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# Management and the effect of MITI's R&D project: case study from a supercomputer project

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**Abstract**

This report analyzes the results of the Supercomputer Project, which was executed as a government-sponsored R&D project starting in 1981. The conclusions of this paper are as follows: (1) There was not much need for the government to carry out the Supercomputer Project on a national-scale because three companies had already decided to introduce supercomputers and were ready to implement R&D for practical use when the national project was inaugurated. Therefore, there was little room for the government to intervene in this matter. (2) One possibly appropriate way to evaluate the quality of this project would be on the number of paper citations resulting from it. There were fewer for this project than for similar computer projects. We can therefore judge that this project had relatively little effect. (3) A high-speed computer with 10GFLOPS, one of the objectives of the project, was successfully made, but the devices that were developed to replace silicon have never been applied to computers. As stated above, we cannot say that the project has proven to be successful. However, we discovered that devices to replace silicon, such as JJ devices and HEMT devices, were not suitable for computer use. They were, however, used with mobile phones and high-speed devices for satellite broadcasting instead, resulting in a large profit. When evaluating an R&D project, it is important to evaluate the accomplishment of the objective set before the project is launched, but the indirect effects, which could not have been anticipated, also have to be evaluated.


*Keywords:* Technology policy; Research consortium; Supercomputer project

## 1. Introduction

Many people believe that Japan's sharp economic growth in the past was due to MITI's industrial technology policies.[1] The policies include government-sponsored R&D projects, which attract a great deal of attention.[2] The project involving the High-speed Computer Systems for Scientific and Technological Use (herein referred to as the Supercomputer Project) is one of the government-sponsored projects, established with the objective of improving and speeding up the computer's performance. This project ran from 1981 to 1989, and with the Scientific Computer Research Association as the leader, companies that joined the association and the Electrotechnical Laboratory carried out the R&D. The MITI coordinated the overall project and provided capital.

In 1982, one year after the Supercomputer Project was launched, the Fifth Generation Computing Project[3] was begun and both projects continued simultaneously for six years as government sponsored computer projects with the MITI in charge (Fig. 1). The Real World Computing Program,[4] which was started in 1992, took over the Fifth Generation Computing Project.

The necessity of government participation in R&D has

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[1] See Okimoto (1989), Watanabe et al. (1991), Watanabe and Honda (1991), Watanabe and Honda (1992).
[2] See Fransman (1990) and Callon (1995).
[3] See Nakamura and Shibuya (1996) and Odagiri et al. (1997).
[4] See Nakamura (2001).

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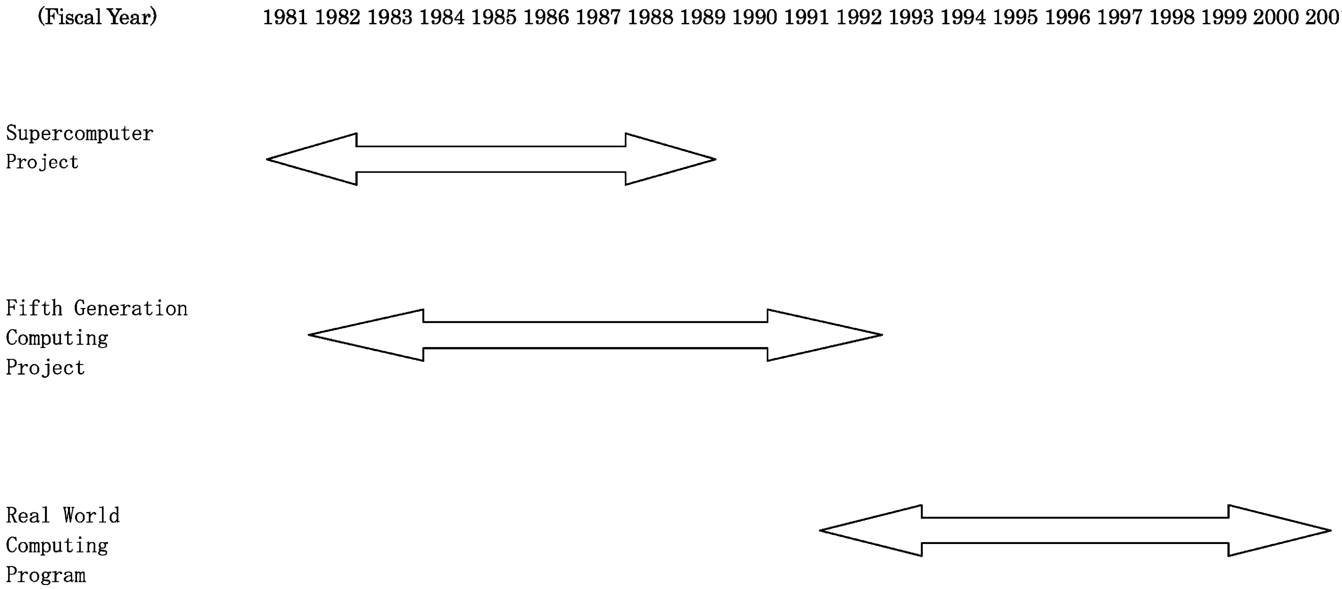


