# Industrial Value Chain Reference Architecture (IVRA)

Industrial Value Chain Initiative

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# Part 1: Reference Architecture

## Smart Manufacturing Unit (SMU)

Smart Manufacturing is a system of systems that faces diversity and individuality of industrial needs, drastically improving its productivity and efficiency through mutual communication and connection of autonomous units of manufacturing organizationsSuch an autonomous unit we call an SMU - smart manufacturing unit. SMUs can be looked at from three views: asset view, activity view and management view. SMU features a human element - - e.g. a human being who discovers a problem, defines a problem, and solves a problem.

### Asset View

The asset view of an SMU shows assets valuable to the manufacturing organization. Assets identified in this view are properties of the SMU, and some of them can be transferred between different SMUs as needed. An asset would be an object of any activities. It can also be a proactive subject executing such activities. For example, personnel in some cases conducts an activity upon receiving instructions, and in other cases it acts based on own decision regarding the situation.

In this view, there are four classes of assets as follows.

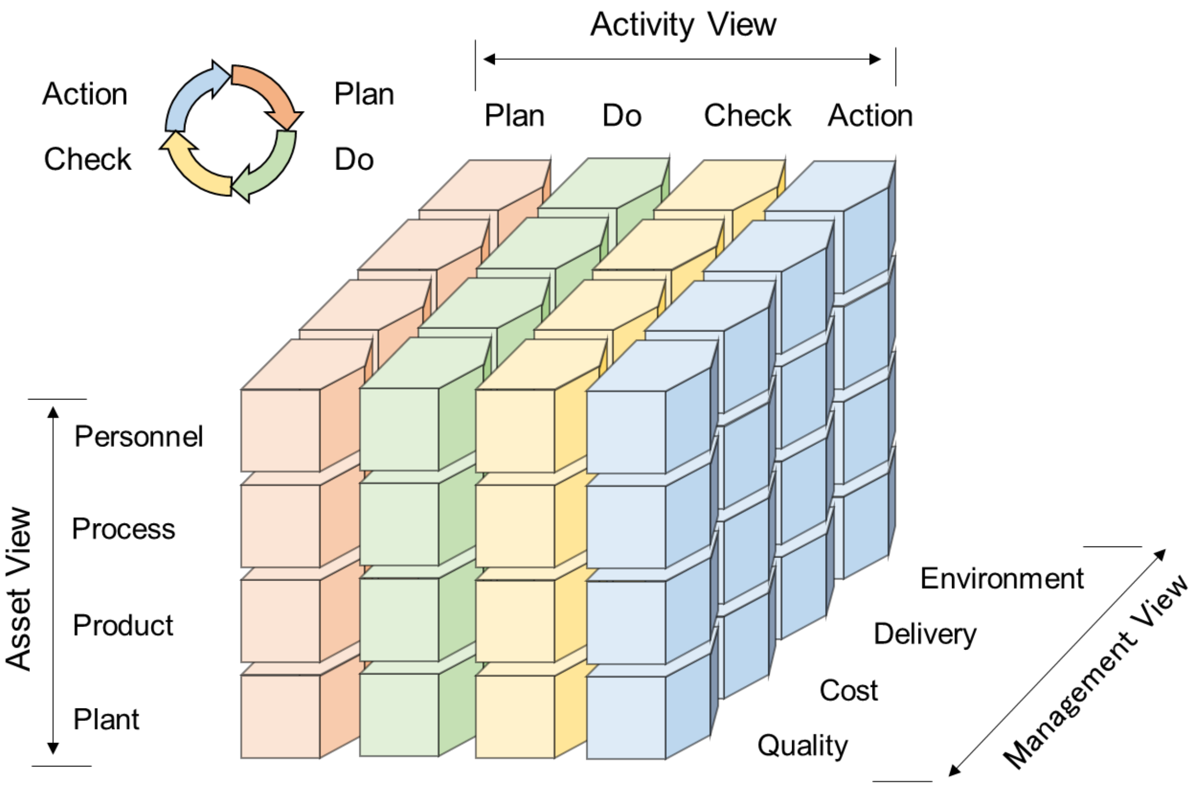


Figure 1: Three Views of Smart Manufacturing Unit

■ **Personnel assets**

Personnel working at production sites are valuable assets. Plant workers conducts operations such as producing a product in the physical world. Personnel also makes decisions and gives instruction to other persons, regardless of whether being a manager or not.

■ **Process assets**

Manufacturing sites have valuable knowledge of the operation such as production processes, methods and know-hows. These knowledge on processes are also assets for manufacturing.

■ **Product assets**

Products created as an outcome of manufacturing and materials to be consumed during production are both assets. In addition, things that eventually become a part of product such as components and assemblies are also counted as product assets.

■ **Plant assets**

Equipment, machines and devices used for manufacturing products are regarded as assets of the plant. Things necessary for operation of equipment such as jigs, tools and subsidiary materials that are also constituent of a plant belong to this kind of assets.

## Activity View

Smart manufacturing creates value as outcome of various activities conducted by human and equipment. The activity view covers such activities performed in SMUs. The activities are done at each manufacturing site in the physical world. They can be seen as a dynamic cycle continuously improving targeted issues proactively. Regardless of the purpose or the object of an activity, the activity view is composed of the cycle of four elemental classes of activities: “Plan”, “Do”, “Check” and “Action”.

■ **Plan**

“Plan” is an activity to make a list of action items to be executed either in a certain period or by a deadline. It may also decide the goal of behaviors in order to complete a given mission or to accomplish objectives of an SMU.

■ **Do**

“Do” means to make effort for achieving a certain goal by executing concrete activities at the actual site in the physical world. It can create new assets or change the state of existing asset based on the given goal.

■ **Check**

“Check” is an elementary class of activities to examine whether the goal set by the planning activities has been achieved. It is analytically measuring or sensing how the physical world has changed as a result of execution, as well as to investigate causes when the goal has not been achieved.

