Feature Article *"From Vision Development to Practical Implementations"*

Front Line of Toshiba "Next Generation Manufacturing Solutions"

As the countries of the world promote next generation manufacturing, waves of massive changes are washing the shores of Japan also.
Pioneers in these changes are Industrial ICT Solutions Company and the Toshiba Group.
Succeeding the "Manufacturing DNA" continuously for 140 years since the foundation of Toshiba, Next Generation Manufacturing Solutions are being proposed that fully utilize state-of-the-art IoT technology and big-data analysis technology based on the results of verification at worksites.
From Vision Development to Practical Implementation.
These feature articles introduce our activities for realizing Toshiba's Next Generation Manufacturing Solutions to further evolve the power of the Japanese manufacturing industry and the innovations proposed to its customers from a variety of perspectives.

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Succeeding "Manufacturing DNA" of Toshiba and Renovating Manufacturing Industry by IoT

Value Chain of Next Generation Manufacturing Solutions Linked by IoT

The environment surrounding Japan's manufacturing industry is undergoing radical changes.While grasping the movement of "Industrie 4.0" of Germany that aimed at Mass Customization, and "Industrial Internet" by the United States that promotes the manufacturing industry to transform itself to service business, the Japanese manufacturing industry is required to embrace IoT utilization and big data analysis.In April 2016, Toshiba released "Next Generation Manufacturing Solutions" to further enhance the manufacturing power of Japan.Ceaselessly guarding the "Manufacturing DNA" of Toshiba since its foundation 140 years ago, Toshiba will continue to comprehensively provide solutions from the edge to the cloud so that the manufacturing industry of Japan will be able to exhibit its global presence.

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New Trend of Manufacturing Visible from "4th Industrial Revolution"

The manufacturing industries of the world are facing times of great change.Countries are aggressively investing in new technologies centering on IoT* and big data analysis and are making nationwide efforts to reform manufacturing.This powerful surge, described as "4th Industrial Revolution", will fundamentally change not only the manufacturing industry but the entire industrial structure.

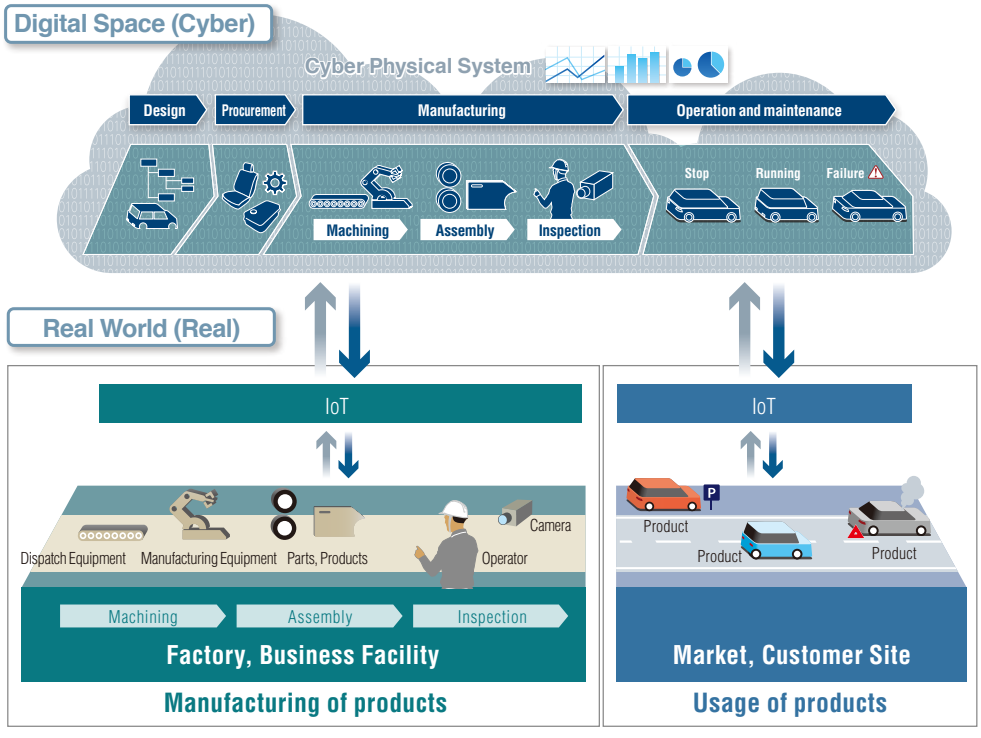
There are two trends in the next generation of manufacturing.The first trend is the reform of the "Manufacturing of products" as innovating production process through the utilization of IoT. The other trend is the reform of the "Usage of products" aiming at enhancing product values and creating new services by analyzing big data collected from places where products are used via sensors and other devices (Figure 1).

The former trend is led by the German national project "Industrie 4.0".In this project, the combined power of industry, administration and academia is mustered to gain overwhelming international competitiveness in manufacturing by mass customization that responds to the individual needs of the customers at a competitive cost of mass products. The whole scheme is based on the "Cyber Physical System", which replicates the manufacturing process of the real world in a digital space and which feeds back real-time grasping of situations and results of data analysis to worksites.

The latter trend is the "Industrial Internet" advocated by General Electric Co., which is rapidly propagating in the United States.Its concept is to collect and analyze data on the operating conditions and the states of parts of industrial machines such as jet engines and gas turbines via sensors to optimize flight routes and maximize power generation efficiency.New business models will be developed through the use of software including cost reductions through energy saving and enhanced safety by predicting signs of failures.

Figure 1 Concept of Next Generation Manufacturing

IoT acquires the data of "How to manufacture products" at factories and of "How to use products" after the shipping from factories. Advanced manufacturing is performed by simulations that can be implemented only in a digital space, by comparing with the past status and by forecasting the near future using a variety of information replicated in a digital space.



*IoT: Internet of Things

As digitalization of the manufacturing industry evolves, manufacturing industries in Japan shall conform to the global trend.The productivity, performance, quality and customer value are enhanced and environmental impact is reduced by fully utilizing IoT throughout the lifecycles of products.Japan must maintain and renovate its manufacturing power by utilizing its forte, "the power of worksites".

Experience and Technology of Toshiba for the Next Generation of "Manufacturing of products" and "Usage of products"

