Fujitsu's Innovation in Manufacturing and Engineering

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Since 2003, Fujitsu has been pursuing innovation in manufacturing based on its strengths in value-added manufacturing, an objective of which has been to raise the skill level of all employees. Our manufacturing environment has been undergoing great changes, with the relocation of production to Southeast Asia and China and less value being added internally due to more unit purchasing stemming from fractionization and increasing openness of technology. Based on an analysis of these changes, this paper outlines Fujitsu's commitment to innovation in manufacturing and engineering with the focus on improving quality, cost, and delivery (QCD) for servers, networks, personal computers, and mobile phones in the processes from development to manufacturing. Going into more detail, it describes our activities for reducing total costs and increasing competitiveness through innovation in manufacturing, originating in the plant and extending upstream to the supply chain and development.

1. Introduction

Since 2003, Fujitsu has been promoting an Innovation In Manufacturing Program that aims to make use of its strengths in high-added-value manufacturing and enhancing the value of human resources. During this period, people have realized that Japan's manufacturing industry is still the country's lifeline and a source of economic power (Commission on Making Things in Japan, 2000),[1] and there has been serious discussion of various manufacturing issues such as the return to domestic manufacturing and the trend towards black box systems.

In this regard, Fujitsu has been making great efforts towards quality manufacturing, both on an individual company level and as a leading enterprise supporting the Japanese economy.

In this paper, we discuss the efforts the Fujitsu Products Groups (hereafter called the Products Groups) have made towards innovation in manufacturing and the prospects for the future.

2. Changes in manufacturing environment

In the last few years, the rapid globalization of the data communications business market has brought about tremendous changes in the manufacturing environment. Firstly, greater sophistication in communications technologies has made the manufacturing of products more difficult and the importance of consistently factoring quality, cost, and delivery (QCD) into design and manufacturing has been continually growing for core products. Secondly, in the highly competitive global marketplace, the provision of higher value to customers' business and lifecycles in terms of QCD has become an important element of differentiation, and it has become essential to be best-in-class regarding both technological capabilities and the services provided to customers. Thirdly, in pace with the increasing trend towards technologies becoming more component-based and open, the proportion of total costs accounted for by external procurement has been rising and processing costs have been falling, leading to an increase in the importance of quality control for externally procured parts and a reduction of component inventories due to shorter lead times. Fourthly, owing to the hollowing of Japanese industry resulting from the shift of manufacturing to China and other countries, there is growing unease about the future. To combat this, it will be necessary to focus on total costs and make domestic manufacturing increasingly innovative, while at the same time prevent a hollowing out in terms of knowledge and technologies by refraining from the easy option of outsourcing.

3. Efforts made so far

In response to the above changes in the manufacturing environment, the Products Groups have made efforts to optimize their production systems, shorten development and manufacturing lead times, raise productivity, and strengthen quality control systems. As a result, in the three-year period beginning in 2001, we were able to halve inventory and reduce plant costs by 30%.

1) Optimization of production systems

Production systems have been optimized by making an overall appraisal of lead time and total cost factors, including customer service (delivery, quality, etc.), distribution costs, and defect-related costs (product repair, disposal, defective work costs).

The following is a brief review of the market, production, and procurement characteristics of four major types of products.

- Network devices

Relatively high dependency on overseas markets for sales. Final assembly plants are located close to Japan, North America, China, and other important markets.

- Mission-critical servers

Integrated development and production in Japan to accommodate the latest technologies and need to maintain high reliability

- Notebook PCs

Integrated production continues in Japan while maintaining the competitiveness of domestic production in terms of total costs and ability to meet the need for high quality and fluctuations in demand.

- Hard disk drives (HDDs)

A major part of the HDD market is overseas, and mass-production of HDDs has been conducted in Southeast Asia since 1994. Currently, virtually all HDD production is done overseas, including the production of key components.

2) Shortening lead times and raising productivity

In the three-year period beginning in 2001, efforts were made to halve inventories company-wide; reduce lead times in all areas spanning development, production, logistics, and procurement; and raise productivity.

Some of these widely ranging activities are described below.

- Development

Activities in this area have centered on raising design quality with a view to shortening the time to market for the Groups' products and speeding up work procedures. These activities include the development of the integrated CAD environment EMAGINE[2] (which supports the overall electrical design process of products), raising design efficiency through the introduction of the 3-D design verification tool Virtual Product Simulator (VPS),[3] shortening manufacturing preparation times through the use of design data, and prior design verification using simulations.