■ **Action**

Based on the result of the check, "Action" is a KAIZEN element improving the function of an SMU by defining the ideal situation and tasks for fixing any problems of the target. The action tries to change the structure or the system of the SMU itself in order to fill the gap of the current condition. Although machines and devices do not modify their own structures by themselves, an SMU in which human is immanent changes its mechanism autonomously.

### Management View

The management view shows purposes and indices relevant for management. Assets and activities of SMUs should be appropriately steered in terms of quality, cost, delivery and environment, which represent the management view. An SMU is subject to be questioned whether it is eventually totally optimized. Each item of the view can be managed independently. The management classes such as quality management, cost management, delivery management and environment management exist across different asset views or activity views within the targeted SMU.

■ **Quality**

Quality is an index to measure how the characteristic of a product or service provided by SMU serves the needs of customers or the external world. It is possible to discuss improvement of various kinds of qualities e.g. quality of products which are directly connected to value of customers, quality of plants or equipment to make the products or services, and all the quality related to humans and methods.

■ **Cost**

Cost is understood as the sum of financial resources and goods spent directly and indirectly in order for an SMU to provide a certain product or service. The concept of cost includes materials consumed to be converted into products, service invested for operating equipment, consumption of energy, as well as financial resources and goods spent indirectly to maintain and manage plants. Here, value of pre-existing assets is not included.

■ **Delivery accuracy**

Delivery accuracy is an index showing how date and time to deliver to the customer meet the needs of the customers of SMU. Location and method to provide products or services to the customers are also considered. It is required not only to ensure meeting the requested deadline but also to fulfill demands to deliver at the exact time and place indicated, and to deliver in a way optimized for each of customers.

■ **Environment**

Environment is an index measuring the extent SMU is harmonious with the environment without giving excessive load when conducting its activities. It becomes possible to be environmentally friendly by maintaining a favorable relationship with the environment and neighboring regions. It includes managing emission of toxic substances and flow of $CO_2$ and materials, and optimizing energy consumption.

## General Functions of Manufacturing

In a view of manufacturing industry as a whole, it is possible to perceive activities of enterprises by several units of several general functions. The units can be defined under a situation where the flow of demand/supply chain and the flow of engineering information and knowledge have a point of intersection. In each activity, there are corresponding hierarchical levels showing the scope of enterprises depending on the actual processes they have owned. By crossing the three axes of engineering flow, demand and supply flow, and organizational hierarchy level, smart manufacturing as a whole can be modeled as a composition of general function blocks (GFB) as shown in Figure 2.

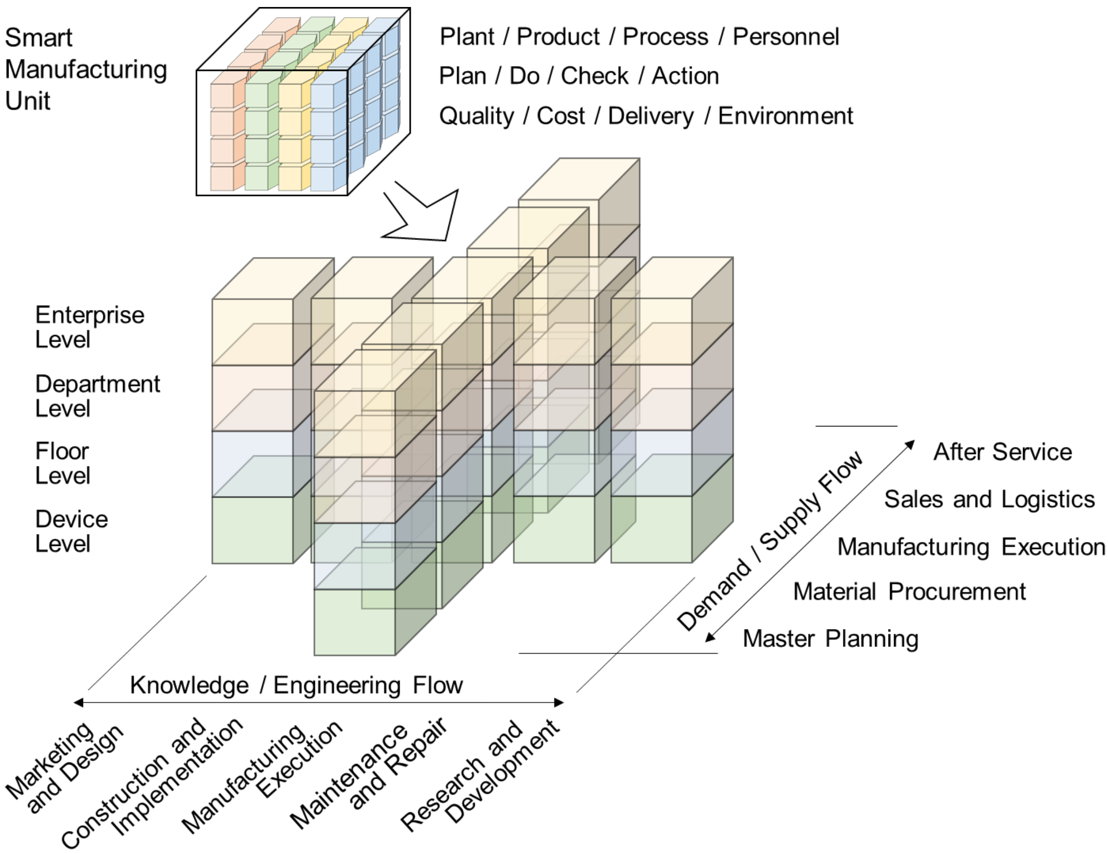


Figure 2: General Function Block (GFB) for smart manufacturing

## Knowledge and Engineering flow

When looking at smart manufacturing from an engineering point of view, knowledge flow such as design information and engineering information would be divided into general functions including marketing and design, construction and implementation, manufacturing execution, maintenance and repair, and research and development. Such knowledge and engineering flow intersects with the flow of demand/supply chain at the phase of manufacturing execution.

