in this step mainly causes physical effects rather than information exchanged.

SCN12 – Benchmarking of assets

Step ID	Name	Description	Actors	Require-quire-ment IDs	Ser-vice	Infor-mation producer	Infor-mation receiver	Information exchanged IDs
SCN 12-1	Provide bench-marking applica-tion	Providing an appropriate benchmarking applica-tion based on management plan (e.g., applica-tion for computing KPIs of facilities, which is used for successive improvement [*kaizen*])	Asset usage advisor		CRE ATE	Asset usage advisor	Compu-ting re-source	InfEx-7
SCN 12-2	Compute actual performance	Transforming the specific information about the usage of an asset into a general performance indicator of the asset	Computing resource	FRca-16, FRapp-5	EX-ECU TE	Compu-ting re-source		InfEx-19
SCN 12-3	Display actual and target per-formances	Provision of the concrete actual and target per-formance indicator value of an asset to the pro-duction manager; this concrete value is related to the (anonymous) distribution of the values of all other comparable connected assets	Computing resource	FRsp-4, FRapp-3, FRapp-5	GET	Compu-ting re-source	Produc-tion manager	InfEx-19, InfEx-20
SCN 12-4	Display perfor-mance distribu-tion	Displaying the computed information via an appropriate dashboard delivered by the bench-marking application	Computing resource & production manager	FRca-17, FRapp-3, FRapp-5	GET	Compu-ting re-source	Produc-tion manager	InfEx-21
SCN 12-5	Recommend improvement plan	Recommendation of improvement plans (i.e., *kaizen* processes) to achieve the target based on displayed information.	Production manager		EX-ECU TE	Asset usage advisor	Produc-tion manager	InfEx-20, InfEx-22
SCN 12-6	Update project plan following recommenda-tions	Updating and execution of the installation plan based on recommendations (e.g., putting *kaizen* process into practice)	Production manager		EX-ECU TE	Produc-tion manager	Asset	InfEx-26
SCN 12-7	Record lesson learned	Recording lesson learned from benchmark in service platform for knowledge sharing and iterative improvement of performance	Production manager	FRsp-14	EX-ECU TE	Produc-tion manager	Service platform	InfEx-22
SCN 12-8	Make payment for benchmark-ing service	Making payment to the data-driven benchmark-ing service provider	Production manager		GET	Produc-tion manager	Asset usage advisor	InfEx-29

SCN13 – Continuous update of asset models for improving usage data analysis of assets

Step ID.	Name	Description	Actors	Require-ment IDs	Ser-vice	Infor-mation producer	Infor-mation receiver	Information exchanged IDs
SCN 13-1	Develop-ment of updated asset mod-el	Continuous update of the digital representation of an asset throughout the life cycle (without assuming specific applications)	Supplier of asset	FRca-9, FRca-15	CRE ATE	Supplier of asset	-	InfEx-1, InfEx-2,
SCN 13-2	Deliver updated asset mod-el	Delivery of the updated digital representation of an asset	Supplier of asset & Asset integra-tor (or operator of asset)	FRca-4	GET	Supplier of asset	Asset integrator (*1)	InfEx-1
SCN 13-3	Reconfig-ure updat-ed asset model	Reconfiguration of the updated digital represen-tation of an asset	Asset integrator (or operator of asset)	FRca-6, FRca-7	CHA NGE	Asset integrator (*1)	Asset	InfEx-1
SCN 13-4	Upload updated asset mod-el	Upload the updated digital representation of asset on the service platform	Asset integrator (or operator of asset)	FRca-8, FRca-9, FRsp-3, FRsp-4	CHA NGE	Asset integrator (*1)	Service platform	InfEx-1

(*1) Similar to SCN02, operator of asset may be able to perform the role of asset integrator

3.5 Information exchanged

The detailed description of information exchanged, which is identified in analyzing scenarios, is shown here. The format of information exchanged follows the format of Information Exchanged in the use case template in IEC 62559-2, which organizes information exchanged as a table with the following columns.

- Information exchanged ID: It is a unique identifier given to each information exchanged. In this document, information exchanged ID is defined by InfEx-Number, where Number is a number (e.g., InfEx-1, InfEx-2, …)
- Name of information exchanged: A name of the information exchanged starting with a noun. Similar to information exchanged ID, names of information exchanged should be unique. It would appear in visualization scheme, for instance, a diagram.
- Description of information exchanged: A detailed description of this information exchanged.
- Requirement IDs: IDs of information requirements referring to information exchanged, and listed in Sub-clause 3.6. Multiple requirements can be given in each information exchanged (comma separated in case of multiple requirements).
- Step IDs: …