Fig. 1. Government-sponsored projects in the computer sector in the last 20 years.

been a subject of considerable debate in the past.[5] If an R&D project were left entirely to non-governmental organizations without government participation, the investment in R&D would not have been sufficient. One of the reasons would have been the inappropriateness of the outcome from R&D. Due to patent protection, the right to the outcome from R&D reverts to those who do the work in varying degrees. However, if the patent protection system is not well organized or if know-how falls outside the protection of the patent, non-government organizations will lose their incentive to conduct R&D, and ultimately the investment will be insufficient. The second reason is the uncertainty of the R&D. There is no assurance that R&D will end with a satisfactory outcome; therefore, non-governmental organizations tend to avoid uncertain R&D projects. As a result of this, the investment would also be insufficient. The third reason is the indivisibility of R&D. R&D has a minimum unit and it couldn't be carried out if the level went below this unit. Consequently, the investment would again be insufficient. Examples of this are development in nuclear energy and space.

Now we will consider the reason why government involvement in the Supercomputer Project is necessary. As mentioned above, the Supercomputer Project and the Fifth Generation Computer Project were carried out simultaneously. We would like to verify why these computer projects were performed at the same time, and if non-governmental organizations really wanted the project to be under the leadership of MITI. In this paper, we will examine closely how government-sponsored R&D projects have been developed and managed, make comparisons with the Supercomputer Project, and analyze the characteristics.

In Section 2, we will explain how government-sponsored R&D projects have been developed and what the characteristics of the Supercomputer Project are. In Section 3, we explain the objectives, expenses, and structure of the Supercomputer Project. In Section 4, we discuss the differences in management between common government-sponsored R&D projects and the Supercomputer Project. In Section 5, we will consider the results of the Supercomputer Project and analyze the results, and in Section 6, we will conclude and consider the ideal style of government-sponsored R&D projects for the future.

## 2. The process of project development

### *2.1. The process of carrying out a common government-sponsored R&D project (Fig. 2)*

When the government directs an R&D project, it receives suggestions from various fields such as industry and academia, and also from national laboratories. Proposals from industry can be in areas that are considered important for future industry but in which R&D is not being currently carried out due to uncertainty and other reasons.

The proposals from academia and national laboratories tend to be for R&D projects that emphasize pure science, compared to the suggestions from industrial circles. The government also has input when the competitive power of some sectors in Japan is weaker than in other countries, and could have a large negative impact on the entire Japanese industry.

[5] See Nelson (1959) and Arrow (1962).