- Production, logistics, and procurement

Efforts in these areas have focused on speeding up the supply chain by being more responsive to changes. This has encompassed switching to weekly production plans; expansion of direct shipping from plant to customer; consignment production; and expanding the application of Just-In-Time (JIT),[note 1] Build To Order (BTO), and

note 1) Procuring what is needed at the right time in the right quantities.

Cell manufacturing.[note 2)]

3) Enhancing the quality of systems

Because the number of systems incorporating externally procured parts and components has been increasing, efforts to enhance the quality of such systems have centered on reinforcing the quality assurance division's systems evaluation center and the introduction of the Supplier Quality Management (SQM) quality control system for externally procured parts in collaboration with suppliers.

4. Objectives of innovative manufacturing and its history

The Products Groups have been carrying out innovative manufacturing activities since 2003; these activities have had two components: innovative manufacturing and innovative engineering. The policy of these activities called for 1) the achievement of higher added-value manufacturing with emphases on reliability for system products and speed and lower costs for ubiquitous products and 2) enhancing the value of human resources (human development). Their goals were to double quality and productivity and halve lead times within two years.

These activities were started with the full-scale introduction of the Toyota Production System (TPS)[note 3)] in production lines, after which the aim was to achieve company-wide innovation as far upstream as the supply chain and development. The introduction of TPS, which was a system foreign to Fujitsu, was adopted by top management with the aim of speeding up innovation.

The results were much better than expected, with the initial goal of doubling productivity being achieved in just a year for some production lines. Also, a pattern became apparent in the company-wide innovation, beginning on-site at the point of origin. The program of our activities for achieving innovation and the significance of TPS in these activities are outlined below.

4.1 Outline of innovation in manufacturing

TPS was introduced independently at 16 Products Groups plants from 2003 onwards, and in 2004 it was introduced at three key plants such as Fujitsu's Oyama Plant and Nasu Plant and Fujitsu IT Products plant under the guidance of consultants. The introduction of TPS under the guidance of consultants was expanded to six more plants from 2005 onwards. TPS is now being introduced at other plants based on what has been learnt from the consultants.

The major aims of TPS are JIT and automation. However, the consultants also stressed the importance of having clear implementation steps in their guidance, and we consider that following this principle has been very effective in instructing people at other plants regarding its introduction.

The steps in the implementation of TPS are as follows:

1) Make flow charts for items and data
2) Streamline flows
3) Separate into individual flows and standardize work procedures
4) Switch to the *kanban* pull system[note 4)]

Switching to the *kanban* pull system enables problems to be visualized, and then constant efforts can be made towards improvement. The application of the *kanban* pull system to the production lines at the Oyama Plant, Nasu Plant, and Fujitsu IT Products plant began in September 2005 and in March 2006 at other plants. At present, its expansion to all lines is underway.

Concrete efforts are now being made towards expanding innovation based on TPS from plants

note 2) A manufacturing system covering multiple processes ranging from the assembly of components to processing and inspection carried out by one or more persons.

note 3) A production system developed by Toyota. Having JIT and automation as its key elements, the system aims to thoroughly eliminate waste.

note 4) A pull system for realizing JIT that uses color-coded cards. ("*Kanban*" is Japanese for a sign or index card.)

upstream to sales, suppliers, and development. Some examples of these efforts are as follows: 1) in the supply chain, our sales personnel engage in direct dialogue with plants to make production smoother; 2) analysis of the operational processes from sales to plants and the flow of information between them is being conducted using TPS analysis techniques; 3) TPS is being expanded to procurement and product logistics; and 4) Fujitsu's parts procurement divisions are carrying out a trial on the use of the *kanban* pull system in parts procurement.

In development, Design For Manufacturing (DFM) is being intensively applied with the aim of achieving ease of manufacturing and raising productivity, and a course in manufacturing has been started for designers.

We have learned many things from TPS regarding innovation in manufacturing, which is still in its infancy at Fujitsu. For example, we have learned the principle of pursuing the ideal situation and tracing problems back to their source rather than limiting ourselves to what we believe we are capable of. We have also learned that the principles and practices of TPS can also be effectively applied in the administration and design divisions to achieve innovation. TPS has also been very effective in the analysis of the flow of information in the supply chain (which extends from sales through manufacturing to shipping), in development, and in making necessary improvements. Achieving future innovations in production lines will depend on the extent to which development, demand, and procurement can be traced back to their sources.