Information exchanged ID	Name of information	Description of information exchanged	Requirement IDs	Step IDs
InfEx-1	Asset model	The virtual representation of asset situated in various locations in IIoT system	IR-2	SCN01-2, SCN02-2, SCN02-3, SCN13-1, SCN13-2, SCN13-3, SCN13-4
InfEx-2	Specifications of asset	Specifications of asset regarding e.g., interface, local data storage, local computational power	IR-3	SCN01-1, SCN13-1
InfEx-3	Setup information of asset	Information exchanged during setup between asset and service platform or actor (e.g., identifier of asset, updated configuration of asset)	IR-1, IR-4	SCN01-1, SCN01-2, SCN01-3, SCN01-4, SCN01-5, SCN02-1, SCN02-4
InfEx-4	Usage data of asset	Usage data of asset (e.g., number of production, down time, energy consumption, and evaluation criteria of its performance) that includes effects of operations on asset performed by various actors	IR-2	SCN06-1, SCN06-2, SCN06-3, SCN07-1, SCN07-3, SCN07-6, SCN08-4, SCN08-5, SCN08-7,
InfEx-5	Implicit description about state of asset	State of asset that is not measurable with conventional sensing technology (e.g., abnormality of asset recognized by implicit knowledge of experts)	IR-3	SCN06-2

InfEx-6	Message generated by asset	Message (such as warning, alarm, application specific notification) that are generated by asset (with specific application running)	IR-1, IR-5, IR-6	SCN07-2
InfEx-7	Application	Executable program run on service platform and/or asset	IR-2	SCN03-1, SCN03-4, SCN12-1
InfEx-8	Specifications of application	Specifications of application such as usage of computing power	IR-3	SCN03-1, SCN03-4
InfEx-9	Setup information of application	Information exchanged during setup stage of application (e.g., configuration and test result of application)	IR-1, IR-4	SCN03-2, SCN03-3,
InfEx-10	Output of application	Specific result of applications (e.g., fault prognostics, diagnostics, quality control, etc.)	IR-1, IR-3, IR-5, IR-6	SCN07-2, SCN07-5
InfEx-11	Function blocks	Definition of function blocks used for composing applications run on service platform and information exchanged in developing them	IR-2, IR-3, IR-5	SCN04-1, SCN04-4
InfEx-12	Specifications of function blocks	Specifications of function blocks such as usage of computing power	IR-3	SCN04-1, SCN04-4
InfEx-13	Setup information of function blocks	Information exchanged during setup stage (development, configuration) of function blocks	IR-1, IR-4	SCN04-2, SCN04-3
InfEx-14	Service platform	Design concept and implementation of software platform of service platform including application neutral algorithms run on service platform	IR-2	SCN05-1, SCN05-4
InfEx-15	Specifications of service platform	Specifications of service platform such as condition of usage	IR-3	SCN05-1, SCN05-4
InfEx-16	Setup information of service platform	Information exchanged during setup stage (development, update) of algorithms run on service platform	IR-1	SCN05-2, SCN05-3,
InfEx-17	Performance of service platform	Application-neutral performance of service platform (such as service level, usage of computational resource)	IR-3, IR-4	SCN09-1
InfEx-18	Generic message generated by service platform	Application-neutral message generated and reported by service platform (e.g., generic warning and alarm, performance of service platform, computed recommendation)	IR-1, IR-3, IR-5, IR-6	SCN07-5, SCN10-1
InfEx-19	Actual performance value of	The actual value of performance indicator of asset comparable with	IR-3, IR-4	SCN12-2, SCN12-3

	asset	that of comparable but anonymous assets (e.g., KPIs, smart manufacturing maturity level which include *kaizen* process capability)		
InfEx-20	Target performance value of asset	The target value of performance indicator of asset (see above)	IR-3	SCN12-3, SCN12-5
InfEx-21	Distribution of performance values of assets	Distribution of performance indicator values of assets comparable one another.	IR-3	SCN12-4
InfEx-22	Lesson learned	Knowledge about future actions to improve performance value of asset gained from analysis of asset on service platform	IR-2	SCN12-5, SCN12-7
InfEx-23	Requests of information to actor	Request of information (e.g., additional usage data of asset) to actor , sent from an actor to other actor (outside of the IIoT system)	IR-3	SCN07-4, SCN08-1
InfEx-24	Recommendations	Recommendations generated based on the analysis of usage data of asset	IR-2	SCN10-2
InfEx-25	Evaluation of recommendations	Evaluation of recommendations	IR-3	SCN10-3
InfEx-26	Schedule of actions of asset	Schedule of future actions of asset (e.g., manufacturing order, maintenance tasks) based on recommendations	IR-1, IR-4	SCN11-1, SCN12-6
InfEx-27	Guidance for actions related to asset	Information that helps actor(s) perform actions related to asset (e.g., information for maintenance assistance) based on recommendations	IR-2, IR-3	SCN11-2
InfEx-28	Acknowledgment	Acknowledgement of execution of actions related to an asset (e.g., maintenance) based on recommendations	IR-3	SCN11-4
InfEx-29	Accounting of service	Accounting of service proposed and agreed between actors	IR-3, IR-5	SCN10-4, SCN12-8

3.6 Requirements

In this document, two types of requirements, functional requirements and information requirements, are considered.