### ■ Marketing and design

Various kinds of knowledge or engineering start from marketing, where market needs are accurately figured out and feasible goals and necessary elements are newly extracted. Based on such needs, products or services to be provided are designed utilizing technical assets within an enterprise which are available as engineering information or knowledge.

### ■ Construction and implementation

Plants and production lines are constructed based on developed grand designs and individual design information. The construction and implementation phase includes trial and experimental production as well as improvement of the production system based on the evaluation so as to enable efficient production upon each individual demand. Change in production lines due to a new product, as well as change of jigs and tools for production, are included in this phase.

### ■ Manufacturing execution

In this phase, manufacturing is executed according to demands and supplies. This phase is the place where the flow get crossed with the another flow of demand/supply chain. Here, the two axises have this common general function blocks. The phase includes not only activities applying engineering information and knowledge to an actual factory floor but also activity for improvement by giving feedbacks for the result of application and further polish the contents.

### ■ Maintenance and repair

The aim of maintenance and repair is to keep assets such as plants and equipment in a condition that the functions envisaged are sufficiently provided. Management items including quality, cost and environment are monitored whether they are in a satisfactory state, and repairs and improvements are triggered when necessary. Concerning the element of personnel, various programs for training or improving skills are also included in this phase.

### ■ Research and development

Research and development provide new seeds of engineering. This is not necessarily based on directly facing new market needs or demands. Instead, element technologies and applied technologies can be embodied to provide solutions to problems without previous solution in spite of need, or to fundamentally solve problems in the existing methods.

## Demand and Supply flow

The supply chain flow, where materials are converted to an end product and in turn delivered to an end consumer, consists of value chain of multiple enterprises. When looking at the supply chain from within an enterprise, the flow can be divided into functional elements such as master planning, material procurement, manufacturing execution, sales and logistics, and after service as shown in Figure 2.

- **Master planning**

For manufacturing industry, balancing demand and supply, leveling and stabilizing the production as much as possible lead to enhancement of revenue. Especially when market environment has high uncertainty, enterprises need to develop capacity plans, inventory plans and master plans in coordination with production planning.

- **Material procurement**

In order to produce a product at the right time, the right volume and at the right place in the plant, an enterprise procures materials to be supplied as needed. Since it is not possible for a single enterprise to produce all components of the final product, it is necessary to have trustful partnerships with suppliers to establish cooperative functions across the enterprises.

- **Manufacturing execution**

Manufacturing can start when all the necessary materials, engineering information and assets such as equipment, jigs and tools are ready for production. In this phase, manufacturing is executed based on production instructions, and then feedback on the results is provided to various departments.

- **Sales and logistics**

Completed products and parts are sold corresponding to customers' demand in order to earn revenue. In many cases, demands of customers have been known in advance and then the products are assigned accordingly from inventory, or products are planned to be produced. Geographical distance between the plant and the place where demand exists is bridged by logistics functions to transfer products.

- **After service**

After sales, enterprises provide services to support customers by e.g. setting up and repairing the products, provisioning and collection of expendable supplies, as well as a disposal service of the products. In the case business model charges for consumption-based service, added value for the usage can be provided in combination.

## Hierarchical Levels

Furthermore, general functions of smart manufacturing can be divided into vertical layers of an enterprise as different function blocks. Here, the vertical layers of an enterprise indicate a hierarchical structure composed of enterprise level, department level, floor level and equipment level. Each level will be briefly explained below.

- **Enterprise level**

This is a level where it is possible to oversee the whole enterprise. Works at this level include those executed by the president or corporate organisationsstaff functions, Department level

The department level is equivalent to a unit of organization that is in charge of each of the general functions in the level of enterprise or any comparable functions. In many cases a department is a unit being formed as an organization that is evaluated by its business function performance. Floor level

This is the level where activities including not only production but also manufacturing related materials are conducted in the physical world. Objects of activities in this level cover a variety such as products, materials, devices, equipment, humans, and so on.

- **Equipment level**

In this level, things in equipment are actually operated by sensors and actuators. Thus machines and controlled components perform a more active role than humans here. Controllers and physical devices belong to this level.

## Function mapping for SMUs

An SMU is equivalent to one or more of the GFBs. It may also correspond to all the GFBs.

The range of GFB(s) corresponding to a SMU is decided depending on each enterprise's situation. SMEs might not have all the GFBs within the company. On the other hand, large enterprises likely have more GFBs inside. From another viewpoint, enterprises do not always correspond to a single structure of an SMU, but rather multiple autonomous SMUs. For example, there are enterprises that allow departments subjective and self-managed activities by making each of them independent. If each area or work station on a factory floor is defined as a SMU, this will enhance bottom-up improvement activities and lead to realization of flexible and smart manufacturing.