4.2 Overview of innovation in development

Eighty percent of product costs are said to be determined at the development stage. Taking the production line as the starting point, innovation is extended to the development area upstream and is linked to a reinforcement of the competitiveness of products and devices. The essential principles of TPS are also valid at the development site. **Table 1** shows an example in which the TPS approach to waste has been applied to development.[4)]

At the development site, JIT concerns the timely development of technologies by first making a flow for development and then streamlining it. Here, the "automation with a human touch" (knowledge, know-how, experience) of TPS is considered to mean the building of a development environment utilizing simulations and IT and also incorporates proposals about DFM from the manufacturing site. Human resources are fundamental to reinforcing development capabilities and require further nurturing.

In activities whose aim is innovation, it is important to go back to basics. To achieve innovation in development, our activities center on upgrading IT systems as a common support technology, visualization in development, and linking development with manufacturing (e.g., DFM activities).

5. Innovation in manufacturing originating on-site

The production site that gives form to a product that meets the customer's specifications is at the point of overlap between the customer's order, the supplier, and development and design. It is also the closest point of contact with customers (**Figure 1**). To achieve manufacturing that meets customer specifications and delivery dates, it is necessary to pursue total innovation, beginning at the manufacturing site that is linked with the solution of problems that emerge at the manufacturing sites of the related divisions.

To achieve innovation in manufacturing production lines, TPS has been introduced company-wide at Fujitsu. Unlike Fujitsu's previous approach to manufacturing, which focused on lot manufacturing, automation, and the initiative of production staff, the pursuit of innovation based on TPS focuses on JIT and automation and initiative is taken by the manufacturing site locally for

Table 1
Measures against waste at development site.

		5 of the 7 kinds of waste targeted in Toyota Production System				
		Waste in transportation	Waste in processing	Waste in inventory	Waste in movement	Waste in defects
Waste in development activities	Examples of waste in development	• Design information not unified or organized • Information cannot be shared	• Omissions in design & evaluation procedures • Superfluous design and evaluation	• Design not possible because specifications and design details not determined in previous processes (work delayed)	• Work proceeding but output delayed (drop in efficiency)	• Defects emerge in evaluation of trial manufacturing • Defects in components due to inadequate specifications
	Examples of causes	• Linking of design data from upstream stages not possible	• Design flow not standardized	• Progress not being made in project	• Workload of designers cannot be assessed	• Insufficient design margins • Inadequate specifications/insufficient verification
Measures to improve development efficiency	Just-In-Time (adjustment of flows, visualization of flows) (timely development)	• Unify standards, and • unify design/manufacturing interfaces	• Visualize project stages (achieve innovation in development processes by making project stages more visible)			• Develop common technologies (components, structures, mounting) in advance • Standardize technologies
	Automation with human touch (knowledge, experience, know-how)		• Promote DFM (listen to opinions from site first)		• Thorough use of IT (3D-CAD/VPS) (strength, electrical noise) (robust design [Taguchi Method])	
	Human resources	• Change designer mindset, upgrade basic design techniques				

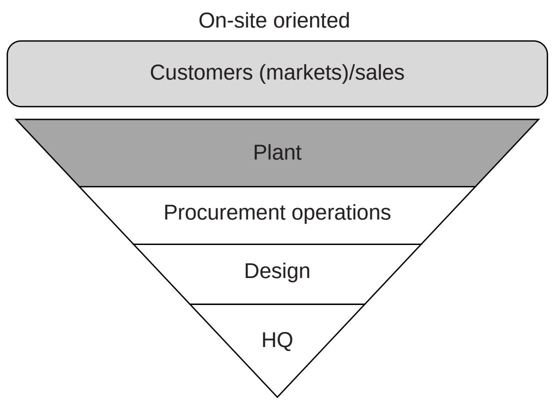

Figure 1
Manufacturing site at closest point of contact with customers.

the product in hand. In introducing TPS, we have made use of external consultants. This was done because of our lack of knowledge concerning the essence of TPS and the steps in its implementation and to help us develop schedules for company-wide innovation.