First, functional requirements of an IIoT system are described following the format of Requirement in the use case template in IEC 62559-2. These requirements are categorized regarding elements of an IIoT system used in Sub-clause 3.4. These requirements are classified to functional domains introduced in the functional viewpoint of IIRA. The functional domains are, namely, control, operations, information, application, business domains. Data flows and control flows take place in and across functional domains. In the functional viewpoint of IIRA assigns various functions to these five domains as listed below.

- Control domain: Sensing, Actuation, Communication, Entity Abstraction, Modeling, Asset Management, Executor
- Operations domain: Provisioning and Deployment, Management, Monitoring and Diagnostics, Prognostics, Optimization
- Information domain: Data, Analytics
- Application domain: Logics and Rules, APIs and UI
- Business domain: ERP, CRM, PLM, MES, HRM, Asset Management, Service Life Cycle Management, Billing and Payment, Work Planning and Scheduling

Second, necessary properties common to some of information exchanged are organized as information requirements. Information requirements are assigned to information exchanged regardless of the scenarios and steps, in which information exchanged appears.

Requirements are organized in terms of categories. In this document, each category is described with the following information.

- Category ID: Category ID is a number uniquely given to each category.
- Category name: Category name is uniquely given to each category. In this document, the category of functional requirements is defined in terms of elements of IIoT system. Category names are FRca, FRsp, FRapp, in which FR means Functional Requirement, and small capital letters indicate an abbreviation of elements of IIoT system (i.e., ca: connected asset, sp: service platform, and app: application), respectively. Information requirements are organized within a category IR.
- Category description: Brief explanation of this category.

For each category, requirements are specified with requirement ID, requirement name, functional domains, requirement description, and Step ID. The ID, name, and description also appeared in the format of Requirement in the use case template in IEC 62559-2. In addition, function domains are given to each requirement following the functional viewpoint of IIRA. Step ID is a pointer to the description of Scenario in Sub-clause 3.4.

- Requirement ID: It is a unique identifier given to each requirement. In this document, Requirement ID is defined by CategoryName-*, where CategoryName is the name of the category, to which this requirement belongs, and * is a number (e.g., FRca-1, FRsp-2, FRapp-3).
- Requirement name: A name of the requirement, starting with a noun. Similar to requirement ID, requirement names should not be as same as other requirement names.
- Functional domains: This column gives functional domain(s) of the requirement following the functional viewpoint of IIRA. A requirement can be assigned to multiple functional domains (i.e., cross cutting functions). In this case, multiple functional domains can be listed, comma separated.
- Requirement description: A description of requirement.
- Reference: Reference to part of the description in this document, where this requirement is introduced. In case of functional requirements, Step ID appeared in Scenarios (Sub-clause 3.4) is regarded as reference. In case of information requirements, Information exchanged (Sub-clause 3.5) is regarded as reference.

Requirements

Category ID	Category name	Category description		
1	FRca	Functional requirement for connected asset		
Require-ment ID	Requirement name	Functional do-mains	Requirement description	Reference (Step IDs)
FRca-1	Disclosure of speci-fications of asset	Asset manage-ment (Control)	Asset should disclose information about asset (e.g., transferable data types and available data transfer interface).	SCN01-1,SCN03-1,SCN08-2
FRca-2	Controllability in data transfer	Communication (Control)	Asset should be able to (and allow service platform to) authorize and control data transfer from itself to specif-ic actors and vice versa.	SCN01-1,SCN01-3
FRca-3	Data transfer by asset	Communication (Control)	Asset should be capable of data transfer between itself and specific actors (with e.g., data transfer interface)	SCN01-2,SCN06-3
FRca-4	Portability of asset model	Asset manage-ment (Control)	Asset model (i.e., digital representative of asset) should be portable (so that the service platform can timely download and manage asset model.	SCN01-2,SCN13-2
FRca-5	Identifiability of asset	Asset manage-ment (Control)	Asset and its model should be identifiable from service platform and applications.	SCN02-1,SCN08-3, SCN08-6
FRca-6	Capability of asset in receiving mes-sages	APIs and UI (Ap-plication)	Asset should be able to receive external messages or commends sent by actors in various input modes (e.g., APIs, buttons)	SCN02-2,SCN06-1, SCN07-3,SCN13-3
FRca-7	Reconfigurability of asset	Modeling (Con-trol), Asset man-agement (Con-trol)	Asset and its model should be reconfigurable (in re-sponse to implicit change of environment (e.g., opera-tion condition) and explicit messages sent by actors, service platform, and applications	SCN02-2,SCN11-3 SCN13-3
FRca-8	Consistency be-tween asset and asset model	Data (Infor-mation)	Consistency should be maintained between an asset and its digital representation in the service platform	SCN02-3,SCN13-4