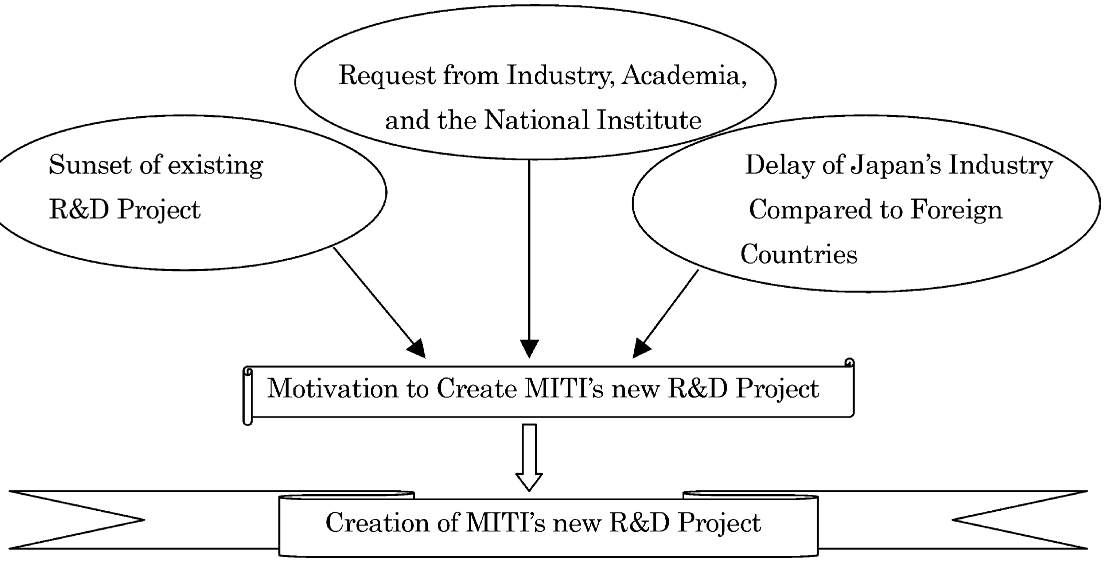


Fig. 2. The general motivation to create MITI's new R&D project.

Along with the completion of previous projects, it is conceivable that the incentives to propose new R&D projects will increase. For example, the Supercomputer Project was launched as an incoming project for the Pattern Information System Project, and the Real World Computing Program was formed to take over the Fifth Generation Computing Project. New R&D projects are often suggested at the time when previous projects are completed.

Plans for R&D projects are indispensable for carrying out R&D. The objective, structure, costs, details, and the schedule of the R&D have to be included in the plan, and an outline of the plan will be needed before money is requested from the Ministry of Finance. A government-sponsored R&D project is usually outlined a few years before the project is launched by the newly established research organization composed of MITI, industry circles, academia, the national laboratories, and so on. For example, when the Fifth Generation Computing Project was initiated, an R&D committee was set up at the Japan Information Processing Development Center (JIPDEC) from 1979 to 1981, and they examined the project and executed the project plan. When the Real World Computing Project was initiated, the New Information Processing Technology Investigation Research Committee was established at MITI from 1989 to 1990, and also its subcommittee was set up at the Japan Information Processing Development Center (JIPDEC) to examine the program and prepare the project plan.

### *2.2. The process of establishing the Supercomputer Project*

#### *2.2.1. Background at the time when the Supercomputer Project was initiated*

When the Supercomputer Project was initiated, CRAY-1 from Cray Research had the best processing performance, with a processing speed faster than 160MFLOPS (million floating point operation per second).

More than 20 CRAY-1 computers were sold while only one domestic computer was sold. The reason for this is that there was more demand for the supercomputer in the United States because of industries such as space engineering, aeronautical engineering, nuclear energy, and military weapons (trajectory calculation, etc.).

On the other hand, IBM didn't launch into the supercomputer R&D, anticipating a small market and low profitability. In the meantime, the supercomputer market itself wasn't the first concern of Japanese manufacturers. They thought that the new semi-conductor and parallel processing technology obtained from supercomputer R&D could be useful for the next generation all-purpose computers. For that reason, Fujitsu, Hitachi, and NEC considered entering the supercomputer market. Fransman (1990) wrote, "Although IBM had not entered this area of supercomputers, leaving the relatively small market to other American firms such as Cray and CDC, the core technologies that were to be developed in the Supercomputer Project, such as new devices and parallel processing, had both technical and economic relevance beyond the narrow field of the supercomputer".

Seen from a technical perspective, the hastening of logical LSI and memory LSI development is indispensable in order to increase the performance and speed-up the calculation capability of the supercomputer. At that time, R&D related to the Josephson Junction Devices (herein called the JJ device) had been carried out mainly by IBM and AT and T Bell Laboratories. On the other hand, in Japan, the Electrotechnical Laboratory started research on JJ devices on a small scale. In addition to JJ devices, devices with gallium arsenide and HEMT (high electron mobility transistor devices) received a great deal of attention as substitutes for silicon. Each participating company wanted to make sure the device was usable with the supercomputer.

However, they couldn't proceed with the R&D under private-sector leadership because they were concerned about the high uncertainty, and even if the R&D proved successful, there was a possibility that the market would be extremely limited because of the high cost.