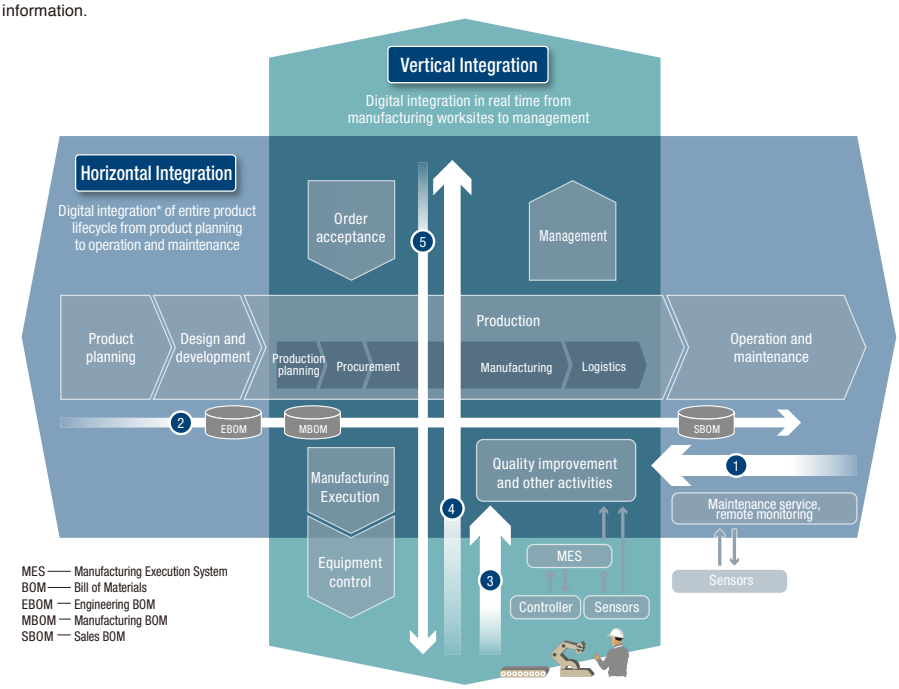
As many countries aim to realize next generation manufacturing, Toshiba has undertaken various pioneering projects utilizing raw data available at worksites.
A typical example of this effort is quality improvement and productivity enhancement activities undertaken at Yokkaichi Operations of Toshiba, which produces NAND-type flash memories.
Sensors are installed in 4,000 units of about 200 types of manufacturing equipment. Information is fed back to worksites at any time after analyzing big data totaling 1.6 billion pieces per day collected from equipment while monitoring operating and processing conditions of the equipment in real time.
Correlation analysis based on several trillion combinations of history such as processing and machining ways and inspection results, using lot-linked output data from manufacturing equipment enables to determine manufacturing patterns that cause manufacturing flaws. This information is reflected in the processing conditions for downstream processes in real time, to greatly improve manufacturing yields.
Additionally, a mechanism has been developed and installed to analyze the operating states of the manufacturing equipment and dispatch systems, to visualize the efficiency of entire production lines at a glance.Based on this information, the lines are leveled and the dispatch and the order of work starts are flexibly changed, thus enhancing the productivity and rates of equipment utilization.
The knowledge gained at own factories is fully utilized in actively providing solutions to issues at customer sites.
Toshiba has supplied a solution to analyze defective factors at the manufacturing lines in Kusatsu factory of Omron Corp. Kusatsu factory is reforming its manufacturing worksites through IoT. This solution has contributed to improve its factory-quality to the next level (See page 7).
In the area of "Usage of products ", there are wide and diverse activities. One example is minimizing downtimes by predicting failures and through preventive maintenance of building facilities, office equipment, information devices, storage systems and other equipment using big data obtained from products and equipment. Another example is the sophistication of plant maintenance operation through voice recognition of workers at worksites.

Development of Next Generation Information Infrastructure, Integrating Value Chain

Toshiba has accumulated new technologies and know-how gained in its versatile experience in these projects. Toshiba believes that a framework to realize horizontal and vertical information integration is necessary as an information infrastructure to realize next generation manufacturing.
"Horizontal Integration" is a horizontal flow to visualize what is happening, when, and where for each product by seamlessly connecting pieces of information in a series of product lifecycles related to product planning, design/ development, production, operation and maintenance.On the other hand, "Vertical Integration" is a vertical information connection from worksites to management level in real time, to visualize operations, to correctly and accurately understand what is happening now and take necessary action (Figure 2).
If the entire value chain can be optimized by these two directions of information integration, yields, quality and productivity can be enhanced. It will also be possible to manufacture products that meet the diverse market needs and wishes of individual customers for creative and flexible manufacturing, and to provide aftersales services with high value by ensuring traceability.
Toshiba is offering a Data Lake for manufacturing "Meister DigitalTwin" by replicating the entire value chain related to products of the real world in a cyberspace. "Meister DigitalTwin" can correlate and store all data from "Manufacturing of products" to "Usage of products" such as business data, data obtained from equipment and devices and data generated by sensors including peripheral environments.
Additionally, "Manufacturing Process IoT" to monitor manufacturing worksites through equipment and sensors and to feed back the responses to worksites, and "Field IoT" to capture the status of use of products in the field are provided. These solutions are linked to Meister DigitalTwin as an environmental architecture that interlinks horizontal and vertical processes.

Figure 2 Framework for Next Generation Manufacturing - Horizontal and Vertical Digital Integration

The entire value chain for manufacturing will be digitally connected for optimization through horizontal integration to connect the lateral flow of product lifecycles and through vertical integration that longitudinally links management information and worksite information.



1 Histories of product use, maintenance and failures are collated with manufacturing information
2 Horizontal integration of bills of materials (BOMs) of products
3 Detailed information of manufacturing process is used in quality improvement and other purposes
4 Information at manufacturing sites is used in management in real time
5 Automatic use of individual order data in production orders, recipes and other purposes

* Digital integration: Conversion into digital data and digital chains

Pioneer in Next Generation Manufacturing and Strong Integration between IoT and Cloud

Under a new framework toward realizing next generation manufacturing, in March 2015, Toshiba first upgraded the solution for its Manufacturing Execution System (MES) (See page 9). In April 2016, Toshiba launched its "Next Generation Manufacturing Solutions" for seamless support of IoT data collection, storage, analysis and utilization at manufacturing worksites (See page 5).
The solutions to provide Meister DigitalTwin as a platform include those that visualize worksite monitoring data in real time in fine detail, that identify defect factors for quality nonconformance and that detect failure signs.Manufacturing that precisely responds to worksite situations, which change from time to time, will be possible by appropriately visualizing and analyzing data generated at "Manufacturing of products" worksites and by connecting them to actions.
The solution to connecting various products and equipment at worksites to a network is provided by cutting-edge technologies such as "Chip to Cloud," which links devices made intelligent by edge computing for real-time processing near a worksite.Our comprehensive IoT solution comprising from the edge to the cloud will create innovative manufacturing environments in which all equipment is linked and autonomously works in accordance with worksite situations.

Cutting Open the Next Generation of the Manufacturing Industry by the Power of Manufacturing Refined over the Last 140 Years

Worksite operations and the real world have to be changed to realize the next generation manufacturing, aside from the mere use of IT. Many more challenges have to be made.A consensus and rules beyond the realm of enterprises and countries needs to be forged.
Toshiba possesses "manufacturing DNA" that has been handed down from one generation to another continually for 140 years.Surmounting many environmental changes surrounding the manufacturing industry that have taken place during this period, Toshiba has continued to refine its power to manufacture products and services from hardware to software in wide-ranging fields such as social infrastructures, industrial machines and equipment, electric home appliances, office equipment, electronic components and semiconductor devices.
Fully exhibiting its power, Toshiba is committed to propelling advanced projects hand in hand with its customers. Toshiba is also committed to new technology development, and will be active in collaborating with global enterprises.Together with the Toshiba Corporate Manufacturing Engineering Center and other organizations that have continued to refine production technology, Industrial ICT Solutions Company will support the next generation manufacturing for customers with a focus on the ICT solution business.

A Innovation to Production Worksites through Technology of "Connoisseurship"

Essential Requirements for Next Generation Manufacturing as Conceived by Corporate Manufacturing Engineering Center

Toshiba Corporate Manufacturing Engineering Center, which supports high-level manufacturing at Toshiba has been engaged in research and development of component and material technologies related to production, production engineering technology, structural design and manufacturing technology, mechatronics technology and other fields.I will introduce in this column how we recognize the problems facing next generation manufacturing and what we would serve to solve them.

