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FROM IMITATION TO INNOVATION: THE VERY LARGE SCALE INTEGRATED (VLSI) SEMICONDUCTOR PROJECT IN JAPAN

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Introduction

Interest in Japanese management style has been mounting rapidly partially as a result of the great competitive strength of Japanese firms, especially those in steel, automobile, and electronics industries. An increasing number of observers in the United States and European countries are now lauding Japanese management. Many U.S. universities have developed or are planning various programs about Japanese management. Two recent books on Japanese management, Ouchi's Theory Z and Pascale and Athos's The Art of Japanese Management, were on the bestseller list in the U.S.

In spite of this strong interest, many discussions are still confined to such topics as workers' loyalty, lifetime employment system, and consensus-oriented decision making. Discussions on the characteristics of the technological innovation processes in Japanese firms are comparatively rare. We know very little about technological innovation processes in Japanese organizations and managerial behavior involved, and even less about the strengths and weaknesses of Japanese technology management compared to that in the U.S. and European firms.

This is not altogether without reason. The technological accomplishments of Japanese industry have been largely based on mass-produced and standardized items, process engineering, and quality control. Japan has not contributed much to developing new concepts and systems or making technological breakthroughs.[1] But many observers believe Japan should change its policies for science and technology from emphasizing imitation to promoting invention. Recent national projects for research and development in Japan have, in fact, moved from catching up with foreign technology to developing originality. Although the stereotypical view of Japan as an imitator or a borrower may still be prevalent in the U.S., I believe that internal technological innovation has contributed to the recent success of Japanese firms.

The purpose of this paper is to analyze the management of a successful Japanese technological organization in detail and to find organizational characteristics which affect the innovation process. The technological organization discussed here is the Very Large Scale Integrated (VLSI) Technology Research Association, which was the central organization of four-year VLSI project (1976-1980) supported by the Ministry of International Trade and Industry (MITI). VLSI circuits are the next generation of semiconductors which will enable manufacturers to build smaller and more reliable computers, calculators, and many other electronic products.

The Association had the following interesting characteristics:

1. It was a high-technology oriented enterprise;
2. It had both public and private components;
3. Participants on the private side were all intensely competitive semiconductor manufacturing companies: Fujitsu, Hitachi, Mitsubishi Electric, Nippon Electric Co. (NEC), and Toshiba. These firms had different interests, priorities, and expectations; and,
4. To accomplish its mission, the Association established cooperative laboratory involving these five corporate participants. This laboratory faced the problem of how to manage researchers who were on loan from competitors.

This project was completed with success in 1980. This success served as a momentum for Japan to accelerate the development of creative technology. Subsequent national projects -- such as Fifth-Generation

Computer Project, Optical Measurement and Control System Project, and Flexible Manufacturing System Project -- are no longer aimed at catching up with foreign advanced technology, but at developing products based on original, creative research.[2] All these projects have been modeled after the organizational principle adopted in the VLSI Technology Research Association. The Association, thus, served as a turning point in the development of Japanese technology.

The following analysis is based on interviews with key participants in the projects and internal records made available by the Association as well as readily available materials such as company records, government publications, and published articles.

The VLSI Technology Research Association

Painful Start

The VLSI Technology Research Association was the central organization of the cooperative public-private VLSI program in Japan. The program's purpose was to develop the technology necessary for VLSI, the very heart of the next generation of computers. For this purpose, approximately 70 billion yen ($288 million[3]) was spent over the four years beginning in fiscal 1976.

The Association was made up of five domestic semiconductor-computer manufacturing companies to coordinate R&D activities. It was unique in that, unlike other research associations supported by the Ministry of International Trade and Industry (MITI), it established a cooperative laboratory involving all five participants at one site: None of the other technology research associations with the subsidies from MITI (at that time about forty research associations existed) had such laboratories. It was also unique in that researchers at the laboratory were members of competitive companies.

It was neither MITI nor the five private companies, but the ruling Liberal Democratic Party (LDP), that initiated the idea of setting up a cooperative laboratory in 1975. At that time, IBM was rumored to be planning a "future system," a new model of computers utilizing VLSI, in 1978, or at the latest in 1980.[4] "We have too many computer makers in Japan to cope with the monster, IBM," said Tomisaburo Hashimoto,[5] one of the powerful leaders of LDP. "The reorganization of the computer industry and the establishment of a more unified and more integrated development organization for VLSI technology are urgently needed."[6]

At first, all the Japanese computer manufacturing companies opposed such assertions. They were instinctively fearful and suspicious of any political initiatives that might lead to their losing discretion and independence. They wanted a supportive government policy or subsidies that would allow them a free hand in pursuing their own interest.

MITI was also skeptical of a massive joint effort aimed at developing VLSI and anticipated strong resistance for the semiconductor companies.