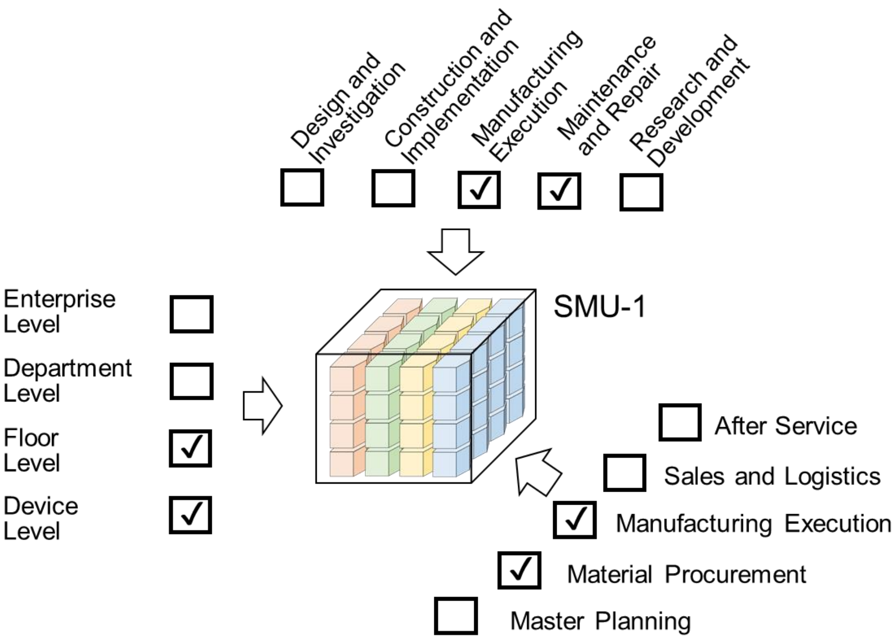


Figure 3 Function mapping for SMU

## Connected Autonomous Manufacturing

Smart manufacturing is a system of systems in which multiple autonomous SMUs are mutually connected. Here, the connection between SMUs can be made either within an enterprise or between enterprises. Generally, for inter-enterprise connections, security management and advanced traceability are more strongly required compared to the intra-enterprise case. However, it is preferrable that reference models can treat such difference in a unified manner.

In addition, especially concerning connections between enterprises, there are frequently financial transactions based on data of accounts receivable and accounts payable. In such transactions, the transfer of a monetary value needs to be managed along with the transfer of things and information. Although there may not be necessity of exchanging money within an enterprise, enabling it in the management system reinforces independent activities of autonomous SMUs in the enterprise.

### Portable Loading Unit (PLU)

A Portable Loading Unit (PLU) is bundle ofelements to be transferred between SMUs. PLU can contain things, information, data and value. When the assets move between SMUs, there might be transfers both in the cyber world and the physical world. Moreover, in each world assets can be sent separately according to characteristics of the objects. A PLU is a unit in which correspondence of all the contents are managed even when they are transferred separately.

■ **Thing**

Products, assemblies, and a part of a plant such as equipment are regarded as “thing” in the physical world when they are transferred from a SMU to another. Since things require physical transports, devices or methods for that must be equipped in the real world.

■ **Information**

Information includes those about products and equipment, methods to produce the products, or operation knowledge for the equipment. Information is represented as a combination of signs on physical media in such describing forms as business reports, tables and spreadsheets, engineering drafts, paper notes and cards. A message received through digital equipment is also regarded as information when it has been recognized.

■ **Data**

Any kind of information can be digitalized and then form data. Data is transferred either by memory media in the physical world, or on a platform in the cyber world. However, data always exists in the cyber world and is embodied as a thing or information in the physical world.

■ **Value**

For both a sender and a receiver of things, information and data, those transferred assets have own value. Thus to send them can be viewed that values for the assets are also transferred. Transfer of value which is intangible exists often as a flow of opposite direction from a flow of a thing, information or data. The flow may take the shape of payment for the price associated.

A Reliable Connection Center (RCC) manages transfers between SMUs by the unit of PLU. For transfer of assets between SMUs, security and traceability are particularly significant.

Concerning security, all parties involved in a transfer such as the sender, the receiver and relay agents would be requested for authentication. In addition, the PLU locks assets with physical and digital keys and manages them at a secure level. When the content transferred is data, the PLU must use encryption. Especially value transfer needs to be executed more securely by managing a ledger.

A suitable traceability management is required when a PLU is sent in batches of different substances, or when there is time lag between transfers. Every PLU has a globally identifiable management tag. The tag enables managing current location and status of each PLU as well as tracing it whenever needed.

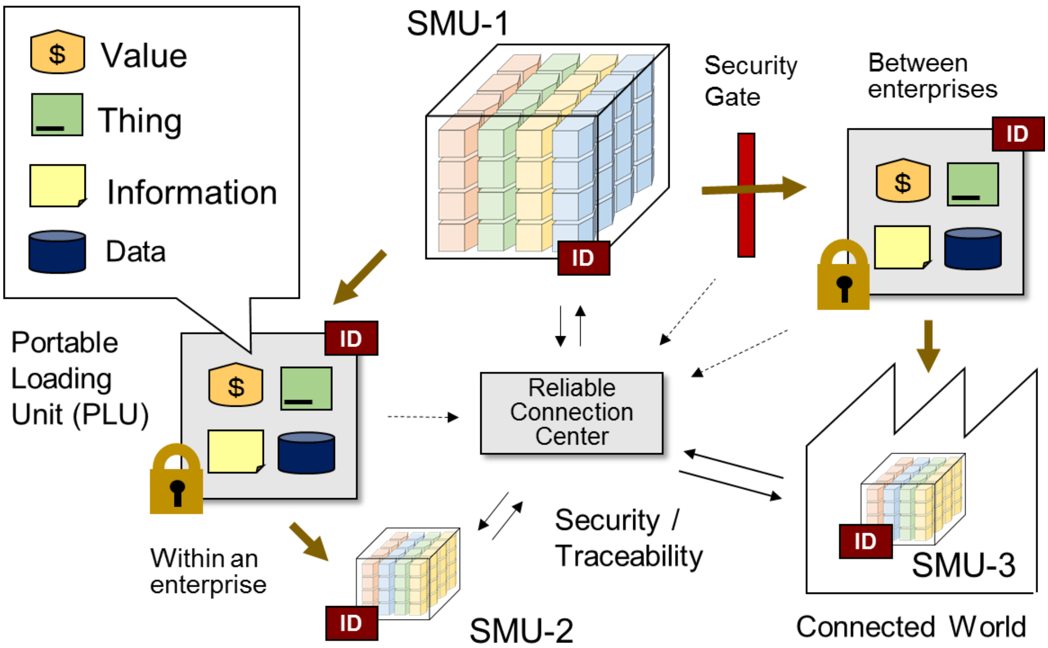


Figure 4: Portable Loading Unit for connected manufacturing

# Part 2: Cyber Physical Manufacturing Platform

## Scenario in the Physical World

Cyber Physical Systems (CPS) or Cyber Physical Production Systems (CPPS) is a system where the physical world and the cyber world are synchronized and integrated with each other. Here, the physical world is the world of everything that actually exists with tangible assets, while the cyber world is digitalized in order to operate and calculate by IT systems. Taking into account that manufacturing has originated long time before the advent of IT , it should be modeled from the perspective of the physical world in the beginning. Then, the approach tries to delegate a part of the physical models to the cyber world if it is digitalized.