When our activities towards innovation were commenced in 2003, their goal was to double productivity in two years. However, through preparatory training in which employees were made aware of TPS and its goals and how to implement it from the 2Ss (Sort and Straighten), a 1.5-fold increase in individual employee productivity was achieved at some plants in just a year. In addition, at some plants, storage space was halved by reducing the number of external warehouses, and manufacturing lead times were halved as well. The full-scale introduction of TPS began in 2004, when we started to use external consultants. Activities before 2004 were reviewed and revised, and efforts were made to create plants and working environments in which problems could be visualized. These efforts were made through the TPS steps of streamlining flows, dividing them into individual flows, and introducing the pull system.

In terms of productivity, the application of TPS to production lines halved direct working, halved lead times, and reduced work by 70%. Regarding TPS's fundamental objectives of enhancing awareness and improving behavior patterns, there was a drop in the number of workers who said they were unable to do a particular task, and workers started encouraging each other and learning more about TPS. Activities such as these for achieving innovation in production lines will be used as the starting point for the full-scale pursuit of innovation in all our plants — which directly communicate and closely cooperate with other Fujitsu's plants and external manufacturing companies — and in Fujitsu's sales and development divisions.

6. Reinforcement of technologies to support innovation in manufacturing

Manufacturing technologies must be reinforced to support activities for achieving innovation in manufacturing at the plant level. As we head towards an age in which there will be full-scale ubiquitous computing, there are increasing expectations for greater miniaturization, higher functionality, and higher performance in IT equipment. In mobile phones for example, new features are being constantly added, for example, high-resolution cameras, authentication devices, and Internet connection functions. Also, for the servers and network devices that provide the infrastructure for mobile phones, increases in performance that allow larger volumes of data to be processed at higher speeds are being pursued. It is therefore important to rapidly provide the added value required by the customer in state-of-the-art products and devices, and this will continue to be true in the future. In this regard, we consider the following to be essential issues in production technology (**Figure 2**).

1) Key technologies that differentiate Fujitsu's manufacturing

In miniaturizing mobile devices and raising the performance of servers and network devices, the high-level technologies that go into the key devices and their components are a powerful tool for achieving differentiation. Miniaturization and higher densities are a natural progression in electronic devices, and the mastery of technologies for manufacturing in the submicron to nano-order range will be of great importance in gaining superiority over competitors.

There are limitless possibilities for the use of micro-processing technology in the creation of devices such as micro electro mechanical systems (MEMS), optical components, and sensor devices, and high-density mounting technology is important for ensuring the performance and reliability of final products.

Fujitsu is making great efforts to develop such nano-technologies because we consider them to be fundamental to future manufacturing.

2) Manufacturing technologies that can accommodate product launches in a timely manner

Formerly, the manufacturing technology division demonstrated its skill by showing how well a product designed by the development division could be made. However, now that getting a product to market quicker than other companies is a condition for winning the competition, in manifesting new technologies as products, it is necessary to have very close contact with the development division and bring existing technologies and know-how together from the early design stages. This can be done by having a flexible array of manufacturing equipment on which a virtual verification can be performed at the equipment design stage and which can be used to form production lines very quickly.