Indeed, MITI had continued its efforts to promote reorganization of the computer industry throughout the 1970's. In 1971, in order to counter the introduction of the IBM's 370 series of mainframe computers, MITI forced reorganization of six Japanese computer makers into three paired groups: Hitachi-Fujitsu, Nippon Electric-Toshiba, and Mitsubishi Electric-Oki Electric. But competition among these three pairs also remained strong. In fact, even between "partners" there was considerable conflict, especially betweeen Hitachi and Fujitsu. Despite the request of MITI, they did not cooperate closely within the groups either in production or in sales. Ultimately, the six firms remained largely independent.

The final program on VLSI technology development was built under the strong influence of LDP. They had the following two prerequisites:

1. A reorganization of reworking the existing three groups. Two groups were created: Fujitsu-Hitachi-Mitsubishi Electric group (called group A) and Nippon Electric-Toshiba group (Group B). Oki Electric, which was in serious financial difficulty then, was squeezed out; and,
2. Establishing a cooperative laboratory to enforce joint effort by the five companies.

Although all five companies complained to some degree, they could not help following "a bureaucrat's blueprint"[7] in order to draw government subsidies.

Outline of te Association

The VLSI Technology Research Association began operations on March 10, 1976 as a four-year national project. Approximately 70 billion yen ($288 million) was spent over the period, of which about 43 percent (30 billion yen) was in the form of repayable interest-free loans from the Japanese government (Table 1 shows an outline of the Association).

The members of the Association were Fujitsu, Hitachi, Mitsubishi Electric, NEC, and Toshiba. They are all highly diversified companies producing not only semiconductors but also computers and other equipment. The consumer electronics companies, such as Matsushita Electric, Sharp, and Sony, were excluded.[8]

Figure 1 shows the organizational chart of the Association and the posts of involvement of the participating companies.

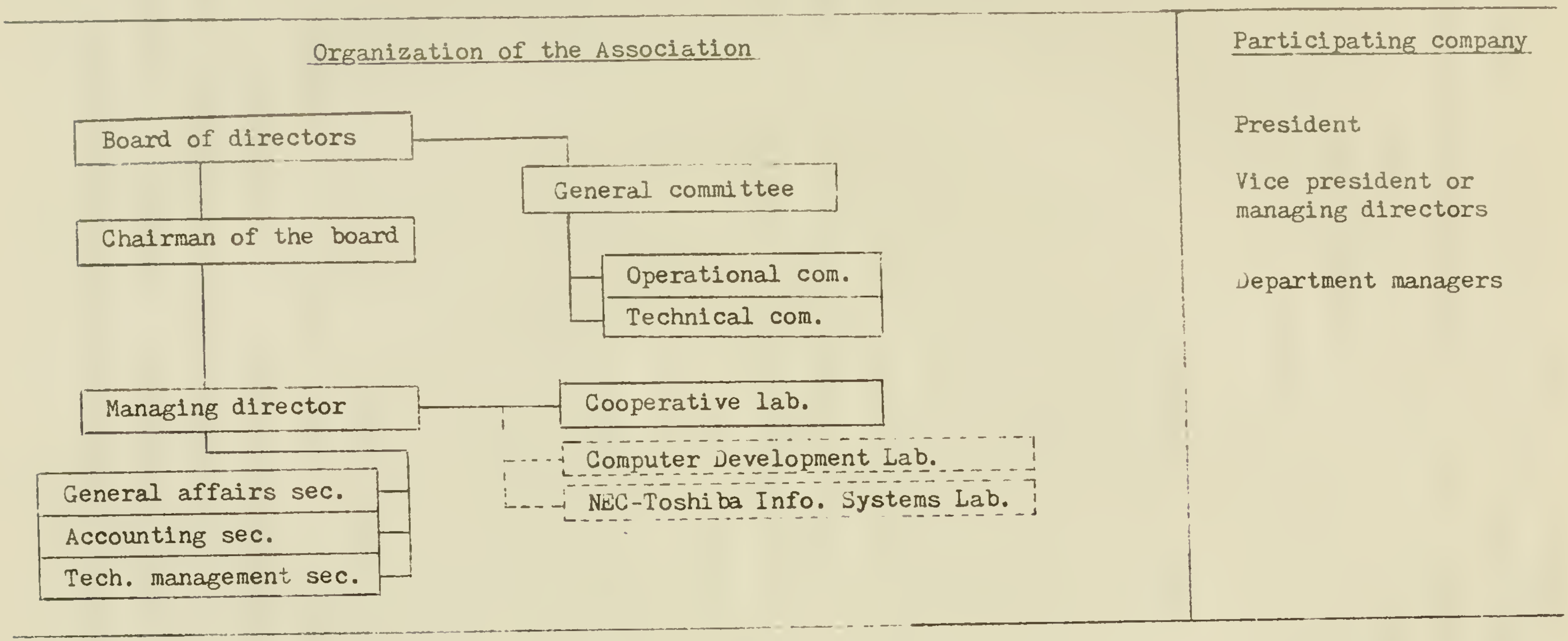
The president of each participating company was appointed as a director of the Association. But the board of directors had little decision-