In SMU, scenes of “Plan”, “Do”, “Check” and “Action” are detailed in accordance with location and situation. As seen in many different departments, various actors are performing their works. In order to describe it as a model, a scene has to be organized by the units of an actor and its activity. For achieving a uniform granularity of activities, all activities shall be defined by a series of actions, each of which can be defined as any operation to either things or information.

As shown in Figure 5, each scene can be described with actors with a pre-defined role. Then the actors perform with things and information exchanged among actors. By indicating in addition what kind of activity each actor does, the contents of the scenario can be roughly understood.

Such a flow of activities in the physical world including transition of time and place can be defined as a scenario. Figure 5 shows a relationship of such activities as a scenario description chart. Since different locations are drawn separately in the figure, things and information transferred between locations can be figured out. In addition to transition of scenes, flows of things and information between scenes must be clearly indicated in a scenario description.

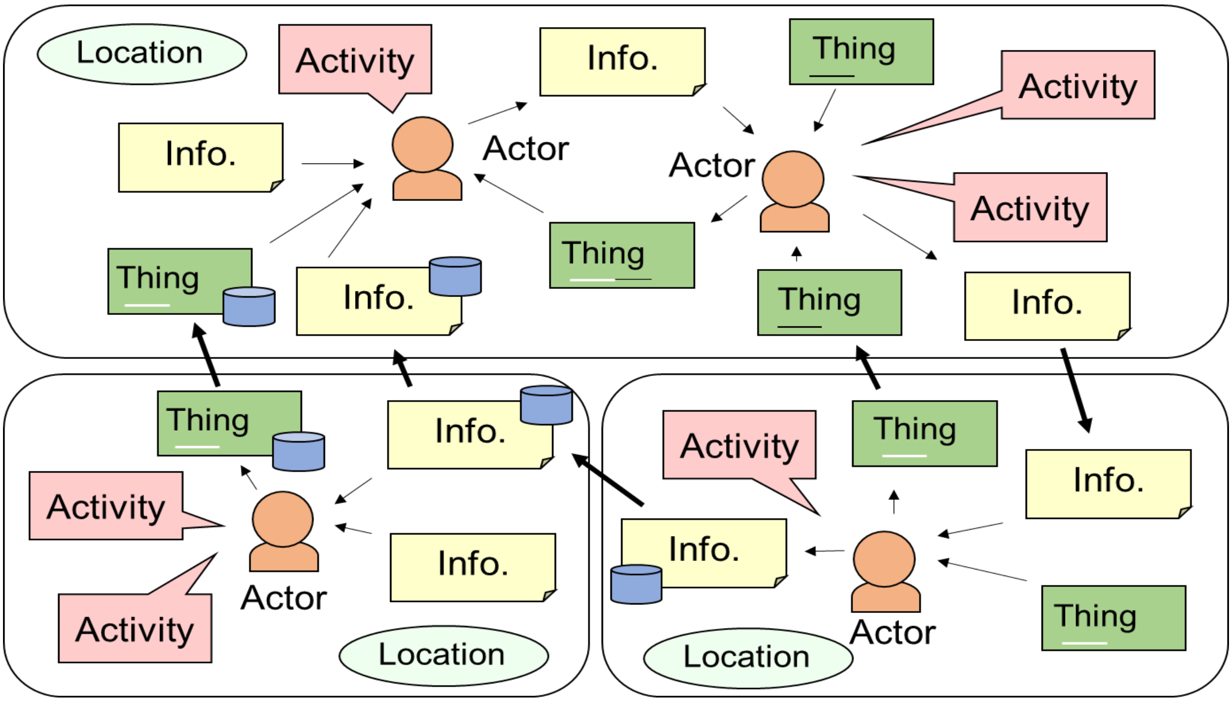


Figure 5: Scenario Description Chart

# Cyber Physical Integration

A scenario description chart shows flows of things, information and activities in the physical world. In Figure 5, the cylinder symbol marks on some “things” and “information indicates that thing and information are connected to the cyber world. In other words, things with the cylinder symbol are IoT devices with sensors and/or actuators inside, and information with a cylinder represent ICT devices for data I/O. To execute printing information is another example.

Digitalized things and information are recognizable in the cyber world as data. Figure 6 is an example explaining that the physical world and the cyber world are connected via things and information. Suppose that a worker on factory floor makes decisions based on information obtained from a tablet computer of the plant. In this case, the tablet displaying the information is the contact point between the cyber world and the physical world. If the worker uses an IoT device connected to the network, contents of operations in the physical world become data that can be treated in the cyber world.

Once things and information in the physical world are converted to data in the cyber world, it would be possible to utilize huge computer power, tremendous network capability of data accumulation and transmission. Therefore, the contact point between the two worlds becomes significant. At the contact point, analog things and information of the physical world connect to the cyber world enhanced by digital technology, such as IoT and ICT devices.

SMU contains personnel as a special type of asset that is a constituent element of manufacturing. A worker on a factory floor as an asset takes actions toward products and parts utilizing a certain equipment in the plant which are also assets. Information necessary then is a part of process which is an asset as well. Such assets in the physical world are digitalized by IoT and ICT devices. They are transferred to data as another form assets in the cyber world. Data in the cyber world further increases its added value by network connection and various functions provided as software.

In the current manufacturing environment where the physical world and the cyber world interrelate each other, it is required to mutually compare and analyze manufacturing cases among individual sites. For this purpose, common terminology and diagram methods indicated in Table 1 shall be provided.