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Approach to Next Generation Manufacturing Begins with Utilization of Worksite Data

Unlike previous generations when the infrastructure to handle manufacturing data was fragile, at present, the types and volumes of data that can be acquired at the manufacturing worksites are increasing.Tools to visualize and analyze data have been released one after another. Whereas data was checked by human eyes, data is now analyzed by image processing technology and can be recognized as patterns relatively easily.We believe that a mechanism and an environment to phenomenally enhance the speed to understand and improve those parts that were not visible before will be the first step to an approach to next generation manufacturing.
Nevertheless, product characteristics and manufacturing types have to be fully considered to collect manufacturing data and to effectively use such data.For example, optimization of production proceeding and lot management is an important element in build-to-order manufacturing of large product such as turbine.At the process system production line of the super mass production type such as the semiconductor, it is necessary to investigate factors that cause defects and malfunctions from various angles.

Next Generation Manufacturing Meeting Specific Characters Promoted by High-Level "Connoisseurship" Gained at Worksites

One of the strengths of Toshiba Corporate Manufacturing Engineering Center in meeting the challenges that face next generation manufacturing is its "connoisseurship" skills to discern whether ICT can be utilized effectively in accordance with manufacturing characteristics.Know-how gained at various products and production worksites could be applied for the other cases by decomposing whole production process to fine granularity. For example, mass product's production management know-how could be applied to repetitive processes of design-to-order products.
The utilization of ICT is indispensable to feedforward and feedback control for optimizing dynamically the conditions that are found in and between the processes of semiconductor device manufacturing.For this purpose, high level know-how and versatile knowledge have been accumulated to infer a fluctuation mechanism for quality and efficiency. The accuracy and efficiency of this mechanism have been enhanced through big-data analysis and simulation technology.In the future, this technical and experiential potential will be utilized to a maximum and the production engineering technology will be spread to the upstream and downstream of product lifecycles such as the optimal planning-design-production process. This will be accomplished by taking design, manufacture, component and material procurement into consideration of stable production, and transportation cost after the shipment.
Some of the major hurdles to overcome will be how next generation manufacturing should be realized and how worksite data can be used for improvement.Toshiba Corporate Manufacturing Engineering Center will further refine its connoisseurship skills and high technology gained at many worksites to overcome such hurdles.In close collaboration with Industrial ICT Solutions Company, our center will contribute to achieve next generation manufacturing featuring a high affinity at worksites, and to create a new value from manufacturing view point.

Total Support for Next Generation Manufacturing Worksites

The Revolution of the Manufacturing Industry Begins Here Toshiba "Next Generation Manufacturing Solutions"

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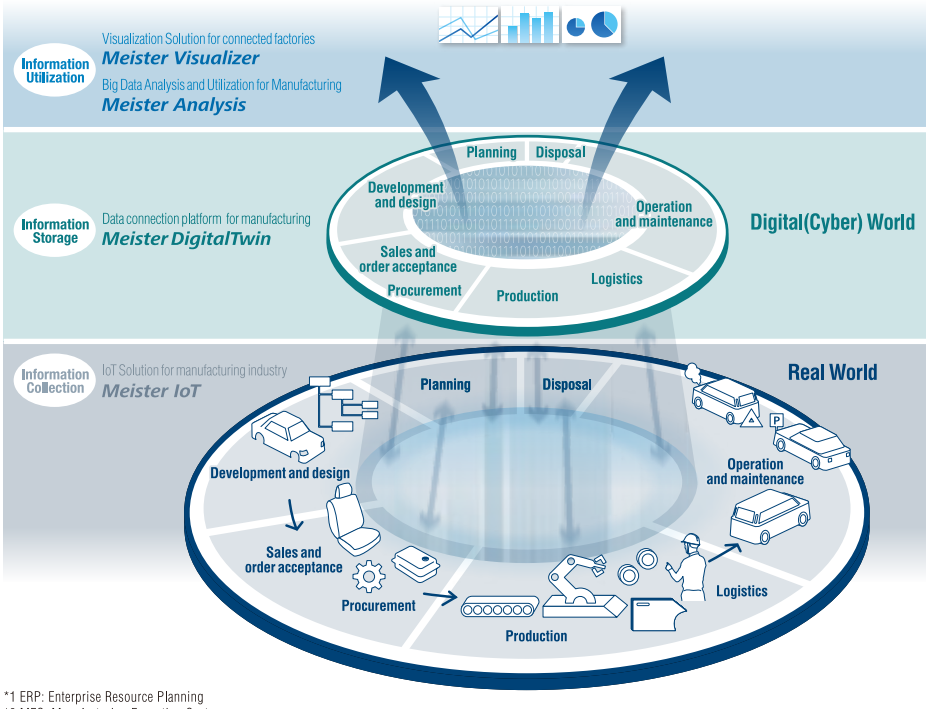
The entire value chain is optimized by "Horizontal Integration" and "Vertical Integration" of digital data and data from "Manufacturing of products" to "Usage of products" is synchronized. This will lead to flexible manufacturing suiting mass customization, to create high value-added services and to build new business models.Based on this fundamental framework, Toshiba has released "Next Generation Manufacturing Solutions".This article describes Toshiba's solutions released in April 2016 as first service products. They are: "Meister Visualizer", a visualization solution for connected factories; "Meister Analysis", an analysis and utilization solution of manufacturing big data; "Meister IoT", an IoT solution for the manufacturing industry; and "Meister DigitalTwin", a data connection platform for manufacturing that is linked to the former solutions.

Three Layers as Keys of Next Generation Manufacturing

Under the mission of introducing next generation manufacturing incrementally to the Japanese manufacturing industry for its future, Toshiba has first developed solutions especially for higher productivity and quality improvements at manufacturing worksites.
For these solutions, it is important to meet the requirements of next generation manufacturing in three layers, namely, "information collection", "information storage" and "information utilization" (Figure 1).
In the "information collection" layer, an environment to collect and process various and diverse data in real time by sensors and by other devices is necessary. Such data includes data of all equipment, products and buildings in factories and people working there.
The "information storage" layer is tasked to store a huge volume of collected data from worksites, to combine it with data from business systems such as ERP*1 and MES*2, and to replicate in a digital space what is happening at manufacturing worksites and other places accurately.
The "information utilization" layer is tasked to convert the collected data into a practical value that enhances the competitive power of customers, such as supporting continued activities to improve quality and productivity using the manufacturing data replicated in the digital space.

Figure 1 Three Layers Needed to Implement Next Generation Manufacturing

Various and diverse data generated in the real world is "collected". Such data generated at worksites and business data is combined for "storage" to replicate accurately "what is happening at worksites" in a digital space.
This data is "utilized" after visualizing and analyzing it, to realize next generation manufacturing.



The Reality at Manufacturing Worksites That Block Next Generation Manufacturing

Nevertheless, it is not easy to realize such requirements of the layers in conventional manufacturing worksites.
For example, the "information collection" layer has major problems such as how to harmonize with legacy systems that are already in operation and how to connect with the equipment whose communication protocols are different.It should be considered how to operate efficiently very large volume of sensor data collected in time series.