Table 1. Outline of the VLSI Technology Research Association

Purpose	To develop the technology necessary for VSLI
Period	4 years beginning in fiscal 1976
Funds	70 billion yen ($288 million) including 30 billion yen from the government
Members	Five leading semiconductor-computer manufacturing companies - Fujitsu - Hitachi - Mitsubishi Electric → Group A (Fujitsu, Hitachi, Mitsubishi Electric) - Nippon Electric Co. - Toshiba → Group B (Nippon Electric Co., Toshiba)
Research items	Microfabrication technology, semiconductor crystal technology, design technology, processing technologies, testing technologies, and development of actual devices
Laboratories	Two kinds of laboratories established - cooperative laboratory to work on the common and basic technology - Two group laboratories to work on the applied technology Group A - Computer Development Laboratories (CDL) Group B - NEC-Toshiba Information Systems Laboratories (NTIS)
Managing director	Masato Nebashi, a retired MITI bureaucrat
Manager of cooperative laboratory	Yasuo Tarui, an engineer on loan from MITI's Electrotechnical Laboratory
Location of the office & cooperative laboratory	A wing of the central research laboratories, NEC (Kawasaki-shi, Kanagawa)

Note: Made by the author based on published materials.

Figure 1. Organizational Chart of VLSI Technology Research Association and the Posts of Involvement of the Participating Companies



Source: Internal materials of the Association.

making involvement and met only two or three times each year. Below the board came the general committee whose members were vice presidents or managing directors of the five companies. It met every month, and made final decisions for the Association. Under the general committee were added two more specialized committees, the operational and the technical committees. They were composed of department managers of the participating companies and met the most frequently. The role of the operating committee was to cope with general, administrative problems. The role of technical committee was to select research topics, to staff research studies, and to allocate the required resources, including both financial and human resources.

There were two kinds of laboratories in the Association: the cooperative laboratory and the two group laboratories. The cooperative laboratory (and the office of the Association, too) was located in a wing of the central research laboratories of NEC (Kawasaki-shi, Kanagawa). Because there was a hot controversy between the five companies on this location, about half a year was required to determine it.

Two group laboratories, Computer Development Lab, Ltd. (CDL) of Fujitsu-Hitachi-Mitsubishi group (group A) and NEC-Toshiba Information Systems, Co. (NTIS) of NEC-Toshiba group (groupB), were scattered among the related companies.

The principle was established that the chairman of the Association's board should be filled alternately by company president of group A and then one of group B. The first chairman of the board was Hitachi's president, Hirokichi Yoshiyama, who was the first representative of group A. The managing director of the Association was a retired MITI bureaucrat, Masato Nebashi, who had much experience in managing national projects as an executive official. The manager of cooperative laboratory was Yasuo Tarui, an engineer on loan from MITI's Electrotechnical Laboratory, or ETL, which handles basic electronics research for the ministry. He was one of the research pioneers in Japanese semiconductor technology.

Research items announced by the Association were:[9]

1. Development of micro-fabrication methods which provide capability to handle sub-micron IC geometries. This precludes the use of photo lithography and involves, for example, electron beam and X-ray exposure equipment;
2. Development of low-defect diameter silicon wafer substrates;
3. Development of improved computer-aided design technology;
4. Development of practical processing methods using micro-fabrication equipment;
5. Development of evaluation and testing techniques for VLSI; and
6. Definition of logic devices that can utilize the above results.

As seen in Table 2, the development of "common and basic technologies" among these technologies was the primary goal of the cooperative laboratory. The group laboratories were supposed to develop "applied technologies."

In addition to the five major participating companies, about fifty additional companies, such as Toray Industries, Canon, Olympus Optical, and Toppan Printing, also worked in close cooperation with the cooperative laboratory in making machines on experimental bases.

The number of researchers at the cooperative laboratory was about 100, most on loan from five participating companies. Most of these researchers stayed with a four-year project in its entirety.

In addition, a few of the researchers from MITI's Electrotechnical Laboratory (ETL), including Tarui, joined the cooperative laboratory.

Table 2. Category of Technology: The Definition by the Association

	Category of Technology		
	Common tech.	Basic tech.	Applied tech.
Microfabrication technology	x		
Crystal techonolgy	x		
Design technology			x
Processing technologies		x	x
Testing technologies		x	x
Development of actual devices		x	x
Under.the jurisdiction of:	Cooperative Lab.		Group Lab.

Note: Made by the author based on published materials.

Research Results

When the Japanese VLSI project started as a national project, many people viewed the effort pessimistically. There were mainly two reasons. First, many engineers thought that there were substantial technological obstacles to be overcome to make VLSI microcircuits[10]. Not only were new microfabrication instruments and techniques required, but a more scientific understanding of the materials and processes was also needed. Second, in addition to this technological difficulty, many strongly doubted that the five participating companies would work in close cooperation while simultaneously competing in the semiconductor market. Indeed, even after the Association started, many troubles and conflicts among the five companies continued. For example, as described above, a hot controversy on the location of the cooperative laboratory rages and it took about half a year to resolve this issue. Furthermore, the firms were dissatisfied with how the association and the cooperative laboratory were established. They felt they were forced to organize the cooperative laboratory.