### *2.2.2. Inauguration of the research committee for outlining the Supercomputer Project*

Computer-related government-sponsored projects that had translated into action before the Supercomputer Project were the Super-high Performance Electronic Computer Project (1966–1971) and the Pattern Information Processing System Project (1971–1980). In 1978 a Research Committee was set up at the Japan Electronic Industry Development Association to discuss what kind of computer project should be executed after 1981. During this time, there were differences of opinion about whether projects concerning hardware or software should be conducted. An example of a hardware project was the Knowledge Robot System (concerning research and development of the supercomputer), and an example of a software project was the Natural Language Information Processing System (concerning R&D of automatic translation). The leader of the Knowledge Robot System was Tooru Motooka, a former professor at Tokyo University, whose objective was to create a pioneering computer. The leader of the Natural Language Information Processing System was Hiroshi Inose, a former professor at Tokyo University, who insisted that the R&D of automatic translation would be essential in the future although it would not lead to immediate business. There were a considerable number of participants from industry in the research team, but the majority of the attendants were working with the Pattern Information Processing System that was mainly a software project. Therefore, the Natural Language Information Processing System, which was a software project, was a top-rated contender. In the end, the Research Committee report revealed that both the Knowledge Robot System and Natural Language Information Processing System would be executed as R&D projects in the future and one would not be placed above the other. They established a Research Committee at the Japanese Electronic Industry Development Association in 1979 and began discussions. A report issued in March 1980 was limited to joint proposals for a supercomputer system, knowledge-based systems, and machine translation.

Takuma Yamamoto, former president of Fujitsu, supported the Machine Translation System at first, but after studying computer development in the United States, he realized how behind Japan was in hardware technology and he began highly recommending the supercomputer.[6] MITI judged that the machine translation system would have opportunities to be focused on R&D projects in the future, but the supercomputer would lag farther behind the United States and the opportunity to catch up would be lost forever if they did not act soon; therefore, they started supporting the Supercomputer Project. There was also an opinion that hardware projects were appropriate for the next project because the success rate of past hardware projects was high. The VLSI Project and the Super-high Performance Electronic Computer Project were both concerned with hardware, and the Pattern Information Processing Project was research and development focused on software. Ultimately, the Supercomputer Project was proposed as the next project. These discussions were usually led mainly by the Industrial Electronics Division of the Machinery and Information Industries Bureau, but when the Supercomputer Project was proposed for the next large-scale project, the Agency of Industrial Science and Technology was appointed to perform procedures such as requests for a budget.

As mentioned above, Fujitsu, Hitachi, and NEC had intended to enter the supercomputer market and had positive opinions about the R&D of supercomputers. Other companies, such as Toshiba, Oki, and Mitsubishi, did not intend to enter the market but they thought that the supercomputer technology, which would be developed by other companies, would spill over into public and private sector R&D, and that the technology would be very useful in developing all-purpose computers in the future. It was considered that the commercialization of the project would be relatively easy and would be profitable in the future, compared to the Fifth Generation Computing Project that was being planned for launching in the following year. Generally speaking, Japanese companies were likely to have the misapprehension that participating in a government-sponsored R&D project was essential for keeping up with other companies. Therefore, as insurance they had a tendency to take part in government-sponsored projects whether or not it was profitable for them. Against such a background, Fujitsu, Hitachi, NEC, Toshiba, Oki, and Mitsubishi joined in the project.

Similar to the other common MITI's R&D projects, a public and private sector Research Committee was set up before the Supercomputer Project was initiated in order to outline the project. There were several motivations behind the Supercomputer Project: to replace the Pattern Information Processing System Project, to answer strong requests from the industrial and academic communities, and to strengthen its competitive position

[6] Fujitsu offered to serve as a negotiator for external matters. As a result, Fujitsu became the main contractor of the project commonly known as the Yamamoto Project.

in the field considering the industry trend in Japan and abroad. Therefore, the motivation was exactly the same as the motivation for the common MITI R&D projects mentioned in Section 2.1 above.

#### 2.2.3. The differences between the Supercomputer Project and the Fifth Generation Computing Project

As indicated in Section 1, the Supercomputer Project and the Fifth Generation Computing Project were under R&D during the same period. In this section, I deal with the differences between the two projects and determine if there was any merit in executing them at the same time. The Fifth Generation Computing Project put emphasis on software development and basic research. However, the Supercomputer Project put emphasis on hardware development and it was only one step towards making the project fit for practical use. These two research and development projects moved in different directions.

The Fifth Generation Computing Project was formed mainly by the Electronics Policy Division of the Machinery and Information Industries Bureau and was executed mainly by the Electronics Policy Division. On the other hand, the Supercomputer Project was formed mainly by the Industrial Electronics Division of the Machinery and Information Industry Bureau and was executed for the most part by the Office of Large-Scale Programs of the Agency of Industrial Science and Technology.

The participating researchers of the Fifth Generation Computing Project and the Supercomputer Project didn't have much interchange. Six major computer manufacturers were taking part in both projects but the researchers of these projects did not overlap. For those manufacturers, the purpose of the Supercomputer Project was to conduct R&D of computers that could be produced on a commercial basis in the short term, making full use of the national budget. On the other hand, the original purpose of the Fifth Generation Computing Project was to perform the basic R&D of computers, which had mid- to long-term promise. Therefore, there was nothing to prevent these projects from being executed simultaneously.