3) Manufacturing technologies accelerating the

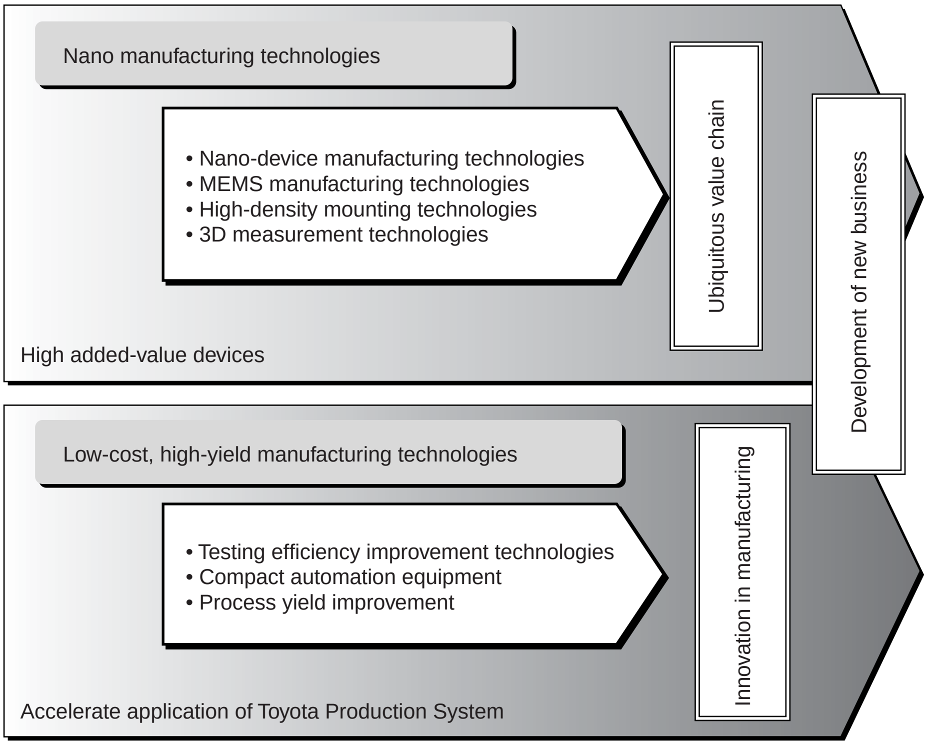

Figure 2
Themes in development of production technology.

spread of TPS

To reduce production costs and shorten lead times, we have to create a framework in which there is high accuracy and no waste in the process from the procurement of parts through manufacturing and testing to shipment. In the case of BTO products in particular, it is necessary to provide the production line with the mounting data and testing conditions for the assembly of products for individual orders as quickly and accurately as possible. Linking up with the sales and engineering divisions and making use of cutting-edge IT such as automatic manufacturing data generation systems and in-process control systems utilizing RFID tags makes it possible to achieve highly accurate and efficient manufacturing systems.

7. Innovation in upstream development

The focus of Fujitsu's activities in upstream development has been on speeding up the development process, enhancing design quality, and raising productivity.

7.1 Innovation framework

1) Efforts towards speeding up development

At the development site, while the various functions and structures of products can now be visualized through the use of 3D CAD, many different types of verification are still required at the design stage due to the greater densities and compound functions that products now have. For this purpose, Fujitsu has developed VPS, which allows virtual verification to be performed on digital mockups using 3D data at various stages, including design, manufacturing, and recycling, and it is currently being used in design reviews. In the development of printed circuit boards (PCBs), we have recently started using world-class transmission simulation technology to achieve the reduced noise margins needed for higher clock frequencies, lower voltages, and higher density packages. By using this technology, we have reduced the development periods, for example, by eliminating noise problems at the trial manufacturing stage for system products (**Figure 3**).

2) Efforts to enhance design quality

To enhance design quality, it is necessary to quantify robustness with respect to variations in development technologies and changes in usage conditions and also achieve visualization and standardization in the development process. Regarding robustness, we have embarked on a project whose objective is to promote optimization in the design and manufacturing processes through the application of the Taguchi Method,[5] which includes reinforcing engineers' development capabilities. We have also gathered together a team of in-house experts and are making use of their skills to solve the major problems in each business division.

Furthermore, since 2005, we have been holding in-house study meetings in which the participants — people with long experience of working in Fujitsu's business divisions — share information and discuss solutions to common problems. Recently, linking simulation with the Taguchi Method has enabled us to focus on design factors more effectively, and this has helped greatly in shortening analysis times.

Another activity has been the development and application of a design management system that supports visualization in the design process. This system clarifies individual work items by standardizing design flows and incorporating design standards, guideline checklists, and other features into them. This system facilitates understanding of design resources and proper resource shifts and has already helped to reduce