*1 ERP: Enterprise Resource Planning
*2 MES: Manufacturing Execution System

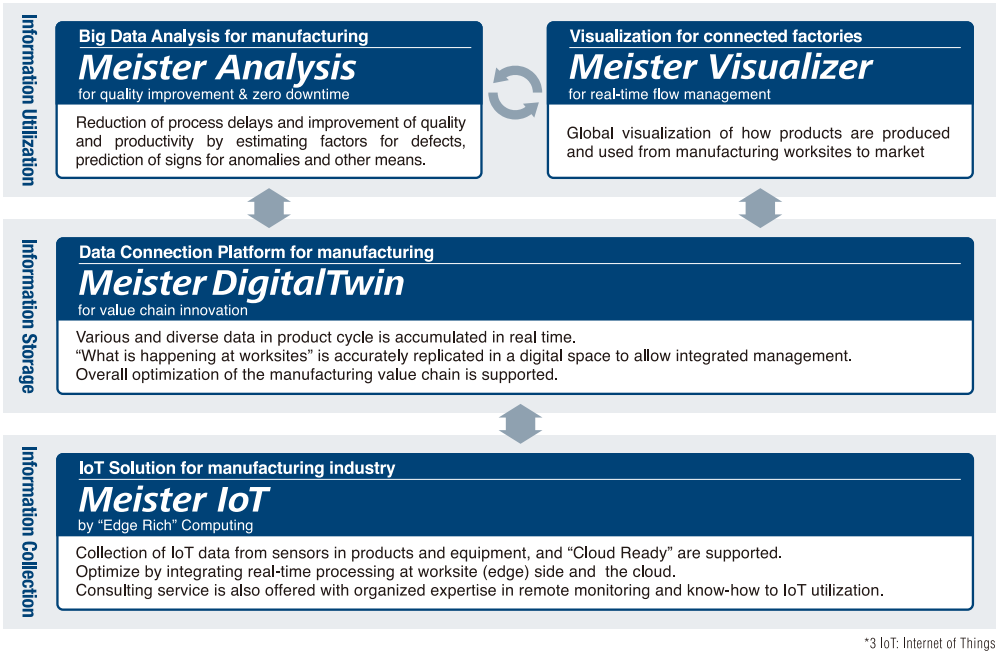
An obstacle for next generation manufacturing in the "information storage" layer is silo-mentality between manufacturing processes.Mere collection of data from locally optimized processes is not adequate for overall optimization and to achieve new goals.A mechanism connecting processes seamlessly, is needed to know in what situation each piece of data is generated and to what data such data is related.
The "information utilization" layer has a challenge of the effective utilization of data in accordance with intended purposes.Correlations of such integrated data become amazingly diverse and complex the larger the volume of such integrated data is.This layer is required to make an accurate and detailed analysis of big data, and to quickly draw out knowledge for solving problems at factories and knowledge that matches intended purposes.This layer is also required to visualize worksite data, which changes from time to time, to take actions and to make decisions timely.

Total Support of Information Collection, Storage and Utilization on a dataconnection platform for Manufacturing

Toshiba "Next Generation Manufacturing Solutions" solve issues facing "information collection" and "information storage". At the same time, the solutions comprehensively realize "information utilization" tailored to the customer requirements.The greatest feature of Toshiba's solutions provides a total and continuous support of these three layers, allowing customers to take the first step toward next generation manufacturing.The solutions embody the strength of Toshiba as a manufacturer that knows every detail of manufacturing worksites. Toshiba can apply its excellent IoT[*3] knowledge to manufacturing worksites in the optimum way.
"Meister IoT", an IoT solution for the manufacturing industry is proposed to build an environment for "information collection" that is the starting point for next generation manufacturing.The family of products such as IoT devices and gateways can be installed externally or lately to the existing equipment or devices at manufacturing worksites.These products convert equipment "cloud ready," allowing "edge computing" in real time, with a minimum delay and efficiently at places that are closer to worksites, instead of processing all of such data by the cloud.At the same time, Toshiba offers a consulting service to support the introduction of IoT to manufacturing worksites by the organized methodology from know-how of the remote monitoring in the social infrastructure and from use of IoT at manufacturing worksites.
"Meister DigitalTwin" is a manufacturing information platform integrating every data of the manufacturing process for optimizing an "information storage" environment.This platform implements a newly developed core technology for next generation manufacturing and a general-purpose data model incorporating versatile manufacturing expertise of Toshiba, with a focus on GridDB, a database of a scale out type for big data. GridDB has been installed at many energy sites.This is an information platform that will serve as the core for next generation manufacturing. This platform replicates information in digital space from "Manufacturing of products" to "Usage of products" for integral management, to optimize the whole value chain.
"Meister Visualizer", a visualization solution for connected factories, and "Meister Analysis", a big data analysis and utilization solution for manufacturing, are provided for "information utilization".
In Meister Visualizer, Toshiba's original real-time data processing technology and user interface technology are linked centering on Meister DigitalTwin.Data that is continuously accumulated is seamlessly analyzed and the present status of manufacturing worksites is visualized in real time.Capturing production status and quality information collected from factories throughout the world connected by IoT would raise the awareness of executives and managers. It supports the real-time management, such as real-time optimization of global production planning.
Meister Analysis incorporates the techniques of "Event Pattern Analysis", Toshiba's unique big-data analysis technology that has been proven viable at Kusatsu factory of Omron Corp. and at Yokkaichi Plant of Toshiba (See page 7). Using two templates, "quality factor analysis" and "failure factor analysis," complex correlations of data stored in Meister DigitalTwin are analyzed to find facts and new issues that are not recognized even by skilled engineers are found to devise solutions at worksites.Empirical data in the past are visualized and the results of analysis of factors for defects and failures assumed when problems occurred are accumulated as new explicit knowledge. This will enable continuous improvement of quality and productivity to a higher level (Figure 2).
As manufacturing evolves in the world at an accelerated pace, Toshiba promotes a reform of manufacturing in Japan powerfully through provisioning of Next Generation Manufacturing Solutions that comprehensively support data collection, storage and utilization. Toshiba will continue to develop optimal solutions that meet the needs of customers who aim at innovating manufacturing.The challenge by Toshiba has just started.

Figure 2 Features of Toshiba Solutions

Three layers solve various issues that obstruct next generation manufacturing.All data in "Manufacturing of products" and "Usage of products" is integrally managed in real time and versatile data utilization that continuously enhances quality and productivity is promoted.



*3 IoT: Internet of Things

Toshiba Next Generation Manufacturing Solutions, Proven Viable

Quality Innovation of Manufacturing Sites through Collaboration between Omron and Toshiba

Toshiba has undertaken many projects in the past to realize next generation manufacturing.Among these projects, a verification project that was started in January 2015 Kusatsu Plant of Omron Corp. and that uses raw data at the manufacturing worksites has provided important knowledge and know-how of how to convert data collected by IoT into valuable information.This article describes the quality improvement activities at the Kusatsu factory of Omron, as a model case of "Meister Analysis", Toshiba's analysis and utilization solution of manufacturing big data, which was released in March 2016.

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Zero Defects in High-mix Low-volume Production

Omron Corp. is one of companies representing Japanese "manufacturing" and produces control equipment, factory automation systems, health and medical equipment, electronic components, in-vehicle electronic equipment and other products.At its Kusatsu factory in Shiga Prefecture, Omron manufactures programmable logic controllers (PLCs) that control industrial equipment.Omron has steadily continued to improve the quality of its products and has registered an amazing result in a defect rate at a 1/1,000,000 level. Aiming at realizing a quality innovation to achieve zero defects, Omron has searched for a new technique that utilized IoT[*1].