■ **Table 1: modeling objects**

| Modeling world | Modeling constituent element |
|---|---|
| Physical world | Actor, Activity, Thing, Information |
| Cyber world | Data, Function, Connection |

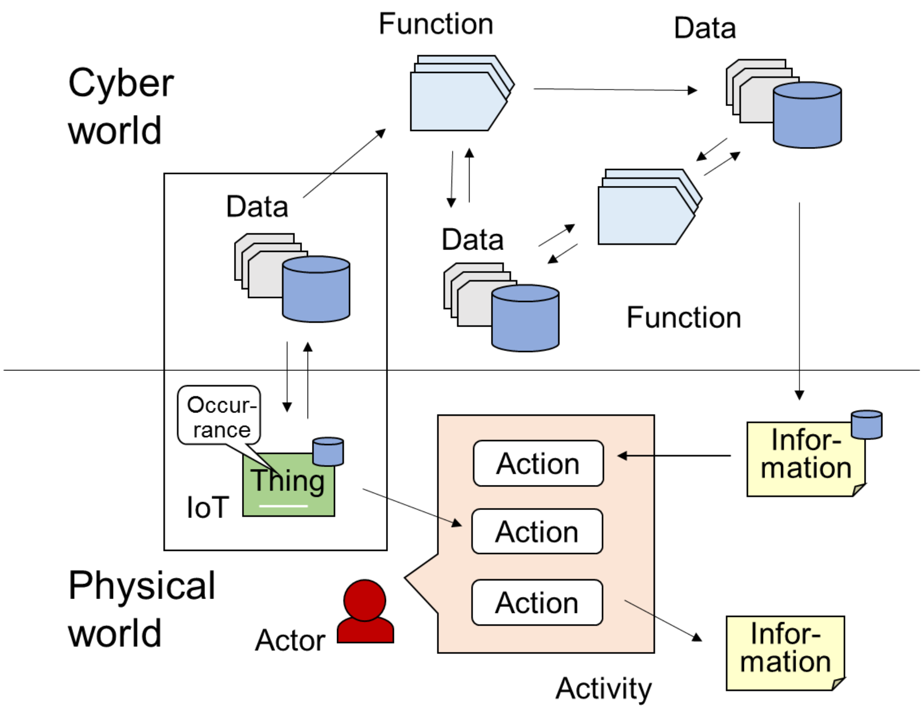


Figure 6: Correlation between Cyber world and Physical world

## Platform for Smart Manufacturing

In smart manufacturing, necessary information needs to be provided at the right time, thet right place, in an appropriate form so that various activities inside SMU get connected effectively. For that, information and data have to be correlated in the cyber world so that the contents written in digital format can be transmitted when and where needed. Such system is provided as a platform for smart manufacturing.

Here, platform is defined in a narrow sense as a system that allows interoperability of data among different manufacturing activities and system components used in the enterprises. Platforms for smart manufacturing defined here consist of multiple components such as devices, applications, infrastructure and tools. Then a platform directly provides end users with values of service by interconnecting those hardware and software.

### ■ Device

A device is a component equipped with hardware performing physically. This component category includes sensors, terminal devices, controllers etc. Devices connect the physical world and the cyber world. Especially an IoT device is connected directly to the network and able to send/receive data in the cyber world.

### ■ Application

An application is a software capable of executing or supporting individual operations in the physical world. In the cyber world, applications process and exchange data provided by the platform. Display devices and input devices such as keyboard are sometimes equipped as peripherals of applications, and they can be also regarded as applications.

### ■ Infrastructure

Infrastructure is a fundamental asset for data transmission and accumulation such as communication cable lines, communication control units, and cloud database. Such networks and proprietary operation systems are sometimes referred to as platforms, but here they are categorized as platform components and its functions for connection capability.

### ■ Tool

Tools are also regarded as components providing common functions such as data conversion, bridging protocols, engineering and administration support of configuration and integration of the components for the platform users. Mainly tools are used either for customizing infrastructure according to the environment or for filling formal and substantial gaps of data among components.

Figure 7 shows relative positions of devices, applications, infrastructure and tools in association with layers of operation, software and hardware respectively and different types of stakeholders.

When data is transferred between SMUs, PLU is used for the data connection. Connections between SMUs are managed by a Reliable Connection Center (RCC), thus a platform does not need to differentiate its functions depending on whether the connection is within the same SMU or with another SMU. When data is sent from/to outside SMU, a suitable network needs to be chosen and the connection ahead would be delegated to the RCC.

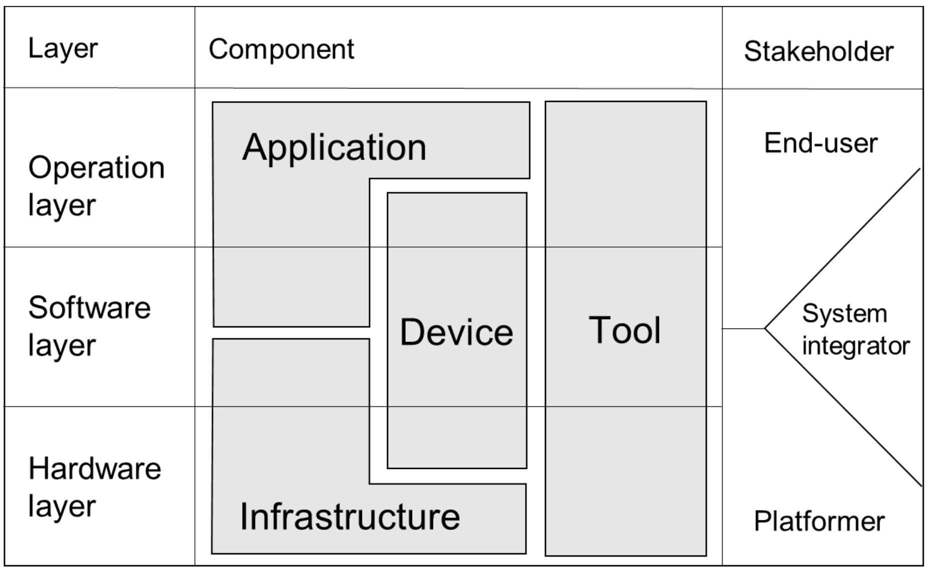


Figure 7: Four categories of Platform Component

# Part 3: Eco-system Framework

## Specification of System of Systems

Smart manufacturing produces results as a system where production in each SMU repeats the activity cycle of "Plan", "Do", "Check" and "Action" in order to improve evaluation indices such as quality, cost, delivery and environment, by utilizing assets including personnel, process, products and plants. In order to grow the overall result, autonomous SMUs get interconnected with each other. In order to realize such a system for connected manufacturing with SMUs, it is necessary to have a smart manufacturing platform enabling data connectivity in the cyber world. The platform consists of multiple components which are systems in a narrow sense, therefore, a platforms can be deemed as a System of Systems (SoS), and an SMU is also a kind of SoS.