FRca-9	Compatibility of asset model with various versions	Data (Information)	Asset should allow existence of various versions of asset model (for providing an appropriate model version according to specification of applications).	SCN02-3,SCN13-1, SCN13-4
FRca-10	Temporary storage of usage data	Data (Information)	Asset should be able to store usage data of asset (incl. data collected with additional sensors) and other information possessed by asset.	SCN06-1,SCN08-4
FRca-11	Capability of asset in executing applications	Executor (Control)	Asset should be able to execute applications (e.g., data collection, monitoring) based on the given schedule or conditions.	SCN06-1,SCN07-2, SCN07-3
FRca-12	Observability of asset	Sensing (Control)	Asset should make its state observable according to the interest of operator of machine	SCN06-2
FRca-13	Capability of asset in scheduling actions of asset	Executor (Control)	Asset should enable service platform and application to schedule authorized actions of asset (e.g., data transfer, application execution, machining tasks).	SCN06-3,SCN11-1, SCN11-2
FRca-14	Capability of asset in reporting state of asset	APIs and UI (Application)	Asset should be able to report messages to authorized target actors (sometimes through service platform and applications)	SCN07-2,SCN07-3
FRca-15	Updatability of asset	Asset management (Control), Modeling (Control)	Asset and its model should be upgradable throughout the life cycle	SCN13-1
FRca-16	Comparability of asset	Monitoring and diagnostics (Operations), Prognostics (Operations)	Asset should provide data useful for comparison of it with the other assets.	SCN12-2
FRca-17	Anonymity of asset	Asset management (Control)	Asset should be able to assure and control anonymity	SCN12-4

Category ID	Categories for requirements	Category description		
2	FRsp	Functional requirement for service platform		
Require-	Requirement name	Functional do-	Requirement description	Reference (Step IDs)

ment R-ID		mains		
FRsp-1	Verifiability of connections between asset and service platform	Provisioning and Deployment (Operations)	Service platform should provide capabilities in verifying connection between asset and service platform (without special skills)	SCN01-4
FRsp-2	Controllability of data transfer by service platform	Data (Information)	Service platform should provide capabilities for configuring data access and transfer between asset and service platform	SCN01-3
FRsp-3	Management of various versions of asset models	Data (Information)	Service platform should provide capabilities to update and manage various versions of asset models (easily for actors without special skills)	SCN02-3,SCN13-4
FRsp-4	Configurability of service platform by receiving messages	APIs and UI (Application)	Service platform should possesses user interface to allow definition, reconfiguration (by receiving message), and acknowledgement, and analysis of information (e.g., application, function blocks, asset model, usage data of an asset etc.) in service platform	SCN02-1, SCN02-3, SCN03-2, SCN03-3, SCN03-4, SCN04-2, SCN04-3, SCN04-4, SCN07-6, SCN08-7, SCN12-3, SCN13-4
FRsp-5	Capability of service platform in sending messages	APIs and UI (Application)	Asset should be able to (autonomously) send messages to authorized target actors (sometimes through connected assets and applications)	SCN07-5, SCN10-1
FRsp-6	Disclosure of specifications of service platform	Provisioning and Deployment (Operations)	Service platform should provide its specifications to authorized actors (regarding e.g., function blocks library for developing applications)	SCN03-1
FRsp-7	Verifiability of functions of applications	Provisioning and Deployment (Operations)	Service platform should provide environment to verify functions of application	SCN03-3
FRsp-8	Basic analytical functionality of function blocks	Monitoring and Diagnostics (Operations), Prognostics (Operations), Analytics (Information)	Service platform should provide function blocks for basic data analytics on which application-specific algorithms are built.	SCN04-1
FRsp-9	Function block development and testing	APIs and UI (Application), Analytics (Information)	Service platform should provide environment (application) to develop and test function blocks used for building application	SCN04-2, SCN04-3

FRsp-10	Updatability of function blocks	Management (Operations)	Service platform should make its function blocks updatable, while maintaining execution of application built with old function blocks.	SCN04-4
FRsp-11	Service platform development and testing	APIs and UI (Application), Analytics (Information)	Service platform should provide environment for developing and testing itself	SCN05-2, SCN05-3, SCN05-4
FRsp-12	Updatability of service platform	Management (Operations)	Service platform should be updatable	SCN05-4
FRsp-13	Runtime adaptability of service platform	Management (Operations)	Service platform should be able to execute applications (e.g., data collection, alarm generation, analysis) considering the availability of power of computing resource	SCN06-3, SCN07-5, SCN07-6 ,SCN08-7, SCN09-1
FRsp-14	Maintainability of collected information	Data (Information)	Service platform should be able to store and organize collected information such as the usage data of assets for executing applications through life cycle of assets and the history of recommendations and decisions performed by actors	SCN06-3, SCN12-7
FRsp-15	Data transfer by service platform	Data (Information)	Service platform should provide information transfer between service platform and an asset	SCN06-3, SCN07-5, SCN08-5
FRsp-16	Measurability of performance of service platform	Management (Operations)	Service platform should provide performance measures (regarding e.g., service level)	SCN09-1
FRsp-17	Temporal consistency among connected assets	Management (Operations)	Service platform should be able to maintain temporal consistency among connected assets	SCN11-1
FRsp-18	Interoperability of service platform in business domain	ERP, PLM, Asset management (Business)	Service platform should be able to communicate with systems in business domain (e.g., ERP, PLM)	SCN11-1