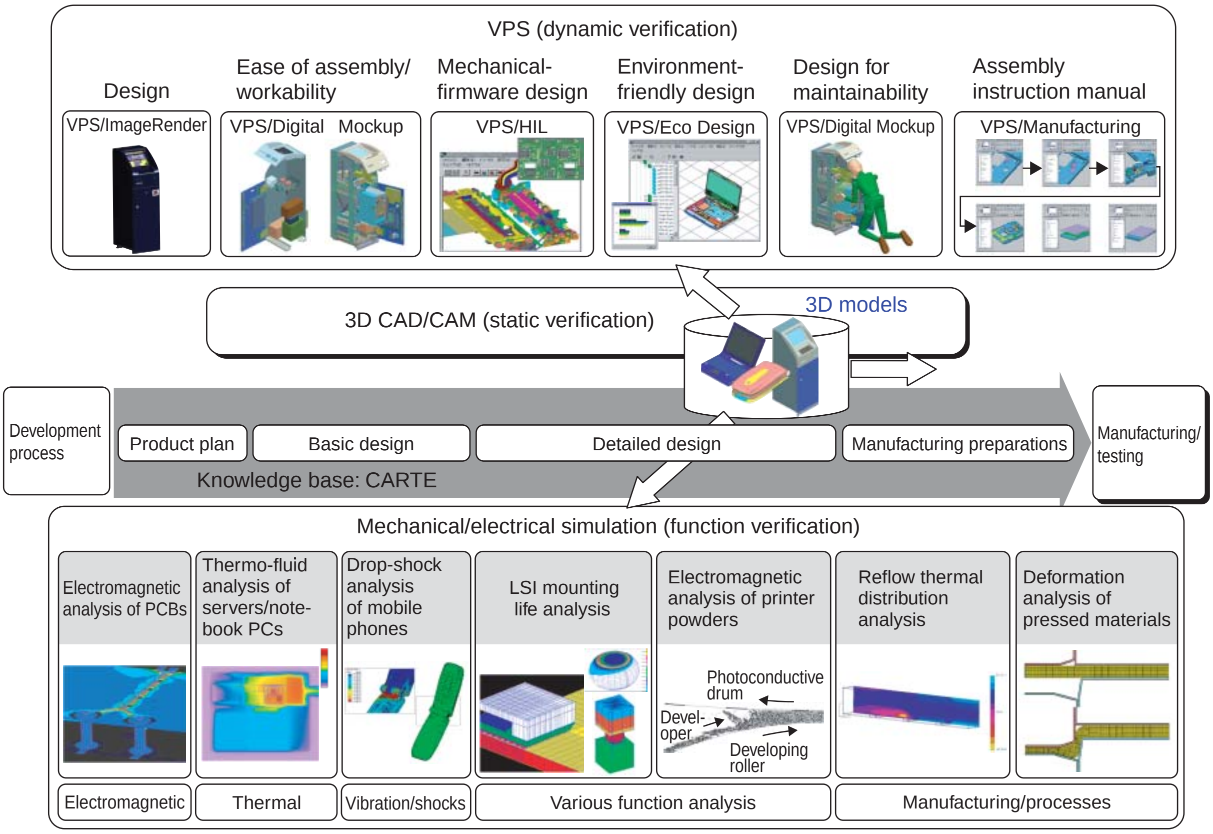

Figure 3
Development environment using VPS and simulation.