## 3. Outline of the Supercomputer Project[7]

### 3.1. Purpose of the R&D

The goal of the Supercomputer Project was to manufacture, operate, and evaluate a supercomputer with 10GFLOPS using the techniques mentioned below (Fig. 3):[8]

1. Develop new devices suitable for high-speed processing mountings to be used as substitutes for silicon devices.
   - EGaAs devices (GaAs Field Effect Transistor Devices): Compound semiconductor devices with higher electron mobility compared to silicon devices;
   - EHEMT devices (High Electron Mobility Transistor Devices): Transistor devices with structurally higher electron mobility;
   - EJJ devices (Josephson Junction Devices): Making use of super-conductivity.
2. Multiple Instruction streams and Multiple Data streams (MIMD) and a computer language suitable for parallel operation needed to be developed in order to achieve the parallel operation of a multiple processor composing the core of the computer.
3. Perform research and development of a high-speed computer to actualize MIMD and LHS (large-capacity high-speed storage) to provide data without interruption.

### 3.2. Details of the R&D

#### 3.2.1. JJ devices

Superconductivity was invented in 1911 and then Brian Josephson of Cambridge University proved logically that power transmission by superconductivity occurs by putting insulation between superconductors. This technique was recognized to be applicable for semiconductors, and the R&D of JJ devices was carried out.

1. Systems

| | |
|---|---|
| High Speed Parallel Processor | 10gflops (Computation Speed) |
| Large Capacity High Speed Memory System | 1gbyte (Memory Capacity) |
| | 1.5gbites/second (Transfer Speed) |
| Dedicated Parallel Processing System | 0.1gflops (Computation Speed) |

2. Devices

| | | |
|---|---|---|
| Logic devices | Integration | 3,000gates/chip |
| | Delay time | 10picoseconds/gate (low temperature) |
| | | 30picoseconds/gate (room temperature) |
| Memory devices | Integration | 16k/chip |
| | Access time | 10nanoseconds |

Fig. 3. Performance targets of the Supercomputer Project.

[7] See Kashiwagi (1984), Yuba (1986), Yuba and Kashiwagi (1987), Fransman (1990), and Callon (1995).

[8] The project's objective was to obtain a processing speed 1000 times faster than the computers of that period. Therefore, their concrete target was to increase speed by ten times using new devices and to increase speed 100 times faster using a parallel processor.

JJ devices achieve efficiency at a low temperature (−279°C). Japan took an interest in the JJ devices because IBM had started its R&D in 1960, and the R&D was initiated mainly by the Electrotechnical Laboratory. After that, IBM concluded that JJ devices were not superior to advanced silicon. IBM withdrew from lead-based JJ devices in 1983 and made a concentrated investment in advanced silicon development. On that occasion, there were discussions about what to do with the R&D of JJ devices for the Supercomputer Project. The Electrotechnical Laboratory had been developing the devices mostly using niobium, and IBM was using lead for that purpose.

Many companies had tried to develop JJ devices using lead like IBM had done, and therefore they wanted to cancel their research when IBM withdrew, and make concentrated investments in other research areas. However, the niobium-based JJ devices had not been proven to be unsuccessful. Therefore, they kept developing the JJ devices using niobium with the Electrotechnical Laboratory, even though there were objections from some companies. Companies such as Fujitsu, Hitachi, and NEC who were researching lead-based JJ devices, ended their research and dispatched researchers to the Electrotechnical Laboratory to continue the R&D of niobium-based JJ devices.

In 1986, superconductivity was discovered in oxide, and the next year the discoverers, K. Alex Mueller and Georg Bednorz from IBM Zurich Research Laboratory, won the Nobel Prize for Physics. At that time, this project was in the final stage, and it wasn't affected by the discovery in a major way. However, it gave a considerable boost to the research into semi-conductors using oxide.

#### 3.2.2. HEMT devices

The capabilities of HEMT devices came into full play when cooled down to −196°C. Fransman (1990) reported, "Early fundamental research on HEMTs was done in 1969 in IBM's Yorktown Heights Research Laboratory by Leo Esaki and Raphael Tsu and in ATT's Bell Laboratories. Fujitsu became committed to research in this area when the decision was made in 1975 to purchase extremely expensive molecular beam epitaxy equipment". After that, Dr. Dingle from Bell Laboratories formed a basic theory about HEMT. Referencing such research results, Fujitsu conducted research and according to Fransman (1990), "In 1980, Fujitsu Laboratories announced the successful development of the High Electron Mobility Transistor (HEMT)."