The types and characteristics of constituent elements of an artificially designed system do not basically change from the state when the designs are decided. Here it is referred to as a system in a narrow sense. On the other hand, functions of SoS such as a platform which is an aggregate of components or SMU using such platforms are fixed afterwards. Given that conventional narrowly-defined artificial systems are homogeneous, SoS shall be heterogeneous systems where different indices and contradictory values are mixed.

Concerning smart manufacturing platforms in such heterogeneous environments, common concrete feasible decision rules have to be established to enable interconnections of components as well as connecting various activities inside/outside the SMU. To give an example, if two persons, who have had no preliminary agreement on usage of terms, talk to each other, they may mutually miss the point of argument due to different images they have for the same terms. To avoid such a situation, an approach of standardization would be adopted where concerned parties define common terminology and rules and after that, each of the parties follow the common terminology.

However, in an age of individuality and diversity, it is difficult to raise common specifications beforehand. Too many common rules may limit individual quality and productivity. Furthermore, in the case where a market is emerging in the industry, in the beginning the enterprises desiring to communicate might not know what kind of common rules are needed. Premature standardization can be seen as a risk to possibilities for new developments in business. Thus, in order to allow an autonomous evolution of individual SMUs, the concept of "Loosely Defined Standards (LDS)" will be introduced here.

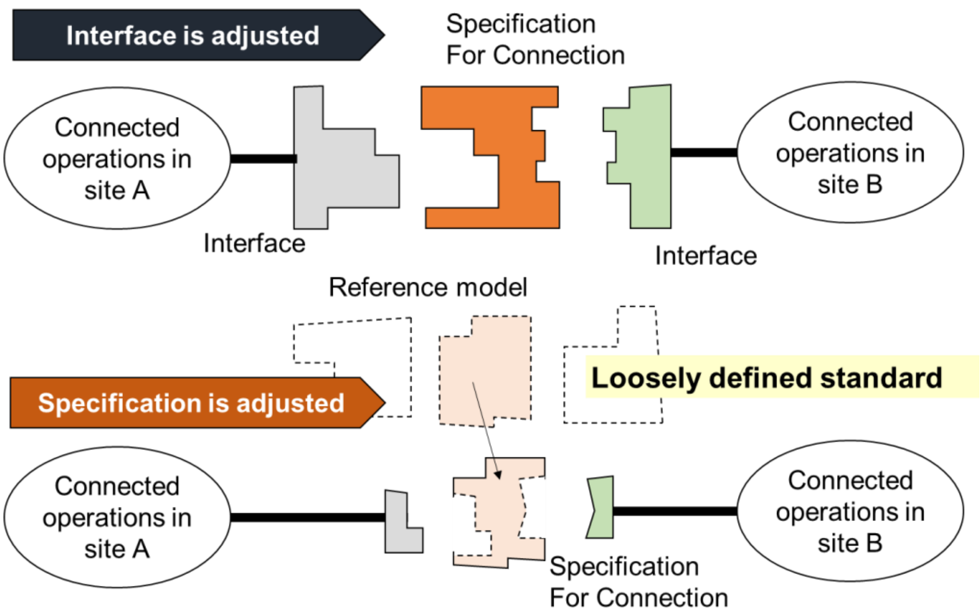


Figure 8: Concept of Loosely defined standard

## Loosely Defined Standard

A fundamental step for building Loosely Defined Standards is to clarify terms and data models that should be defined. Each player to be connected can decide on a common rule in a manner responding to each situation. It is not necessary to have a single rule. In other words, there can be as many common models for connection as the number of group variations. The concept of loosely defined standards eases restrictions of the conventional style which defines only one standard model, forcing each case to comply with one suitable standard. Using loosely defined standards, each case can select from a number of models the most suitable one.

If an enterprise needs to comply with the only common model, considerable changes in business processes are sometimes required. However, such changes would be smaller when following the common part which was decided among actual concerned parties. In addition, local assets of original contents can be kept if a little effort of programming is made to fill the difference between the common model and the individual model of the enterprise. This approach can be a typical case of the “open-and-close strategy” which means individual enterprises take advantage of their own strong points while collaborating in areas where they can cooperate.

However, if there were multiple standards for getting connected, components would need to have the same number of interfaces. When a system for connection is built in a bottom-up manner, there will be a risk that innumerable similar common specifications arise. To avoid such a consequence, the eco-system framework of the Industrial Value Chain reference architecture adopts an approach using reference models as shown in Figure 9. Specifications for connections are always determined by defining differences from a reference model in a higher level. If the reference model in a higher level has a corresponding item, it needs to be applied.

Figure 9 explains relationships of reference among data models. Component data models which is in the most fundamental level of implementation refer to common data models for platforms in the next level. Hence, data models of components constituting a certain platform should be defined following the common model of the platform, which is presented in advance. At the same time, so as not to allow various platforms to respectively present unique but redundant common data models, data models for each domain of platforms are released. The domain data model is then encouraged to be referred by the platforms. Ultimately, each domain model refers to the unified data model consisting of elements which are common in all the domains.

As seen above, common specifications for connection as loosely defined standards are individualized when looking from an upper level to lower, and adversely communalized when looking from a lower to upper. In the exercises of the management framework, an argument whether decision making of specifications should done in bottom-up approach or a top-down approach can be explained in the next section.