But the Association ultimately proved successful and the development of VLSI was achieved basically. The Association finally reported in March, 1980. By this time, the four-year project built three kinds of lithographies using electron beams, which can draw a figure correctly at a high speed with lines of 1 micrometer or less. Moreover, a method of using computer-controlled electron beam systems had been developed; the influence of carbon and oxygen on silicon quality was made clear; and many other processing and testing technologies had been improved.[11]

"Through this project," said the manager of cooperative laboratory, Tarui, "the Japanese semiconductor technology caught up with IBM's technology.

Especially in such narrow areas as an electron beam lithography, it seems to me, Japan moved into first place, past IBM."[12]

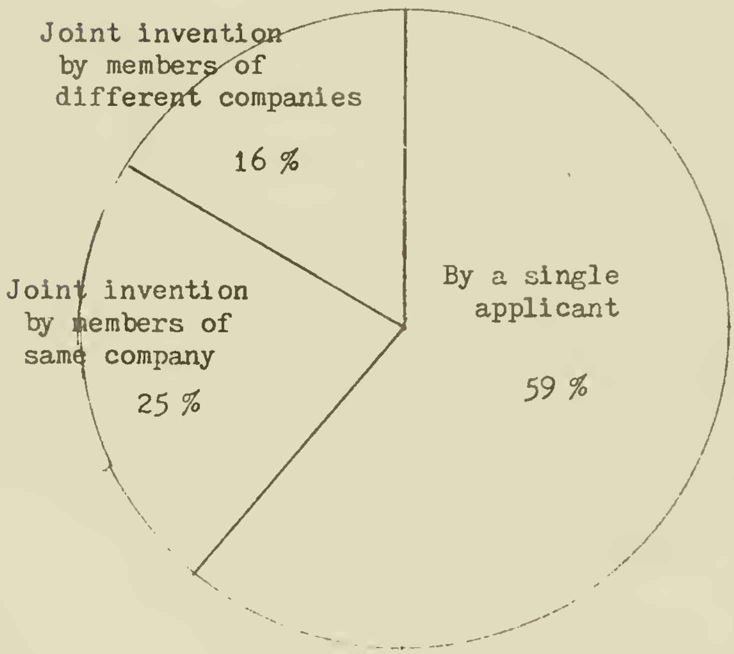
According to a study prepared for the use of the Joint Economic Committee, Congress of the United States, one result of the VLSI program was a strengthening of the domestic Japanese infrastructure in semiconductor production and test capabilities.[13] Indeed, imports of foreign (mostly U.S.) production equipment for semiconductor manufacture fell to about 50 percent share of the domestic Japanese market in 1980 while they accounted for about a 70 to 80 percent share in the first years of the program.

As for patents, the total number of patent applications in the Association as a whole exceeded one thousand, of which about 50 percent were applications by the researchers of the cooperative laboratory.[14] A breakdown of applications by category of applicant, Figure 2, shows that although more than half (59 percent of the total) were due to applications by a single applicant, joint invention by researchers who were on loan from different companies reached 16 percent. "This percentage may appear low, but it indicates a significant interaction among the researchers from different companies," says Tarui.[15]

As the results were published, the Association became famous and the number of visitors to it increased, including representatives of IBM (three visits), Fairchild, Hewlett-Packard, Texas Instruments, Motorola, West Germany's Siemens, Netherlands' Philips, and French and German governments.

The Association also became the target of criticism of unfair competition by U.S. firms. Leaders of U.S. microcircuit makers repeatedly pointed out that the Japanese VLSI project was a kind of non-tariff barrier, and condemned that it was unfair not to open patents owned by the Association.

Figure 2. Patent Applications in the Association: Breakdown of Applications by Category of Applicant



Source: Yasuo Tarui, "Kyodo Kenkyusho ni okeru Kenkyu to sono Seika (The Research Activity in the Cooperative Laboratory and its Results)," in Kogyo Chosa Kai, <u>VLSI no Chumoku Kiso Gijutsu (The Remarkable Basic Technology for VLSI)</u>, Tokyo, September 1980, p.4.

Due to this criticism, MITI announced in January, 1980, that all patents on development coming from the VLSI project would be made available to American companies by way of licensing agreements.

Favorable Conditions for Success

There is not doubt that the success of the Association partially depended on its high level of funding. During four years, an average of 17.5 billion yen ($72 million) was spent every year. This money was two or three times the potential annual R & D expenditure for semiconductors of the five major companies. According to a certain estimate, a quarter to a third of the project's funding was spend in the United States to purchase the most advanced semiconductor manufacturing and test equipment from U.S. equipment manufacturers.[16]

Most of the researchers assembled in the Association were young, active engineers under the age of 40, although they were experienced industrial scientists. It was not the five companies themselves but the manager of the cooperative laboratory, Tarui, who selected them. Judging by academic performance, he made a list of names and then asked the five companies to lend them. He and the core researchers (about 20 people) had been personally acquainted with each other.