At that time, Fujitsu didn't have the confidence to execute all the R&D with its own money because the research was still in the fundamental stage. Accordingly, Fujitsu suggested developing the HEMT devices within the Supercomputer Project, which was initiated in 1981.

The R&D of HEMT as a part of the Supercomputer Project was initiated by Fujitsu and Oki. Fujitsu succeeded in developing 16kbit SRAM, applying the outcome of the research and taking a large step to put HEMT to practical use in 1987. On the other hand, companies such as Hitachi and NEC didn't participate in the research of the HEMT but executed R&D on their own.

#### 3.2.3. GaAs devices

GaAs devices have an advantage over silicon in processing speed. Meindl (1987) reported, "The principal reason that chip designers resort to gallium arsenide is speed". On the other hand, GaAs has lower heat conductivity compared to silicon, and heat elimination would be an obstacle when devices get smaller. Meindl (1987) reported, "A transistor can be made to switch faster by applying more power to it, but so doing increases the buildup of heat in the device. For extremely small devices, the speed of switching may be limited by the capacity of the substrate to conduct heat away from the device. Because silicon has three times the thermal conductivity of gallium arsenide, very small silicon devices may be able to switch just as fast as those made of the ostensibly "faster" material".

### 3.3. Schedule of the R&D

With reference to the discussion of the Research Committee at the Japanese Electronic Industry Development Association from 1980, "The R&D of the High-speed Computer Systems for Scientific and Technology Use — the new theme for the fiscal 1981 large-scale project" was outlined, and they requested funds from the Ministry of Finance based on this material in September 1980. After receiving funds, they brushed up the above-mentioned material and drew up a fundamental plan for the R&D of the High-speed Computer Systems for Scientific and Technology Use dated October 13, 1981.

Below is the schedule for the R&D from 1981 (Fig. 4).

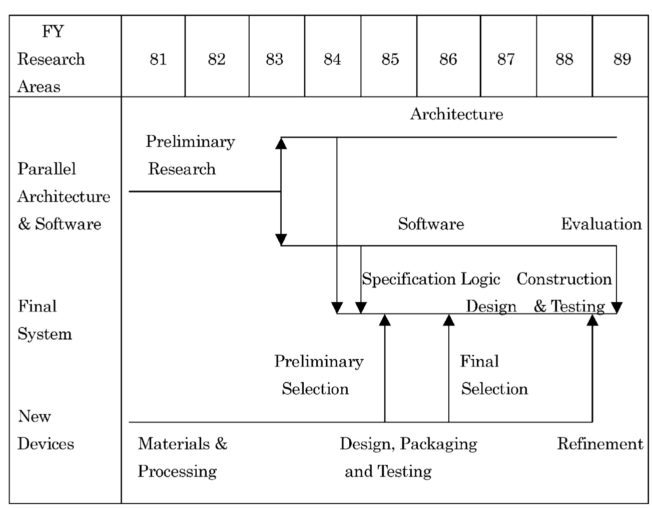


Fig. 4. Schedule of the Supercomputer Project.

*3.3.1. The R&D of new high-speed logic devices and high-speed memory devices to replace silicon*

Research into the fundamental design of each device was conducted in 1981; the material and process technique research was conducted in 1982 and 1983; and the LSI technology research was conducted in 1984 and 1985. With reference to the outcome of these research projects, the policy and objective of the R&D was discussed at the Interim Evaluation Sub-committee for New Devices under the Supercomputer Project Sub-committee, and research into advanced technology was started in 1988.

Concerning the JJ device, development of a Josephson computer for using niobium-type materials was developed. For HEMT and GaAs devices, high-technology research was conducted to make system mounting possible.

*3.3.2. R&D into parallel processing to operate multiple fundamental processors simultaneously*

In the research of the parallel processing architecture, fundamental research took place, the discussion and selection of the architecture of each sub-system was made, and the Electrotechnical Laboratory manufactured a trial SIGMA-1 and developed a higher level language, and then studied what would be suitable for practical use. In the research of parallel processing software, they executed the development of the parallel processing programming language, PARAGRAM, and proved the operational reliability of the high-speed parallel processing system in 1989.

*3.3.3. The R&D of the integrated system composed of a high-speed parallel processor, a large-capacity high-speed memory system, and a dedicated parallel processing system*

The fundamental specification and design of the high-speed parallel processing system, which is composed of a high-speed parallel processor and large-capacity high-speed memory system, and a dedicated parallel processing system, were formed from 1984 to 1986. To demonstrate each system, a detailed design and production of the data processor for the generator and resource satellite data processor started in 1987. The production was completed in 1989 and the evaluation test of each system was conducted using an evaluation system.