The verification project undertaken by Omron and Toshiba involved a manufacturing line for printed circuit boards embedded in these PLCs.In short, the characteristic of this project is hyper high-mix low-volume production. Omron is manufacturing PLCs of several thousand models to meet a variety of applications. For this reason, products of the same models cannot be produced in large quantities as in the manufacture of printed circuit boards for personal computers.Omron produces some of these models only several times in one year.

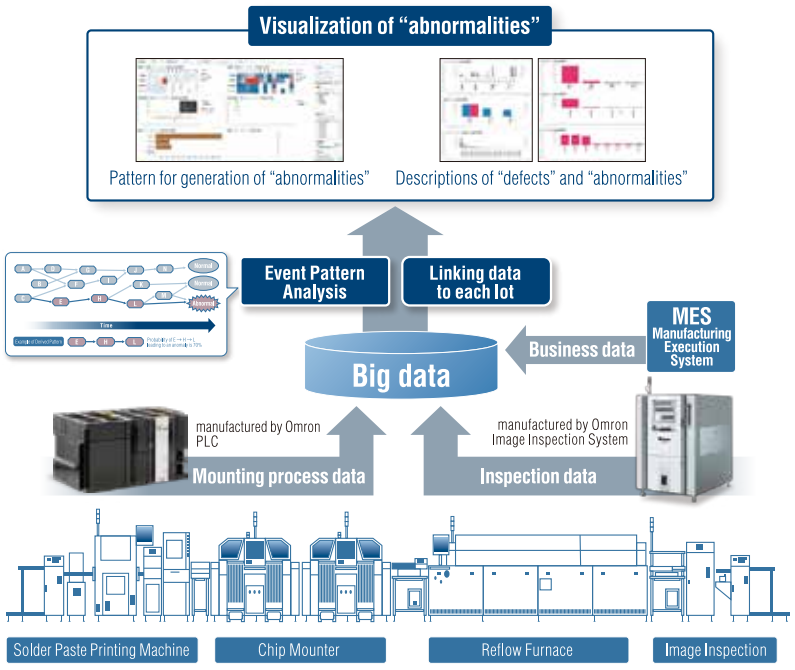
It is not easy to prevent defects from being generated while aiming to achieve a higher yield when such defects are generated only very rarely.What was needed to accomplish the high target of achieving zero defects was an activity to minimize the risk of defects by analyzing a large volume of data acquired in manufacturing processes using ICT.

Visualizing "Abnormalities" Happened with Each Product

What was used in this project of Omron who aimed at realizing a further quality innovation was a system to estimate factors and mechanisms for defects as "Why have such defects occurred?" by analyzing data. This system fully utilizes Toshiba's original "event pattern analysis technology" (Figure 1).

Figure 1 Outline of Prototype System at Omron

Toshiba's original event pattern analysis technology is used with equipment log data, sensor data, data of inspection result and data obtained by the Manufacturing Execution System (MES)."Abnormalities" that take place in the manufacturing process are visualized.



*1 IoT: Internet of Things

Omron had been analyzing factors using data from manufacturing equipment when defects were occurred.However, data acquired from each piece of equipment was in independent of each one. For this reason, when a defect is occurred, its factors had to be inferred by finding "abnormalities" and by elaboration of collating data with log from the independent piece of equipment and sensor data.In many cases, Omron's manufacturing processes use plural pieces of equipment. It was difficult to say that a defect was caused by "an abnormality" with one specific piece of equipment.Human power is limited to identifying relationships between combination of plural "abnormalities" and a defect, to determine factors for a defect from a very large volume of data.In response to this problem, Toshiba organized a project team centering on the members of the Toshiba "IoT Technology Center".In addition, all the skills, knowledge and know-how accumulated in the Toshiba Group including "Corporate Manufacturing Engineering Center" that is responsible for advanced research and development of manufacturing engineering for the entire Toshiba Group were brought together. In this effort, a study was made to analyze how best to solve Omron's problems. What data should be collected from the manufacturing equipment and how should analysis be conducted?

Process data such as equipment log data and sensor data, as well as data of inspection result, data of the Manufacturing Execution System (MES), were connected to each product lot. It was able to determine in which sequence anomalies were generated and what quality results resulted by identifying "abnormalities" taking place in the manufacturing process as "events" through threshold calculations that were calculated by statistical calculations.Using Toshiba's event pattern analysis technology, event combinations (patterns) that commonly took place for a defect were then identified. An effort was made to search deeper factors for defects in high-mix low-volume manufacturing lines. This was accomplished by displaying numbers and trends of defects and events, as well as the number of defect patterns, related manufacturing processes and other data.

Gain New Explicit Knowledge from Visualized Event Data

This section describes how data analysis of Toshiba that employs the event pattern analysis technology is actually used at Kusatsu factory of Omron Corp.

At Omron Kusatsu factory, printed circuit boards flow through the manufacturing lines in the following sequence and are then assembled as products.

①Solder printing - Solder paste is coated in specified positions on a substrate.

②Component mounting - Electronic components are mounted on a substrate on which paste is coated.

③Reflow - Solder paste is melted by heating it to solder electronic components.

④Inspection system - Visual inspection is made to find defects by image inspection equipment and by visual inspection by inspectors.

Data obtained in the manufacturing processes ① to ④ and inspection result data are connected to individual printed circuit boards.Events such as whether alerts were issued by component mounters and whether sudden temperature fluctuations beyond a preset range took place in the reflow furnace are translated as events in relation to the large amount of time-series data generated as explained above. Using the event pattern analysis technology, event combinations that were occurred commonly with defects are identified.For example, if events are found to occur in the order of [E]→[H]→[L] with a defect of a certain type, combinations (patterns) of these three events can be considered as a probable cause of this defect (Figure 2).

Toshiba showed the event patterns that were actually obtained to Omron. Aside from event patterns that were already known, patterns that were somehow felt at the manufacturing worksites and patterns that were never encountered before were detected. Factors for unknown patterns were analyzed by an in-depth investigation of their generation mechanisms and the effectiveness of this analysis technique was verified.

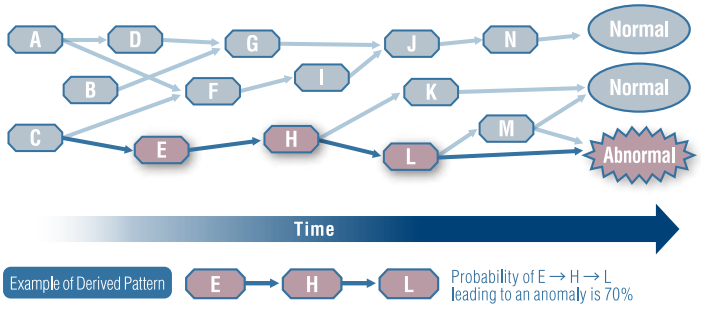
Toshiba has built a prototype system to allow this type of analysis to be used in routine "kaizen" (continued improvement) activities at its manufacturing worksites.A mechanism was provided allowing viewing data of events, patterns and the presence or absence of defects, as well as the types of any defects generated in a manufacturing process, in a spreadsheet program. This data was linked with each printed circuit board.Using a user interface built on a BI[*2] tool, this data, as well as numbers and manufacturing processes of events, patterns and defects generated and other data, were visualized to understand correlations of plural events more intuitively.It was possible to change view point, such as viewing by a specific product, a specific defect or a specified period of time. Thus, visualization of analysis data facilitated new "awareness" of Omron, and contributed to the daily kaizen activities at manufacturing worksites of Omron.Kusatsu factory of Omron continues to analyze data even at present in an effort to further improve product quality while accumulating new explicit knowledge.