But these resource conditions cannot explain entirely the remarkable success of this project. For example, compared with annual research expenditures of U.S. major semiconductor manufacturers, as Table 3 shows, the amount of $72 million in the Japanese project was not overwhelmingly large. "This amount of money is not so much for R & D expentiture," commented Mark Shepard, chairman and chief executive of Texas Instruments. "We can afford to bear, and do bear, such expenditure alone."[17] Also, Bell Laboratories was said then to commit 1,500 men and $117 million

Table 3. R & D Expenditures in U.S. Major Semiconductor Manufacturers

	R & D Expenditure ($ million)	
	1976	1977
Fairchild Camera & Instrument	44.0	43.6
Intel	20.7	27.9
Motorola	101.5	109.7
National Semiconductor	24.9	31.8
Texas Instruments	72.2	96.2

Source: Business Week, June 27, 1977, p. 68 and July 3, 1978, p. 76 and Annual Report of Intel Corporation for 1980.

to the development of VLSI.[18]

There were other favorable conditions which were extrinsic to the Association. The first favorable condition is the fact that everybody knew the target of the project to be the so-called "future system", IBM's new model of computers utilizing VLSI. In Japan, IBM was expected then to introduce "future systems" at latest in 1980. Therefore, both the target and the time limit were clear from the first. This condition was favorable for the integration, motivation, and concentration of research efforts of many members. Also, by limiting the cooperative's duration, cooperative R & D was prevented from degenerating into collusion in the product market.

Second, it was important that the five companies had already accumulated the administrative know-how of joint R & D (e.g. patent management, budgetary request procedures, etc.) through their repeated experience of participating in the national projects with subsidies from the government. With this past experience, many administrative troubles could be avoided.

Third, timing was another important point. The establishment of the Association in the latter half of the 1970's was well-timed from a technological point of view. Many people thought that revolutionary changes in semiconductor technology were needed to make VLSI, but by the middle of the 1970's, many ideas were present which deserved to be scrutinized, including the use of X-ray or electron beam lithography in place of photo lithography and the influence of carbon on silicon. The technology necessary for VLSI then was changing from the initiation stage in the innovation process to the evaluation and implementation stage of many ideas, and problem solving by groups rather than individuals, began to be fruitful. Just at this favorable time, the Japanese project started and many hopeful ideas and resolutions were checked and analyzed systematically by 100 men.

Finally, the most important point I think is the existence of the cooperative laboratory. The project succeeded in integrating various development capabilities of its member firms, who were competitors in the same market, by providing a "place" for organized activities.

As previously noted, the Association established two kinds of laboratories: the cooperative laboratory and two group laboratories. But, because the group laboratories were physically scattered among the companies, there was little exchange of information among them. By contrast, in the cooperative laboratory, much exchange of information and frequent interactions of personnel took place. High levels of communication with personnel of different specialties, careers, and companies occurred and stimulated each other.

An important question, here, is <u>why</u> and <u>how</u> the high levels of communication could occur among researchers who left competitors on a temporary basis. In order to answer this question, we have to consider the intrinsic or managerial variables as well as the extrinsic variables discussed above. The existence of the cooperative laboratory per se is of course important, but this laboratory naturally raised the difficult problem of how to manage researchers who were on loan from competitive companies. Then, what kind of management enabled the high levels of communication and led to the substantial joint efforts?

Characteristics of the Management

The management of the cooperative laboratory had many remarkable characteristics. As its members were all intensely competitive companies, it was most important to stimulate the frequent communication between researchers of different companies. In this connection, the method of staffing in the laboratory is relevant.

Staffing: The cooperative laboratory consisted of the following six research teams:

First -- Microfabrication technology (Hitachi)

Second -- Microfabrication techonology (Fujitsu)

Third -- Microfabrication technology (Toshiba)

Fourth -- Crystal technology (ETL)

Fifth -- Processing technology (Mitsubishi)

Sixth -- Testing and devices technology (NEC)

In parentheses are the names of the companies from which team leaders came. All team leaders were technological specialists in their fourties. They led and coordinated the daily research work. There was no hierarchal level under them, but researchers of each team were divided into a few groups with different themes.

The principle of staffing adopted was that each team should not be composed of members from the same company. Therefore, under the team leader who was on loan from Toshiba (the third team), for example, we could find researchers not only from Toshiba but also from the other companies, although the majority of them were from Toshiba.[19]

Planning: The first and most difficult decision which the cooperative laboratory faced was the selection of the research themes and scheduling. The themes were narrowed severely and considerable effort was spent on obtaining consensus in theme selection.

It was the principle of the Association that the research themes of the cooperative laboratory were limited to "common and basic technology," in which the cooperation among five companies seemed to be easier than in "applied technology." To put it concretely, microfabrication technology was selected as one of common technologies. This was widely believed to be among the key factors of new processing technologies designed to get the microcircuit industry into VLSI. Semiconductor crystal technology was selected as another common technology. Regarding the residual technologies, the development of basic technologies among them was assigned to the cooperative laboratory; the development of applied technologies was assigned to group laboratories (see Table 2).

That three of the six teams were devoted to microfabrication technology shows just how critical the association considered this technology to be.