### 3.4. Trends in expenses for R&D

Total expenses for R&D for the nine years from 1981 to 1989 was about 18.7 billion-yen, which was obtained from General Accounting and Special Accounting (Table 1). The national expenditure was donated to the Scientific Computer Research Association directly from MITI. However, from fiscal 1989, funds were provided for the Scientific Computer Research Association from MITI through the New Energy and Industrial Technology Development Organization in the same way as for other projects. The original research and development expenses were estimated at 23-billion yen, but were reduced by 4 billion-yen due to budget restrictions. Therefore, they gave up trial manufacturing of high-speed parallel processors and borrowed a commercialized processor from Fujitsu for demonstration.

## 4. The system and management of research and development

### 4.1. R&D system and management of a common government-sponsored project

*4.1.1. The main organization of joint R&D*

There are usually two possible R&D systems when the MITI directs a joint R&D project. One establishes a Research Association for the Mining and Manufacturing Technology founded on the Research Association for Mining and Manufacturing Technology Law, and the other establishes a foundation, which is a non-profit organization, founded on Civil Law 34. An example of the former was the Research Association for the VLSI Research Consortium, and an example of the latter was the Institute for New Generation Computer Technology (ICOT), which was a leader of the Fifth Generation Computing Project. The Research Association is composed of researchers from companies, with the funds provided from each company to carry out the joint research of a specific subject. They are public-service associations that take the benefits from the outcome of their research; after attaining their objectives they are dissolved. On the other hand, the foundations are non-profit organizations that conduct projects for the public's permanent benefit. Most of the MITI sponsored R&D projects have been conducted by the Research Association, and most of the large-scale projects that were part of the plan for the R&D of the Supercomputer Project, were researched and developed by the Research Association. The reason for this was that, while large projects continued for almost ten years, the officer in charge from MITI was replaced every two or three years. And because the administration and management was difficult at MITI, it was probably necessary to integrate the project with the Research Association.

*4.1.2. Central research laboratories and distributed research laboratories*

After deciding on the main organization of the R&D project as mentioned above, the next issue is to decide where the actual research should be carried out: at a central research laboratory or at distributed research laboratories. The Institute for New Generation Computer Tech-

Table 1
Budgets for the Supercomputer Project[a]

| Fiscal year | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 |
|---|---|---|---|---|---|---|---|---|---|
| Total | 30 | 813 | 1567 | 2510 | 2770 | 2888 | 2947 | 2777 | 2431 |
| General account | 30 | 813 | 1567 | 2248 | 1603 | 1237 | 887 | 736 | 341 |
| Special account | | | | 262 | 1167 | 1651 | 2059 | 2041 | 2090 |

[a] Unit: million yen.

nology (ICOT) and the VLSI Research Consortium are examples of central research laboratories. Most of the R&D projects have been carried out at distributed research laboratories and central research laboratories were seldom used. However, many revolutionary outcomes were possible because the researchers from each company would gather in one place for specific R&D. MITI had strong intentions to execute R&D with a central research laboratory at the head, hoping for such revolutionary research outcomes. On the other hand, the companies were displeased with a central research laboratory, and preferred a distributed research laboratory to execute research because they would have to dispatch their superior talent to the central research laboratory and the loan period might be extended at the wishes of that laboratory. Sometimes, too, the researchers don't return to their companies and become a university staff member after the loan period has expired. Generally speaking, most of the research subjects at the central research laboratory tend to do pre-competitive basic research. However, the research subjects of a distributed research laboratory are likely to be in areas that aren't far from commercialization.

The decision whether to use a central research laboratory and distributed research laboratories like the Research Association is discussed below (Fig. 5). Distributed research laboratories are formed in the existing companies where R&D of the Research Association is carried out. Researchers can engage in R&D for the Research Association and the research for his or her own company simultaneously, and the company can manage the researchers efficiently. However, as shown in the figure, the researchers of the distributed research laboratory from company A cannot exchange their opinions with the researchers of the distributed research laboratory from companies B and C, and they cannot make the best use of the accumulated advantages. On the other hand, the central research laboratory is composed of researchers from different companies. Dispatched researchers are released from their own jobs, and can engage in the research of the central research laboratory. For MITI, this system has the merit of making it possible to perform highly efficient R&D, but it works less well for the companies because they lose superior researchers. The accumulated merits could produce a satisfactory result rich in fresh ideas because the dispatched researchers from different cultures can get together and put the research and development into practice.