Category ID	Categories for requirements	Category description		
3	FRapp	Functional requirement for application		
Requirement R-ID	Requirement name	Functional domains	Requirement description	Reference (Step IDs)

FRapp-1	Updatability of application	Management (Operation)	Application should be updatable through its life cycle	SCN03-4
FRapp-2	Composability of application	Data, Analytics (Information)	Application should be composed of functional blocks offered by the service platform	SCN04-1
FRapp-3	Configurability of application	APIs and UI (Application)	Application should provide user interface to define data acquisition schedule, data analysis schedule, and reporting condition (e.g., threshold or schedule) and show (visualize) its output information (e.g., recommendation) so that the output information of actors' interest is interpretable by actors	SCN06-3, SCN10-2, SCN10-3, SCN11-4, SCN12-3, SCN12-4
FRapp-4	Runtime adaptability of application	Logic & Rules (Application), Management (Operations)	Application should be adaptable to changing the availability of power of computing resource and service platform-specific characteristics.	SCN06-3
FRapp-5	Application specific functionality	Logic & Rules (Application), Optimization (Operations)	Application should be able to run algorithms with application-specific functionality (e.g., data collection, analysis, recommendation, benchmarking) as expected in time.	SCN06-3,SCN10-1, SCN12-2, SCN12-3, SCN12-4
FRapp-6	Disclosure of specifications of applications	Provisioning and Deployment (Operations)	Application should provide its specifications to service platform (regarding e.g., usage of computational power and memory) and authorized actors (regarding e.g., reliability and response time) in advance of its execution	SCN06-3, SCN07-6, SCN08-7
FRapp-7	Capability of application in reporting messages	APIs and UI (Application)	Application should be able to report messages to authorized target actors (sometimes through service platform and connected assets)	SCN07-2, SCN07-5, SCN10-1

Category ID	Categories for requirements	Category description		
4	IR	Requirement related to information exchanged		
Requirement ID	Requirement name	Functional domains	Requirement description	Reference (Information exchanged ID)
IR-1	Validity	Actuation (Control), Executor	Conformity of information exchanged regarded as input data of IIoT system element should be carefully	InfEx-3, InfEx-6, InfEx-9, InfEx-10, InfEx-13, InfEx-

		(Control)	validated regarding the format and contents, both expected and unexpected.	16, InfEx-18, InfEx-26
IR-2	Intellectual property		Intellectual property of information exchanged should be protected. (e.g., License, Patent)	InfEx-1, InfEx-4, InfEx-7, InfEx-11, InfEx-14, InfEx-22, InfEx-24, InfEx-27
IR-3	Presentation	Modeling (Control), APIs and UI (Application)	Information exchanged that may be presented to actors should be shown in useful and ergonomic way.	InfEx-2, InfEx-5, InfEx-8, InfEx-10, InfEx-11, InfEx-12, InfEx-15, InfEx-17, InfEx-18, InfEx-19, InfEx-20, InfEx-21, InfEx-23, InfEx-25, InfEx-27, InfEx-28, InfEx-29
IR-4	Privacy	Data (Information)	Privacy of information exchanged that may data and know-hows owned by specific actors should be protected. (Information exchanged should be accessible by authorized actors).	InfEx-3, InfEx-9, InfEx-13, InfEx-17, InfEx-19, InfEx-26
IR-5	Generality	Modeling (Control)	Information exchanged should be independent of specific applications and use cases.	InfEx-6, InfEx-10, InfEx-11, InfEx-18, InfEx-29
IR-6	Notifiability	APIs and UI (Application)	Generation of information exchanged should be explicitly notified to intended information receivers (e.g., alarms)	InfEx-6, InfEx-10, InfEx-18

Annex A.

A.1 Relationship between steps and functional requirements (matrix version)