About a year was spent in discussing and selecting research themes, including the discussions prior to the establishment of the Association. An informal working committee was organized with Tarui and some academics as leaders, and face to face negotiations and discussions were carried on among the five companies. The industrial association of all five companies, Electronic Industries Association of Japan, acted as a mediator.

Because the companies had different interests, priorities, and expectations, there were many conflicts. But confrontation was allowed at all times, although this consumed much time. "They made no attempt to disguise their hostility; they discussed and discussed without disguising their selfish desires. That confrontation looked like a quarrel," says the managing director, Nebashi.[20]

Such confrontation took place not only with regard to the selection of the research themes but also to the scheduling, annual budget, staffing of the research teams, and purchasing plan of large scale mechanical instruments. Face to face contact and confrontation was the norm for planning in the cooperative laboratory.

Formalization: Because the Association was a national project, many documents were needed. For example, a detailed annual application for government subsidies had to be completed. Every quarter a full statement of expenditure was required in advance. Furthermore, research themes to be chosen, with scheduling and staffing, were also written down in detail. In order to complete these documents, frequent face to face contact and confrontation among first-line researchers was also necessary.

"Because an annual application for the government subsidies, once submitted, permitted no change, this procedure was more severe and more detailed than the budget procedure in my company," says one of the researchers.[21]

The highly formalized process found in the cooperative laboratory was not only the response to the government requirements but also the result of managerial behavior which aimed at establishing a common framework among the researchers. "The clerical work of various kinds are helpful, I think, to rearrange the points of view of things," says the managing director, Nebashi.[22] Such formalized process was indeed useful in making clear and sharing the content and focus of joint efforts among researchers.

Evaluation system: How were the researchers evaluate? They were evaluated by the parent companies: The Association itself did not evalute them. Personnel managers of the five companies judged their members by their own stadnards. The office of the Association provided them the relevant personnel information including working hours and team leaders' views, but this information was only suggestive. Neither an integrated evaluation system nor any kinds of special bonus plans were developed by the Association.

Why did the five companies, not the Association, evaluate the researchers? There were two reasons. First, it was helpful to relieve the Association of the administrative burden. Although about fifteen clerks were also on loan from the five companies, that did not suffice. Second, Nebashi was afraid of the researchers' feeling of isolation from their companies. He thought such anxiety to be one of the most serious barriers to cooperation. So, in order to remove their anxiety, it was necessary to keep a relationship to their parent companies. Leaving evaluation in the hands of parent companies was one of the means.

The fact that the Association had no evaluation system of its own might have been detrimental to its integration. But, I think this fact enabled the researchers to be free from evaluation and interact frankly with each other.

Direct means to prompt communication: Finally, various means were adopted to prompt interaction between research teams in the innovation process. First of all, the research themes which were concerned with all teams were inserted consciously. One of the examples was the problem of warping of silicon wafers. This concerned not only the fourth team in charge of the crystal technology but also the other five teams: to the first to third teams in designing mechanical equipment; to the fifth team in heat treatment; and to the sixth team in devices technology.

In order to share research restuls, an internal meeting was held one or two times every month and recent research results were reported and discussed there. Usually about 40 researchers participated in it. The research results were also written down and published on occasion in booklet form. This booklet, which was called "the cooperative laboratory report," circulated among the researchers. Furthermore, all research rooms were opened to each other every Saturday.

Many opportunities for off-the-job communication also existed. A number of voluntary extracurricular groups in sports and travel were organized by the researchers. And, it seems to be most important, they drank together again and again at night, usually at the executive office or the reception room of the Association.

Through such intesnse and multiple communication, the cooperative laboratory became gradually a social unit, not as a convenient conglomeration but as a unified organism. Related to this point, the leadership of the managing director, Nebashi, was significant.

Leadership

There were two influencial leaders in the Association: the manager of the cooperative laboratory, Tarui, and the managing director of the Association, Nebashi. They were leaders of different types. Tarui was a typical engineer who was on loan from MITI's Electrotechnical Laboratory (ETL). He was by nature methodical and scrupulous. His interest was almost limited to the technological affairs in the Association. He assumed technological leadership in the organization.

By contrast, the managing director, Nebashi, was a retired bureaucrat of MITI who had much experience in managing national projects as an executive official. He organized the various internal organizational arrangments in the Association, and undertook the external negotiations alone. Although there were many problems, such as between the five companies and MITI and among individuals, he settled these problems. Indeed, he was an excellent trouble-shooter. Moreover, he was a very generous, warm, and magnanimous man. Because of this character, he was well-liked by the researchers as well as clerks who were both on loan from the five companies.

The important leadership points we should indicate here are as follows:

1. There were two leaders who were different in their abilities, characters, and personalities;
2. Each undertook the distinct role proper to his characteristics; and,
3. They knew where to draw lines and did not encroach on each other's roles.

Nebashi's leadership deserves more attention. He said, "On the research topics and the way of research, the manager of the laboratory, Tarui, had the full authority. Otherwise, nothing but failure will result. And so, I did not interfere in the research itself. My great interest in the organization was the human problem: how to coordinate the researchers from different companies and make them interact. I wanted them to become good friends, communicate to each other, and open their hearts.