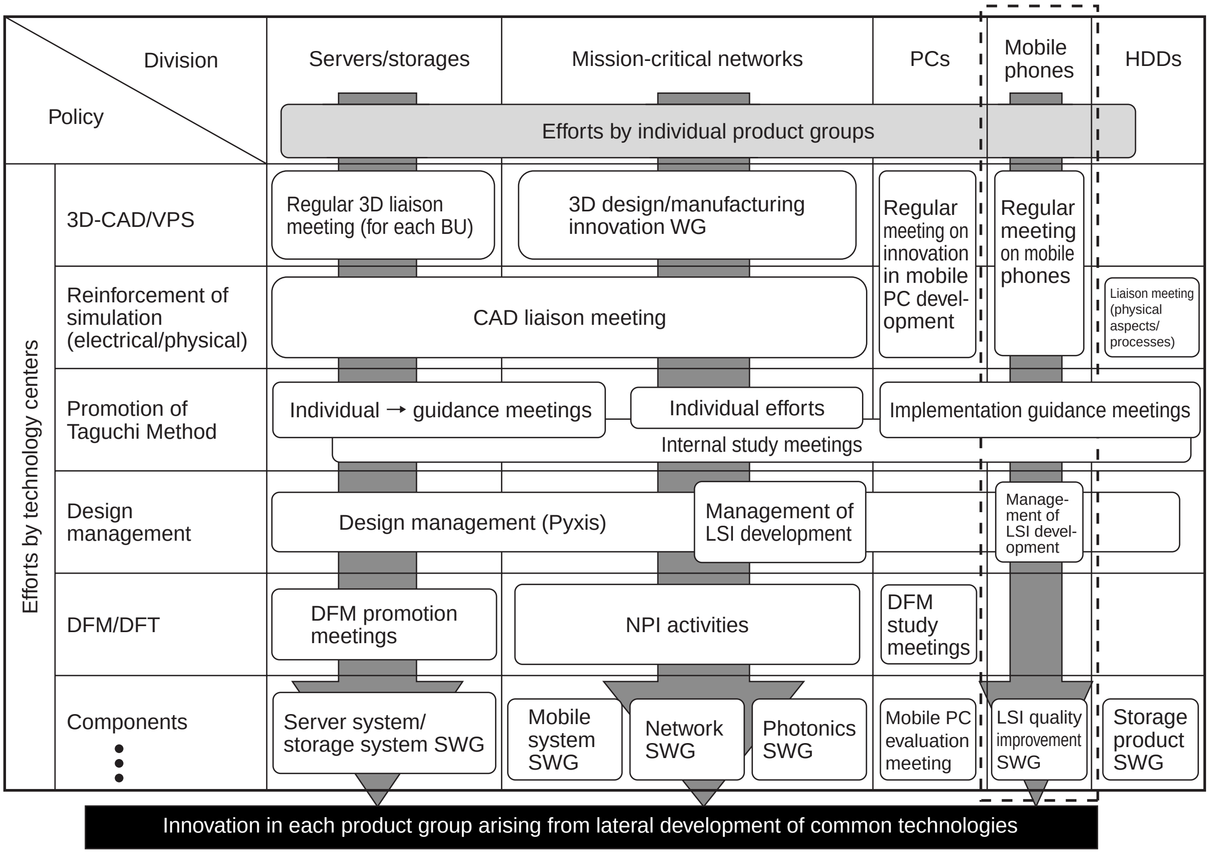

Figure 4
Innovation in each product group arising from horizontal development of common technologies.

the design remaking in LSI design, PCB design, and firmware design projects.

3) Efforts to increase productivity (promoting DFM)

The efforts of the development division are reflected in the productivity indices. For example, the first run rate[note 5)] and working time are greatly affected by the achievement of manufacturability at the design stage. DFM diagnosis functions incorporated in VPS and EMAGINE are used for DFM verification. Most DFM diagnosis parameters are incorporated in the system as design guidelines that cover requests that have been made from the site as a result of innovative manufacturing activities and previous fault information.

4) Enhancing engineers' skills and raising their awareness

No matter how good a system or framework is, it is still essential for the engineers who use it to be motivated and to raise their awareness regarding it. With the aim of enhancing basic development capabilities, Fujitsu has been running courses for engineers and operating a skills certification system in collaboration with our in-house educational organization (Fujitsu University). Courses currently available include courses on 3D-CAD/VPS, electrical system CAD, simulation, and the Taguchi Method. The development of people who will continually accept the challenge of innovation based on these skills will increase in importance.

note 5) The proportion of products on a production line that go straight to the final process without being rejected as substandard; i.e., the number of good products divided by the number entering the production line.

7.2 Organizational efforts in upstream development

The activities and systems we have considered so far are being used to develop common technologies and services that span the various product development divisions (horizontal activities). At present, in addition to increasing our skills in technology development, we are engaging in organizational efforts in upstream development in each business division by forming deeper links in the development process of each product (vertical activities) (**Figure 4**).

To greatly increase the pace of development and design quality and also cater to the need to develop products with higher and higher performance, the creation of an innovatory product development environment will be of great urgency. As an example of this, innovation in simulation technology will start to change the direction of manufacturing. We foresee that there will be unified analysis for the overall structural and electrical aspects of product models and that the fusion of individual analysis techniques will enable us to analyze phenomena that had previously been impossible to analyze, and in the near future we will aim towards "immediate manufacturing" without trial production.

8. Conclusion

Fujitsu is now in the third year of using TPS, and the innovation achieved through its introduction has produced results way beyond our initial expectations. In the future, it will be introduced on a full scale in the supply chain and upstream development in addition to being used to achieve innovation in production lines. In the next stage, we need to develop the human resources to support this activity, develop a "continuous improvement" manufacturing culture, and create an environment that supports such a culture.

Considering the size of Fujitsu, the types of business we are involved in, and the global scale of our markets, it will be necessary to have a core group of people to be responsible for instilling a sense of dedication to innovation in manufacturing, which is the essence of the mindset that will be passed on to future generations. In addition, to show the way in improvement activities, provide guidance to Fujitsu's plants and partner companies, and develop employee skills, we should give serious thought to establishing a manufacturing investigation division similar to the one that Toyota has.

Fujitsu will continue to devote itself to the pursuit of innovation in manufacturing. Our goal is to help our customers add value to their business by providing products and services that incorporate the technologies we have developed and the experience gained through these activities.

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