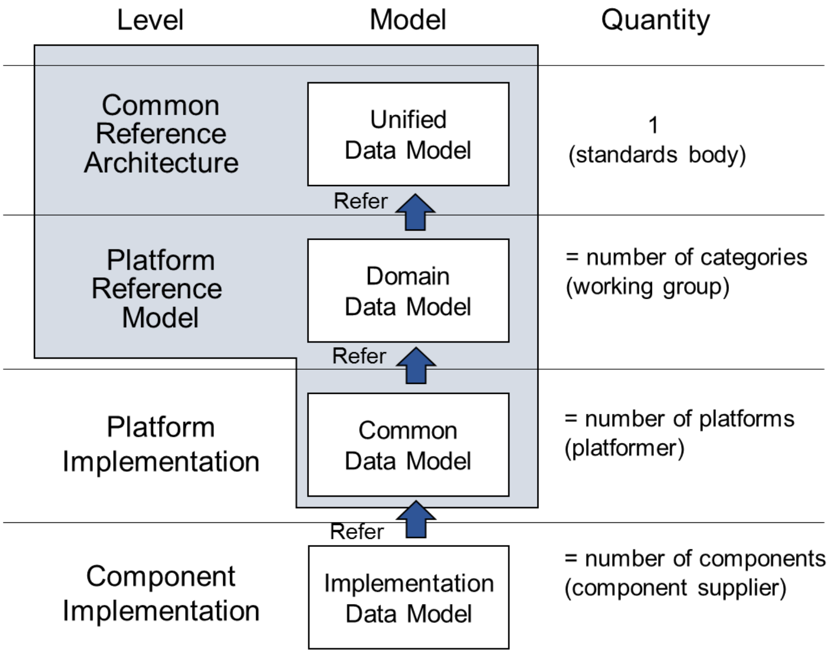


Figure 9: reference level of data models

## Eco-system Management Framework

In order to enable an SMU to independently evolve as System of Systems (SoS) reflecting the diversity of reality in the physical world, the platforms have to be able to accept stepwise modifications of specifications for connection.

For development of an SoS, a hybrid system of top-down innovative approach and bottom-up approach with incremental improvement is desirable. Here, an SoS for smart manufacturing will be described in a top-down manner based on the platform reference architecture. This article is an executive summary of the platform reference architecture. The platform profile specifications provided by platformers and the component profile specifications for each component are defined complying with the platform reference architecture.

On the other hand, scenarios for connections described according to different needs of different manufacturing sites are so diversified that it is difficult to be realized by a top-down approach. Therefore, such problems and tasks of current situation (AS-IS) should be written in a bottom-up manner. When additionally describing a system to solve such problems as ideal situation (TO-BE), requirements on a platform for realization should be written as scenario and use case requirements. Table 2 shows the relationship of the documents.

The scenario and use case requirements that were provided from a bottom-up approach starting form needs of various industry sectors and operations have diversified perspectives and domains. Thus it is almost impossible to integrate them into one. Instead, based on such different perspectives and domains, several categories are set and a reference model is defined for each of them. As of December 2016, eight categories indicated in Table 3 are registered as the platform reference models for category. The categories follow the mapping structure of the general function blocks in Figure 2.

The platform profiles, as well as the component profiles composing the former, define their own functions according to the corresponding platform reference model. In other words, implementation of the connected systems is facilitated by reducing man-hours for integration through the concept of loosely defined standards, enabling an enterprise to take advantage of its own characteristics. This is caused by the process of adjusting to common reference models to the maximum.

On the other hand, such reference models are useful information for platformers and component suppliers for implementing 80% of functions by grasping approximate needs instead of dealing with each case of individual users. As a result, a virtuous cycle is expected where an increase in platform and component providers complying with reference models in turn causes increase in individual needs of customers based on the reference models.

Thus, defining a set of the specifications shown in Table 2 might be effective for the framework to implement the eco-system of smart manufacturing. The Industrial Value Chain Initiative (IVI) continuously revises the content of loosely defined standards in an annual cycle by assembling stakeholders of each specification.

■ **Table 2: specifications for smart manufacturing eco-system framework**

| Title of specification | IVI platform committee | IVI standard committee | IVI platform WGs | Platformers | Component suppliers | Scenario WGs (end users) |
|---|---|---|---|---|---|---|
| Platform reference architecture | D | | R | R | R | R |
| Platform common dictionary | | D | R | R | R | R |
| Platform reference model for category X | | C | D | R | R | C |
| Platform profile specification | | C | | D | C | |
| Component profile specification | | C | | C | D | |
| Scenario and use case requirements | | C | C | C | C | D |

R: reference, D: define, C: check

■ **Table 3: Categories for platform reference model**

| No. | Category Name | Explanation |
|---|---|---|
| 01 | Production Engineering Information | Considers the configuration of production lines based on design information, then manages engineering data from the prototyping stage to mass production. |
| 02 | Quality Management Information | Continuously improves quality, cost and delivery by utilizing quality data of products, skill data of personnel, and performance data of equipment all of which are obtained at the plant floors. |
| 03 | Production Planning and Control | Performs dynamic control of production lines according to a change in the production plan, specification or shop-floor condition reported by data of manufacturing progress. |
| 04 | Supply Chain Management | Exchanges data necessary for supply chain or engineering chain among companies in a secure manner. Information of manufacturing operations management is exchanged as well. |
| 05 | Small Sized Enterprise Information | Integrates significant functions for production management of SMEs by combining general three functions of selling, purchasing and production. |
| 06 | Preventive Maintenance | Manages data for predictive maintenance of equipment by collecting various kinds of data. Then it decides countermeasure for fixing the problem for future improvement. |
| 07 | Asset and Equipment Management | Tries to increase overall equipment effectiveness by utilizing the operation data of equipment. The activities are integrated with production management and quality control. |
| 08 | Maintenance Service Management | Monitors status of utilization of products after selling in order to provide customer services such as repair support and preparing spare parts. |