Step ID	Name	FRca-1 Disclosure of specifications of asset	FRca-2 Controllability in data transfer	FRca-3 Data transfer by asset	FRca-4 Portability of asset model	FRca-5 Identifiability of asset	FRca-6 Capability of asset in receiving messages	FRca-7 Reconfigurability of asset	FRca-8 Consistency between asset and asset model	FRca-9 Compatibility of asset model with various versions	FRca-10 Temporary storage of usage data	FRca-11 Capability of asset in executing applications	FRca-12 Observability of asset	FRca-13 Capability of asset in scheduling actions of asset	FRca-14 Capability of asset in reporting state of asset	FRca-15 Updatability of asset	FRca-16 Comparability of asset	FRca-17 Anonymity of asset	FRsp-1 Verifiability of connections between asset and service platform	FRsp-2 Controllability of data transfer by service platform	FRsp-3 Management of various versions of asset models	FRsp-4 User interface of service platform	FRsp-5 Capability of service platform in sending messages	FRsp-6 Disclosure of specifications of service platform	FRsp-7 Verifiability of functions of applications	FRsp-8 Basic analytical functionality of function blocks	FRsp-9 Function block development and testing	FRsp-10 Updatability of function blocks	FRsp-11 Service platform development and testing	FRsp-12 Updateability of service platform	FRsp-13 Runtime adaptability of service platform	FRsp-14 Maintainability of usage data of assets	FRsp-15 Data transfer by service platform	FRsp-16 Measurability of performance of service platform	FRsp-17 Temporal consistency among connected assets	FRsp-18 Interoperability of service platform in business domain	FRapp-1 Updatability of application	FRapp-2 Composability of application	FRapp-3 Configurability of application	FRapp-4 Adaptability of application	FRapp-5 Application specific functionality	FRapp-6 Disclosure of specifications of applications	FRapp-7 Capability of application in reporting messages
SCN01-1	Define data to be transferred	○	○																																							
SCN01-2	Connect asset to service platform			○	○																																					
SCN01-3	Provide access to usage data		○																	○																						
SCN01-4	Validate connection																		○																							
SCN01-5	Accept connection																																									
SCN02-1	Identify asset model in service platform					○																○																				
SCN02-2	Reconfigure asset						○	○																																	
SCN02-3	Update reconfigured asset model								○	○											○	○																				
SCN02-4	Acknowledge reconfiguration																																								
SCN03-1	Design application	○																						○																	
SCN03-2	Configure application																						○																		
SCN03-3	Deploy and test application																						○			○															
SCN03-4	Improve application																						○															○			
SCN04-1	Design function blocks																										○											○			
SCN04-2	Develop and embed function blocks																						○					○													
SCN04-3	Deploy and test function blocks																						○					○													
SCN04-4	Improve function blocks																						○						○												
SCN05-1	Design service platform																																									
SCN05-2	Develop and implement service platform																													○											
SCN05-3	Deploy and test service platform																													○											
SCN05-4	Improve service platform																													○	○										
SCN06-1	Collect usage data by asset						○				○	○																														
SCN06-2	Collect usage data by operator of asset												○																													
SCN06-3	Collect usage data by service platform			○										○																		○	○	○					○	○			○	○	
SCN07-1	Analyze usage data by asset																																								
SCN07-2	Generate an alarm by asset											○			○																											○
SCN07-3	Analyze usage data by operator of asset						○					○			○																											
SCN07-4	Request analysis of usage data of asset																																								
SCN07-5	Generate an alarm by service platform																							○								○			○							○
SCN07-6	Analyze usage data by asset usage advisor																						○									○								○		
SCN08-1	Request additional data																																									
SCN08-2	Select sensors	○																																								
SCN08-3	Connect sensors					○																																			
SCN08-4	Record additional data										○																															
SCN08-5	Provide additional data																																				○					
SCN08-6	Disconnect sensors					○																																			
SCN08-7	Analyze additional data by asset usage advisor																						○									○								○		
SCN09-1	Measure performance of service platform																															○			○							
SCN10-1	Generate recommendation																							○															○			○
SCN10-2	Provide recommendation																																						○			
SCN10-3	Discuss recommendation																																						○			
SCN10-4	Do accounting of recommendation service																																									
SCN11-1	Scheduling execution of actions													○																						○	○					
SCN11-2	Request of information for execution of actions													○																												
SCN11-3	Execution of actions							○																																		
SCN11-4	Acknowledgment of execution of actions																																						○			
SCN12-1	Provide benchmarking application																																									
SCN12-2	Compute actual performance																	○																						○		
SCN12-3	Display actual and target performances																						○																○	○		
SCN12-4	Display performance distribution																		○																				○	○		
SCN12-5	Recommend improvement plan																																									
SCN12-6	Reschedule and execute improvement plan																																									
SCN12-7	Recording improvement plan																																				○					
SCN12-8	Do accounting of benchmarking service																																									
SCN13-1	Development of updated asset model									○						○																										
SCN13-2	Deliver updated asset model				○																																					
SCN13-3	Reconfigure updated asset model						○	○																																		
SCN13-4	Upload updated asset model								○	○												○	○																			

A.2 Relationship between steps and information exchanged (matrix version)