"So, what I did was the typical Japanese way: All I did for this four years was to drink with them as frequently as I could. I wanted to understand their complaints on those occasions and tried to eliminate problems."[23]

His effort gradually paid off: The researchers, who showed cold shoulders to each other at first, became good friends and interacted well by the end of the project. At the end of these four years, March 28, 1980, a farewell party was held and all the people enjoyed it. No problem took place in dividing the production and test equipment owned by the

Association among the five companies: The expensive equipment of various kinds was divided peacefully. Moreover, an alumni association was organized spontaneously and an alumni newspaper was issued.

Some people speak of the leadership of Nebashi as "management by whisky."[24] "Nebashi tried to make researchers interact among themselves by using liquor as the catalyzer."[25] It should be pointed out here, however, that his leadership was not simple "supportive-employee-centered leadership." It is true that he focused his efforts on the human aspect of the researchers' problems and tried to be considerate of their feelings. But his leadership has more meaning than mere supportiveness or consideration.

Through daily frequent contact, he always urged the researchers to realize the mission and value of this project. He told them repeatedly that this project was unique in the world and their laboratory became the object of public attention; he told them what was distinctive about the aims and methods of the project; he really infused value beyond the technical requirements of the task at hand into the hearts of the researchers. In his operation, we see the way group values were formed, the commitments of the organization were defined, and a distinctive identity was given.

Selznick distinguishes between <u>organizations</u> and <u>institutions</u> as follows:

> "Organizations are technical instruments, designed as means to definite goals. They are judged on engineering premises; they are expendable. Institutions, whether conceived as groups or practices, may be partly engineered, but they have also a "natural" dimension. They are products of interaction and adaptation; they become the recepticles of group idealism; they are less readily expendable."[26]

"Organizations become institutions as they are infused with value, that is, prized not as tools alone but as sources of direct personal gratification and vehicles of group integrity. This infusion produces a distinct identity for the organization."[27]

According to his terminology, the cooperative laboratory, which was an organization at first, became an institution by the leadership of Nebashi. He embodied the Association's values; he infused it into the hearts of the researchers; he gave it the distinctive character; he lent it a social integration that went well beyond formal coordination and command.[28]

Implications

The case of the VLSI Technology Research Association has some practical implications for the development of Japanese technology. Late in the 1970's, Japan was in the midst of transition from borrowing technology to creating technology. The key concerns of many Japanese at the time were twofold: 1) how to develop original and creative technology; and 2) what kind of R & D organizations should be provided on a national level in order to facilitate that process. The VLSI Technology Research Association started at this turning point and succeeded in integrating various development capabilities of its member firms. It provided a "place" for organized activities among competitors in the same market. this success fueled Japan's acceleration to develop creative technology. Many national projects have been modeled after the organizational principle adopted in the VLSI Technology Research Association. Aside from its technological impact, which was substantial, the key practical implication of the Association was on its social impact to the development process of Japanese technology.

Also, the case of the VLSI Technology Research Association has some general and theoretical implications to R & D management. It shows many determinants for success of technological innovation, including extrinsic variables which project managers themselves cannot manipulate as well as intrinsic or managerial variables which they can manipulate. We found that the following extrinsic variables were significant in the Japanese semiconductor project: monetary resource; external pressure from IBM as the five companies' archrival; accumulation of administrative know-how of joint R & D; timing from a technological point of view; and cooperative laboratory itself as a "place" for organized activities.

More relevant to the purpose of this paper, however, are the implications of the intrinsic or managerial variables. We emphasized the importance of the following factors as the intrinsic or managerial variables: heterogeneity built into the organizational structure and the resulting diversity in specialties, careers, and companies; narrowing down of research themes; substantial allocation of time to build concensus; conflict resolution through confrontation; high levels of documentation; no evaluation of researchers' daily operations, and establishment of ample opportunities for communication. All these factors really show that innovative situations require greater emphasis on high levels of communication among various participants through formal and informal mechanisms.

Furthermore, we also analyzed the implications of leadership as another significant managerial variable. We emphasized the needs of role diferentiation in leadership and the importance of "institutional leadership" which provided identity to the organization.

This discussion suggests that there are two fundamental determinants for success of technological innovation in organizational setting, namely, communication and institutionalization. We found that high levels of communication among members with different backgrounds -- including face to face contacts as well as written technical reports or publications -- are important in R & D organizations. Such communication gives them access to various sources of technological information and helps to stimulate each other. It is, therefore, important for project managers to design an effective network of relationships. In addition, our analysis shows that institutionalization is a fundamental determinant for success of technological innovation in organizations as well. Institutionalization means the process by which value is infused in an organization and the organization acquires a distinctive identity. Effective network of relationships alone is not sufficient when scientists face uncertainty and risk in innovative situations. Emphasis must be placed on institutionalization as well.