Challenge to Continuous Next Generation Quality Improvement through "Co-creation"

In April 2016, Toshiba released "Meister Analysis", a big data analysis and utilization solution for manufacturing that incorporated Toshiba's event pattern analysis technology, which was proved to be viable in Omron's case, as one of its "Next Generation Manufacturing Solutions".Toshiba believes that mentioned analysis using real data at Omron's manufacturing worksite and verification of daily kaizen activities were very meaningful for developing this solution.Because the analysis techniques meeting the high-mix low-volume production could be established, and Toshiba now feels confident that it will be able to powerfully support quality improvement of mass-customization aimed at by the Japanese manufacturing industry.Toshiba will lead next generation manufacturing in Japan by further refining its technology through "co-creation" with its customers.

Figure 2 Event Pattern Analysis Technology

Technology to identify event combinations (patterns), which have a high probability of arriving at specified results, from many event sequences.This technology can be used in assuming factors for defects and failures and in creating models of anomaly prediction.



*2 BI: Business Intelligence

Reliable Solutions Dramatically Reinforce Functions

Meister Series Evolving for Sure Implementation of Next Generation Manufacturing

Toshiba has comprehensively upgraded its global manufacturing solutions "Meister Series", which has supported the major business processes of the manufacturing business since its launch, related to its "Next Generation Manufacturing Solutions".The concept behind this total upgrading is to reinforce the existing products anticipating next generation manufacturing.The upgrading greatly strengthens the functions of the following solutions. "Meister PLM", a PLM solution of a semi-order made type. "Meister SRM", a strategic procurement solution, and "Meister MES", an MES solution.This article describes how these solutions have evolved and what innovations they would bring to customers.

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"First Step" toward Next Generation Manufacturing Is Proposed

Digital data needs to be integrated and all processes of the manufacturing industry need to be mutually linked, to realize next generation manufacturing.In many cases, however, individual processes are separately optimized by their own data formats and communication protocols that don't allow to communicate with the other processes. It has been very difficult to optimize the entire value chain.

In response to this situation, Toshiba has studied various solutions for next generation manufacturing based on a framework of "Horizontal Integration" to connect product lifecycles and of "Vertical Integration" to connect information ranging from the worksite level to the management level.In April 2016, Toshiba released four solutions that comprehensively support "information collection", "information storage" and "information utilization" (See page 5). At the same time, Toshiba is intent on further promoting the innovation by aggressively reinforcing its existing products that have supported the manufacturing industry for many years, as it harmonizes with next generation manufacturing.This effort is a renovation of its Meister Series, global manufacturing solutions.

In the past, Toshiba's Meister Series has totally supported planning, development, production and maintenance, which are the major processes of the manufacturing industry, based on the concept of "connection".The current upgrading reinforces "Meister PLM", a PLM solution which allows the utilization of information on entire lifecycles of products, "Meister SRM" for optimization of and risk management for procurement, and "Meister MES" that connects equipment at a factory to a higher system for manufacturing orders and production management, interlocking with changes in demand forecasts and in production plans. The upgrading anticipates evolving value chain of manufacturing.These solutions will enable the customers to take a bold step in optimizing their supply chains, in realizing "connected factories" and in mass customization, which is the first target of the fourth industrial revolution.

This section describes each of these solutions.

Meister PLM - PLM of Semi-Order Made Type

"Broadly" Defining PLM, "Connection", "Storage" and "Utilization" are Beefed Up

Product Lifecycle Management (PLM) is a mechanism to support reliable accomplishment of quality, cost and delivery due date (QCD) targeted by enterprises. PLM also supports the timely market release of competitive products and maximizing earnings. This support is provided by digitally managing product lifecycles from product design to production, sales and maintenance service.

However, the application of PLM systems in the past tended to be confined only to the management of design information. The reasons were such as PLM systems were evolved from drawing management and a large amount of cost was needed to connect individual business operation systems that were functioning in silos.

Overcoming this, Meister PLM reinforces the three functions of "connection", "storage" and "utilization" to realize management of entire lifecycles of products, which is the original objective of PLM.

In "connection", a personalized order solution (Meister PLM Personalized Order Option) has been released as the first step to respond to the needs for mass customization and for personalized customization beyond mass customization.

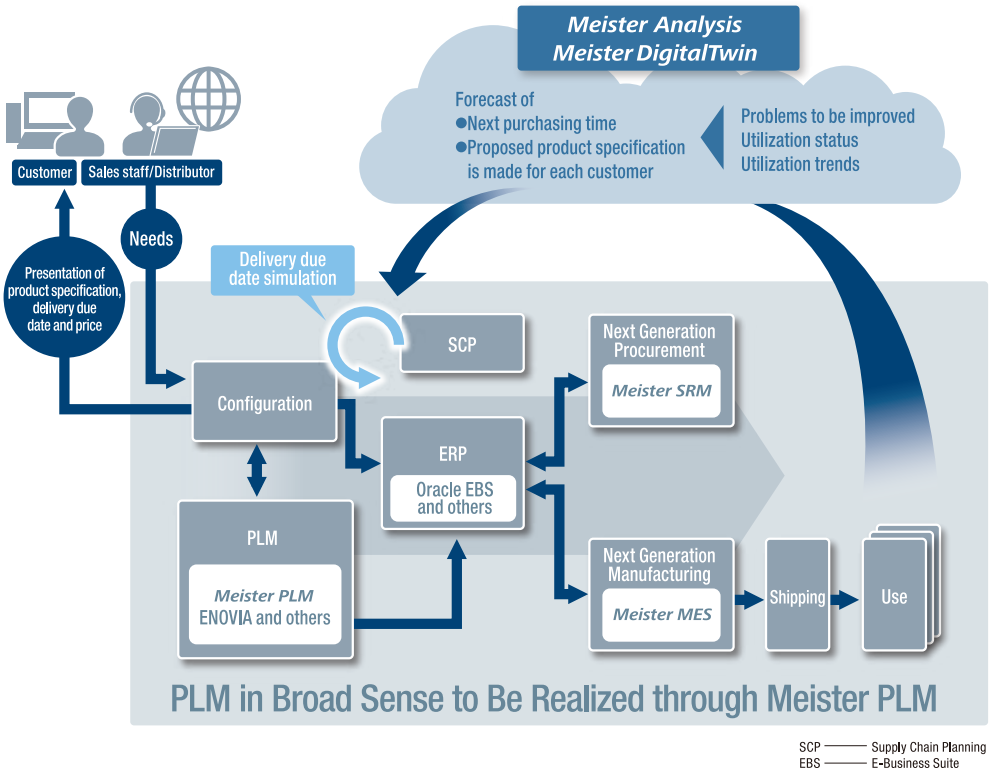
The manufacturers have been responded meeting diverse customer requirements. However, Toshiba believes that a response to personalization will be necessary in the future. Wishes of individual customers will have to be translated to specific forms and these forms will be shared with the customers. The manufacturers will then have to propose products with appropriate QCD and to implement design and production immediately.This solution incorporates a function to seamlessly link PLM to a configurator, 3D-CAD and ERP*1.Requirements

*1 ERP: Enterprise Resource Planning

of customers input online are analyzed and an optimum product specification, price estimate and shape that combine standard specifications are submitted to the customers automatically. Where specific individual requirements needs to be addressed, the specification requirements are instantaneously taken care of in design and production.Thus, the process from requests for quotation to production order after order booking can be shortened dramatically for not only products that can be produced in standard specifications, but also for products that require customized specifications.
Next, in "storage", a product lifecycle cost and value available to the customer, as well as a specification (function and performance) and structure (mechanical, electrical and software), are systematically managed. These information is merged with the individual-product information stored in Toshiba's data connection platform for manufacturing: Meister DigitalTwin, such as how products are produced for and used by each customers to manage product information throughout the lifecycles.
In "utilization," the information of products stored in Meister DigitalTwin and merged as mentioned is finely analyzed, to feed back the result to specifications and structures managed by PLM.The analyzed result is designed to be connected to accomplish the development of next-phase products and a high level of the ability to meet customer requirements (Figure 1).