Step ID	Name	InfEX-1 Asset model	InfEX-2 Specifications of asset	InfEX-3 Setup information of asset	InfEX-4 Usage data of asset	InfEX-5 Implicit description about state of asset	InfEX-6 Message generated by asset	InfEX-7 Application	InfEX-8 Specifications of application	InfEX-9 Setup information of application	InfEX-10 Output of application	InfEX-11 Function blocks	InfEX-12 Specifications of function blocks	InfEX-13 Setup information of function blocks	InfEX-14 Service platform	InfEX-15 Specifications of service platform	InfEX-16 Setup information of service platform	InfEX-17 Performance of service platform	InfEX-18 Generic message generated by service platform	InfEX-19 Actual perfor-mance value of asset	InfEX-20 Target performance value of asset	InfEX-21 Distribution of performance values of assets	InfEX-22 Lesson learned	InfEX-23 Requests of information to actor	InfEX-24 Recommendations	InfEX-25 Evaluation of recommendations	InfEX-26 Schedule of actions of asset	InfEX-27 Guidance for actions related to asset	InfEX-28 Acknowledgment	InfEX-29 Accounting of service
SCN01-1	Define data to be transferred		○	○																										
SCN01-2	Connect asset to service platform	○		○																										
SCN01-3	Provide access to usage data			○																										
SCN01-4	Validate connection			○																										
SCN01-5	Accept connection			○																										
SCN02-1	Identify asset model in service platform			○																										
SCN02-2	Reconfigure asset	○																												
SCN02-3	Update reconfigured asset model	○																												
SCN02-4	Acknowledge reconfiguration			○																										
SCN03-1	Design application							○	○																					
SCN03-2	Configure application									○																				
SCN03-3	Deploy and test application									○																				
SCN03-4	Improve application							○	○																					
SCN04-1	Design function blocks											○	○																	
SCN04-2	Develop and embed function blocks													○																
SCN04-3	Deploy and test function blocks													○																
SCN04-4	Improve function blocks											○	○																	
SCN05-1	Design service platform														○	○														
SCN05-2	Develop and implement service platform																○													
SCN05-3	Deploy and test service platform																○													
SCN05-4	Improve service platform														○	○														
SCN06-1	Collect usage data by asset				○																									
SCN06-2	Collect usage data by operator of asset				○	○																								
SCN06-3	Collect usage data by service platform				○																									
SCN07-1	Analyze usage data by asset				○																									
SCN07-2	Generate an alarm by asset						○				○																			
SCN07-3	Analyze usage data by operator of asset				○																									
SCN07-4	Request analysis of usage data of asset																							○						
SCN07-5	Generate an alarm by service platform										○								○											
SCN07-6	Analyze usage data by asset usage advisor				○																									
SCN08-1	Request additional data																							○						
SCN08-2	Select sensors																													
SCN08-3	Connect sensors																													
SCN08-4	Record additional data				○																									
SCN08-5	Provide additional data				○																									
SCN08-6	Disconnect sensors																													
SCN08-7	Analyze additional data by asset usage advisor				○																									
SCN09-1	Measure performance of service platform																	○												
SCN10-1	Generate recommendation																		○											
SCN10-2	Provide recommendation																								○					
SCN10-3	Discuss recommendation																									○				
SCN10-4	Do accounting of recommendation service																													○
SCN11-1	Scheduling execution of actions																										○			
SCN11-2	Request of information for execution of actions																											○		
SCN11-3	Execution of actions																													
SCN11-4	Acknowledgment of execution of actions																												○	
SCN12-1	Provide benchmarking application							○																						
SCN12-2	Compute actual performance																			○										
SCN12-3	Display actual and target performances																			○	○									
SCN12-4	Display performance distribution																					○								
SCN12-5	Recommend improvement plan																				○		○							
SCN12-6	Reschedule and execute improvement plan																										○			
SCN12-7	Recording improvement plan																						○							
SCN12-8	Do accounting of benchmarking service																													○
SCN13-1	Development of updated asset model	○	○																											
SCN13-2	Deliver updated asset model	○																												
SCN13-3	Reconfigure updated asset model	○																												
SCN13-4	Upload updated asset model	○																												

A.3 Relationship between information requirements and information exchanged (matrix version)

		Asset model	Specifications of asset	Setup information of asset	Usage data of asset	Implicit description about state of asset	Message generated by asset	Application	Specifications of application	Setup information of application	Output of application	Function blocks	Specifications of function blocks	Setup information of function blocks	Service platform	Specifications of service platform	Setup information of service platform	Performance of service platform	Generic message generated by service platform	Actual performance value of asset	Target performance value of asset	Distribution of performance values of assets	Lesson learned	Requests of information to actor	Recommendations	Evaluation of recommendations	Schedule of actions of asset	Guidance for actions related to asset	Acknowledgment	Accounting of service
Information Requirement ID	Requirement description	InfEX-1	InfEX-2	InfEX-3	InfEX-4	InfEX-5	InfEX-6	InfEX-7	InfEX-8	InfEX-9	InfEX-10	InfEX-11	InfEX-12	InfEX-13	InfEX-14	InfEX-15	InfEX-16	InfEX-17	InfEX-18	InfEX-19	InfEX-20	InfEX-21	InfEX-22	InfEX-23	InfEX-24	InfEX-25	InfEX-26	InfEX-27	InfEX-28	InfEX-29
IR-1	Validity			○			○			○	○			○			○		○								○			
IR-2	Intellectual property	○			○			○				○			○								○		○			○		
IR-3	Presentation		○			○			○		○	○	○			○		○	○	○	○	○		○		○			○	○	○
IR-4	Privacy			○						○				○				○		○							○				
IR-5	Generality						○				○	○							○												○
IR-6	Notifiability						○				○								○												

A.4 Relationship between both functional/information requirements and functional domains and (matrix version)