Our hypothesis, therefore, is as follows: high levels of communication and institutionalization are two fundamental determinants for success of technological innovation in R & D organizations. The impact of communication on technological innovation within an organizational setting has been emphasized previously in many studies, but the importance of institutionalization has not been analyzed sufficiently.

Institutionalization makes it possible for the basic value or mission, which a R & D organization as a whole pursues, to be internalized among individual researchers. Because of their commitment to this value, they are no longer loyal servants who obey an order blindly. This value served as the check-and-balance by which they carry on their daily operations.

Institutional leadership should be especially important in large-scale, multi-organizational, technology-oriented enterprises. The individual component organizations of such enterprises usually have different interests, priorities, and expectations. The main problem which such enterprises must resolve is not an interpersonal one. Such enterprises must contend with an entirely different kind of problem, namely the problem of managing interorganizational relationships. Leaders in such enterprises, therefore, should not be content with simply opening the path of personal interaction and promoting communication. More importantly, they must deal with possible value conflicts among the component organizations and formulate the basic mission of enterprises as quickly as possible.

NOTES

1. See, for example, James C. Abegglen and Akio Etori, "Japanese Technology Today," Scientific American, October 1980, pp. J5-J30.

2. See, for example, B. L Buzbee, R. H. Ewald, and W. J. Worlton, "Japanese Supercomputer Techology," Science, VOl. 218, December 17, 1982, pp. 118-1193.

3. The conversion rate of 243 to the dollar is used.

4. See, for example, Nihon Keizai Shimbun, Tokyo, June 6, 1975 and September 17, 1975; Asahi Shimbun, Tokyo, July 16, 1975.

5. Nikkan Kogyo Shimbum, Tokyo, May 7, 1975 (translation by the author).

6. Ibid.

7. Asahi Shimbun, Tokyo, July 16, 1975.

8. This is the most different point from the Fifth-Generation Computer Project. For a comparison between the Fifth Generation Computer Project and the VLSI Project, see following table.

Comparison between the Fifth-Generation Project and the VLSI Project

	Fifth-Generation Computers*	VLSI
Purpose	Developing intelligent machines that act like human	Developing the technology necessary for VLSI
Members	Nine companies - Fujitsu - Hitachi - Mitsubishi Electric - Nippon Electric Co. - Toshiba - Oki electrid - Matsushita Electric - Sharp - Nippon Telegraph & Telephone	Five companies - Fujitsu - Hitachi - Mitsubishi Electric - Nippon Electric Co. - Toshiba
Duration	At least ten years beginning from 1981	Four years
Funds	About $40 million/year (not decisive)	$93 million/year
Size of research lab	40 scientists	100 scientists

8. (con't)... Note for above table: *Source: Bro Uttal, "Here Comes Computer Inc." Fortune, October 4, 1982, pp. 82-90.

9. The following is from the Consulting Group, BA Asia Limited, The Japanese Semiconductor Industry: An Overview, January, 1979, p. 112.

10. See, for example, Arthur L. Robinson, "New Ways to Make Microcircuits Smaller," Science, Vol. 208, May 30, 1980, pp. 1019-1022.

11. For further particulars of research results, see Kogyo Chosa Kai, VLSI no Chumoku Kiso Gijutsu (The Remarkable Basic Technology for VLSI), Tokyo, September, 1980.

12. Nikkei Sangyo Shimbun, Tokyo, April 3, 1980.

13. Joint Economic Committee, Congress of the United States, International Competition in Advanced Industrial Sectors: Trade and Development in the Semiconductor Industry, February 18, 1982, pp. 92-93.

14. Nihon Keizai Shimbun, Tokyo, April 7, 1980.

15. Yasuo Tarui, "Kyodo Kenkyusho ni okeru Kenkyu to sono Seika (The Research Activity in the Cooperative Laboratory and its Results)," Kogyo Chosa Kai, op. cit., pp. 4-5.

16. Joint Economic Committee, Congress of the United Stated, op. cit., p. 55.

17. Hiroshi Semi, Nichibei Handotai Senso (The Semiconductor War between U.S. and Japan), Tokyo: Nikkan Kogyo Shimbun Sha, 1979, pp. 155-156.

18. Nikkei Sangyo Shimbun, Tokyo, January 1, 1976.

19. For a more detailed discussion of this principle of staffing, see Tarui, op. cit., p. 4.

20. Masato Nebashi, "VLSI Kaihatsu - Kyogo Gosha ni yoru Kyodo Project no Yonen Kan (Developing VLSI -- Four-year Joint Project involving Five Competitive Firms)," Management, Tokyo, November 1980, p. 60.

21. From interview records with a participant.

22. From interview records with Nebashi.

23. Nebashi, op. cit., p. 60.

24. Speaking of a participant. From interview records with the participant.

25. Ibid.

26. Philip Selznick, Leadership in Administration: A Sociological Interpretation, New York: Harper and Row, 1957, p. 21.

27. Ibid., p. 40.

28. After the project, all researchers returned to their companies without exception. Nebashi was recruited as an executive by IBM-Japan. See Nihon Keizai Shimbun, Tokyo, January 19, 1981.

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