Figure 1 Image of PLM in Broad Sense to Be Realized through Meister PLM

Data from manufacturing worksites, data in aftersales services and data acquired through business operation systems are integrated. An information management infrastructure crosscutting all processes is built to optimize manufacturing.



Next Generation PLM Flexibly Responds to New Manufacturing

New manufacturing utilizes information of entire lifecycles of products such as development, design, procurement, production, sales and maintenance service. A solution that can flexibly combine and expand functions suitable to link to different systems that might have various data models and to meet various business utilization scenes will be needed.Conventional package models have a problem because a large amount of customization work is required for them.On the other hand, if all functions are decided to be developed from scratch, the time needed for the development will greatly increase and it will not be easy to follow rapid changes.
Meister PLM features advantages of both package software and software developed from scratch.Meister PLM can easily respond to customization and add-ons through necessary data models, functional parts, screens for PLM and framework to combine them, as well as links with peripheral systems such as sales, production and service systems.
Systems just fitting customer business operations can be built in a short time at optimum cost by combining data models, screens and functional parts needed in business operations.Meister PLM has an architecture consisting of modules for individual functions and data models so that system changes and expansions can be dealt with flexibly.
Meister PLM powerfully implements information utilization throughout the entire lifecycles of products, as PLM is supposed to realize.This is the next generation PLM solution supporting the revolution in manufacturing.

Meister SRM - A Strategic Procurement Solution

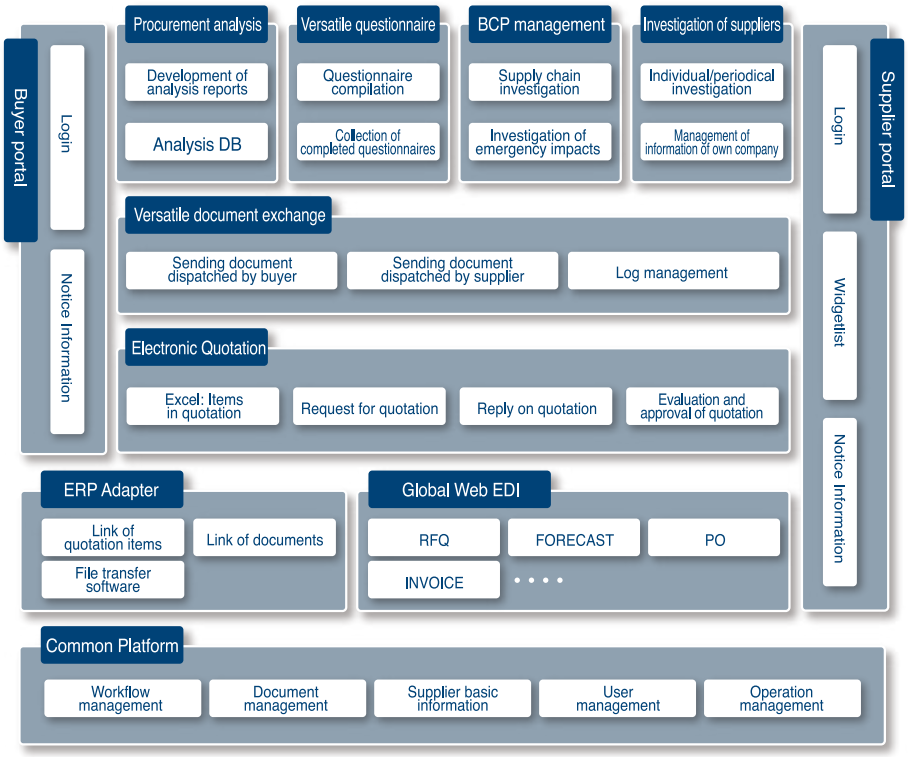
Optimum Procurement by Hedging Risks such as Exchange Rate Fluctuations and Disasters

The manufacturing industry has maintained quality and reduced cost by minutely managing the supply chain from the procurement of raw materials to product production, shipping and sales and by optimizing production planning and procurement activities based on demand forecasts.Nevertheless, accelerated globalization of manufacturing and more production and procurement activities at overseas sites have highlighted exchange rate fluctuations of raw material prices and personnel costs as a factor for blocking the optimization of procurement activities.The Great East Japan Earthquake exposed the problem of a supply chain that spreads like a network.In many cases, production had to be halted due to discontinuance in the supply of materials and components because suppliers of the second and subsequent tiers sustained damage to their facilities even though suppliers of the first tier escaped such damage.Impacts caused by the whole image of the procurement route being invisible pose a great risk in the case of an emergency.
Against this backdrop, Supplier Relationship Management (SRM) is attracting attention because it allows the continuous optimization of procurement activities independent of economic fluctuation risks and disaster risks by the manufacturing industry strategically managing

supplier relations.In "Industrie 4.0", the German Government views supply chain optimization on a national level beyond the walls between enterprises and factories as the final stage for realization of this national project. Thus, SRM is regarded as a prerequisite in realizing next generation manufacturing.
In order to meet this situation surrounding the procurement sector, Toshiba has reinforced the function of its strategic procurement solution Meister SRM.Customized System can be configured smoothly from a standard package. By linking versatile functions such as electronic quotations, supplier investigation and BCP*2 management, the optimization of global and continuous procurement can be achieved while avoiding production shutdown risks (Figure 2).

Figure 2 Schematic of Meister SRM

Meister SRM as a global communication platform linking buyers and suppliers manages diverse buyer information, which is accumulated every day, integrated.
Highly strategized procurement activities optimize cost and eliminate production shutdown risks.



Building a Dynamic Supply Chain by Link between Functions and IoT*3

In manufacturing industry, buyers periodically collect supplier information such as corporate status, financial status, equipment owned by them through supplier investigation.All this information is very useful in understanding supplier situations. However, effective utilization of this information is considered difficult if such information is stored and managed in a file server or on paper.Meister SRM makes supplier investigation through the Internet. The suppliers themselves update the information as necessary and Meister SRM manages it integrated as a supplier database.Buyers can select the best suppliers by examining such information as their technical competences and production capacities in detail.
By managing the location information of the suppliers of the first and subsequent tiers in the supply chain, suppliers in damaged areas in the case of a disaster can be identified and the impacts caused by such disaster can be investigated.This allows supplier-concentration risk mitigation and quick determination of impacts caused to suppliers by a disaster, enabling implementation of BCP such as quickly finding alternative materials and components.
In addition to supplier investigations and the BCP function, Meister SRM also offers an electronic quotation function to acquire detailed cost information of parts and components in a flexible format and a function for exchanging documents of non-regular formats securely with suppliers.
Meister SRM will continue to support building a dynamic supply chain for optimizing procurement activities on a global scale, to more effectively respond to next generation manufacturing.The supply chain information collected by the existing functions is linked to production information collected by backbone systems at business sites and by IoT and is managed systematically, to comprehensively visualize supply routes of individual parts and components and the real-time production status of suppliers.This will enable smooth setting of alternative supply routes in the case of exchange-rates fluctuations and a disaster, to avoid or minimize impacts.Flexible optimization of procurement activities will allow a production system to be built that can flexibly meet changes in customer needs and unexpected increases or decreases in demand.
Meister SRM continues to evolve for higher performance.Meister SRM is a tool to start strategic procurement that will support next generation manufacturing.