Function Requirement ID	Name	Business: ERP, PLM, Asset management	Application: Logic & Rules	Application: APIs and UI	Information: Analytics	Information: Data	Operations: Optimization	Operations: Management	Operations: Provisioning and deployment	Operations: Prognostics	Operations: Monitoring and diagnostics	Control: Actuation	Control: Entity abstraction	Control: Sensing	Control: Executer	Control: Modeling	Control: Communication	Control: Asset management
FRca-1	Disclosure of specifications of asset																	○
FRca-2	Controllability in data transfer																○	
FRca-3	Data transfer by asset																○	
FRca-4	Portability of asset model																	○
FRca-5	Identifiability of asset																	○
FRca-6	Capability of asset in receiving messages			○														
FRca-7	Reconfigurability of asset															○		○
FRca-8	Consistency between asset and asset model					○												
FRca-9	Compatibility of asset model with various versions					○												
FRca-10	Temporary storage of usage data					○												
FRca-11	Capability of asset in executing applications														○			
FRca-12	Observability of asset													○				
FRca-13	Capability of asset in scheduling actions of asset														○			
FRca-14	Capability of asset in reporting state of asset			○														
FRca-15	Updatability of asset															○		○
FRca-16	Comparability of asset									○	○							
FRca-17	Anonymity of asset																	○
FRsp-1	Verifiability of connections between asset and service platform								○									
FRsp-2	Controllability of data transfer by service platform					○												
FRsp-3	Management of various versions of asset models					○												
FRsp-4	User interface of service platform			○														
FRsp-5	Capability of service platform in sending messages			○														
FRsp-6	Disclosure of specifications of service platform								○									
FRsp-7	Verifiability of functions of applications								○									
FRsp-8	Basic analytical functionality of function blocks				○					○	○							
FRsp-9	Function block development and testing			○	○													
FRsp-10	Updatability of function blocks							○										
FRsp-11	Service platform development and testing			○	○													
FRsp-12	Updateability of service platform							○										
FRsp-13	Runtime adaptability of service platform							○										
FRsp-14	Maintainability of usage data of assets					○												
FRsp-15	Data transfer by service platform					○												
FRsp-16	Measurability of performance of service platform							○										
FRsp-17	Temporal consistency among connected assets							○										
FRsp-18	Interoperability of service platform in business domain	○																
FRapp-1	Updatability of application								○									
FRapp-2	Composability of application				○	○												
FRapp-3	Configurability of application			○														
FRapp-4	Adaptability of application		○					○										
FRapp-5	Application specific functionality		○				○											
FRapp-6	Disclosure of specifications of applications								○									
FRapp-7	Capability of application in reporting messages			○														
IR-1	Validity											○			○			
IR-2	Intellectual property																	
IR-3	Presentation			○												○		
IR-4	Privacy					○												
IR-5	Generality															○		
IR-6	Notifiability			○														

References

[1] Aspects of the Research Roadmap in Application Scenarios, Link

[2] Usage Viewpoint of Application Scenario Value-Based Service, Link

[3] Exemplification of the Application Scenario Value-Based Service following IIRA Structure, Link

[4] The Industrial Internet Reference Architecture Technical Report, Link

[5] Benefits of Application Scenario Value-Based Service, Link

[6] IEC 62559-2 Use case methodology-Part 2: Definition of the templates for use cases, actor list and requirements list (edition 1.0)

Authors and Guests

From Japan side, document contents were developed by the following members of the “Use Case Task Force” in International Standardization Action Group, Robot Revolution Initiative:

- Prof. Fumihiko Kimura; The University of Tokyo
- Toru Ishikuma; Azbil Corporation
- Dr. Hitoshi Komoto; National Institute of Advanced Industrial Science and Technology
- Hirozumi Eki; JTEKT Corporation
- Dr. Kiyotaka Takahashi; Hitachi, Ltd.
- Takenori Baba PE, PEjp; Mitsubishi Electric Corporation
- Hiroyuki Itoh; DAIKIN INDUSTRIES, Ltd.
- Dr. Shigetoshi Noritake; Toyota Central R&D Labs., Inc.
- Yutaka Manchu; Robot Revolution Initiative

Advisors

- Shinji Oda; Yokogawa Electric Corporation
- Dr. Youichi Nonaka; Hitachi, Ltd.
- Mitsushiro Fujishima; Mitsubishi Electric Corporation

From German side, some texts and figures shown in Usage Viewpoint of Application Scenario Value-Based Service were shared to be used in this document. Some additional ideas were also contributed by the following members:

- Dr. Annerose Braune; TU Dresden
- Guido Hüttemann; RWTH Aachen University
- Matthias Klein; Universität Stuttgart
- Dr. Ulrich Löwen; Siemens AG, Erlangen
- Tobias Manger; evosoft GmbH, Nürnberg
- Dr. Michael Okon; Fraunhofer-Institut IOSB, Karlsruhe
- Mario Thron; ifak – Institut für Automation und Kommunikation e.V., Magdeburg