Meister MES - An MES Solution

Vertical Integration of Market Needs and Production Sites for Next Generation Manufacturing

Horizontal integration through product lifecycles and vertical integration to link information inside factories to management systems such as ERP are indispensable for realizing next generation manufacturing.As mentioned earlier, Meister PLM will support horizontal integration.On the other hand, "Meister MES", an MES solution described in the following, accomplishes vertical integration and supports mutual linking with product lifecycles.
MES stands for "Manufacturing Execution System" and means a manufacturing execution system that issues manufacturing orders and collects records of results.Based on production plans of factories, Meister MES issues manufacturing orders to operators and equipment.Additionally, Meister MES plays an important role in supporting the execution of manufacturing between ERP and sites such as proceeding management for processes based on actual manufacturing data.
New Meister MES further empowers the existing high-potential functions as an MES and is equipped with epoch-making functions to implement next generation manufacturing.The new Meister MES achieves both a seamless link between control systems located inside

*2 BCP: Business Continuity Planning *3 IoT: Internet of Things

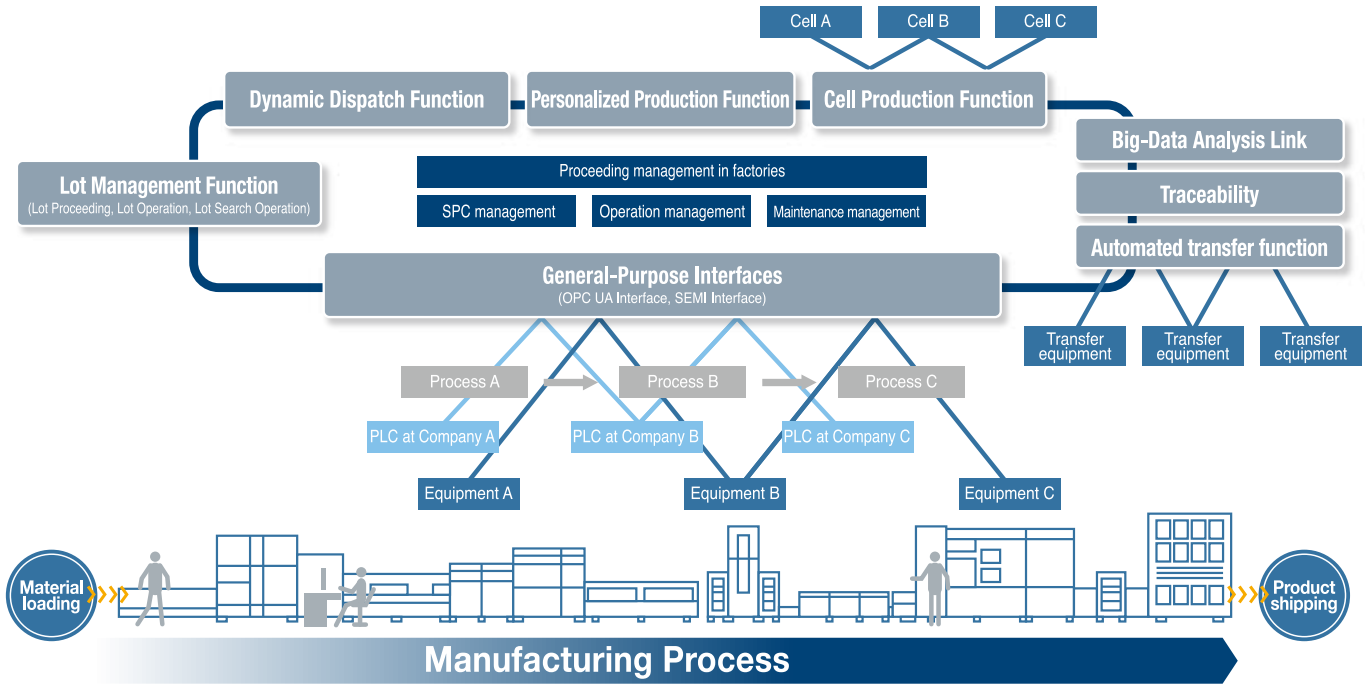
factories that are connected to an IoT network and visual factory operations through precise work orders and result management.This will result in realizing "connected factories", in which the status of production worksites that change from time to time synchronizes with the people working in factories and with the manufacturing equipment installed there.

Looking Hard at "Industrie 4.0", General-Purpose Interfaces, Automation Functions and Reinforced Cell Production Functions Are Provided

Meister MES aims to build a smart production process that autonomously functions based on production plans that incorporate precise individual needs of the customers. Meister MES is designed to function in next generation manufacturing for the production of high added-value products in multiple models and in needed quantities.
Meister MES implements "OPC Unified Architecture (OPC UA) ", which is a communication protocol recommended in "Industrie 4.0" as an interface to connect equipment at manufacturing sites.In fact, Meister MES implemented OPC UA first in Japan. Meister MES can connect controllers such as PLCs through a secure network.
The "dynamic dispatch function" and "automated transfer interface function" have been reinforced as automation functions.The dynamic dispatch function incorporates a work commencement dispatch function to decide and order which lots are to be processed when equipment in each process is standing by for processing and a transfer dispatch function that orders transfer to a downstream process when processing by equipment completes.The automated transfer order interface function connected to this transfer dispatch function enables a link to automated transfer equipment.These functions allow the effective utilization of production equipment and resources and improvement of the throughput of the entire factories.
Additionally, the " cell production functions" to support High-mix Low-volume production have been reinforced.Flexible production lines meeting loads at production sites can be built by viewing plural production processes as a "cell" and by combining such cells so that operators at each process can easily understand the work that is ordered to be undertaken.
The link with "Meister Analysis", a big data analysis and utilization solution for manufacturing released in April 2016, is also a major topic.Production log data acquired by Meister MES and a large volume of data acquired through IoT are mutually linked to analyze patterns of defects and anomalies in high precision.By instantaneously feeding back analysis results to manufacturing orders and equipment control, defects and failures are prevented to improve both yield and productivity, thus allowing production at a higher level (Figure 3).
The Meister series has been reborn as solutions for next generation manufacturing and will evolve its power that has supported manufacturing of various products, in order to fully support next generation manufacturing by its customers.

Figure 3 Meister MES

Indispensable functions in next generation manufacturing such as automated production, dynamic cell production and personalized production are provided as one stop through general-purpose interfaces.
A link to a big-data analysis is supported to build "connected factories" that maximize yield and productivity.



OPC UA —— OPC Unified Architecture (OPC=Object Linking andEmbedding for Process Control)
SEMI —— Semiconductor Equipment and Materals International
SPC —— Statistical Process Control
PLC —— Programmable Logic Controller

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