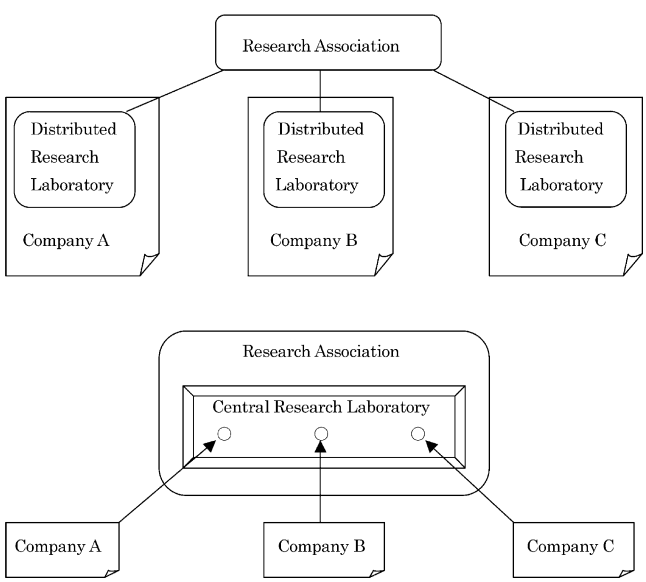


Fig. 5. The difference between central and distributed research laboratories about the research association.

#### 4.1.3. Overall management of the MITI sponsored R&D project

For MITI sponsored R&D projects, MITI first makes a request to the Ministry of Finance for a budget. Then it decides to distribute funds at each area of the R&D and determines the direction of the project in consultation with the Research Committee (Fig. 6).

### 4.2. R&D structure and management for the supercomputer project

#### 4.2.1. The main organization of the R&D project

The R&D on large-scale projects has usually been carried out at the Research Association. According to precedence, they chose the Research Association as the main organization of the R&D. The success of the VLSI Project, which was carried out by the Research Association, was also a reason for the choice.

The Research Association (The Scientific Computer Research Association (SCRA)), which was established for the Supercomputer Project, was dealing mainly with management, and didn't have the facilities to carry out R&D (Fig. 7). To put it concisely, five individuals were on the registry: the managing director and director of

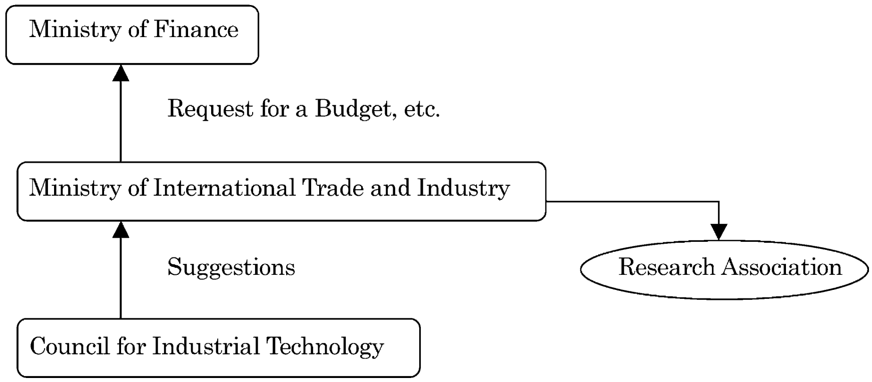


Fig. 6. Overall management of the MITI directed R&D.

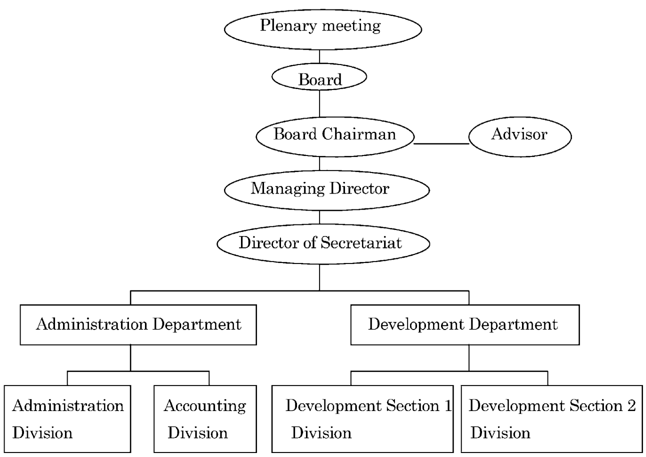


Fig. 7. Structure of the scientific computer research association.

the secretariat (from MITI), the director-general of the administrative department and director of the administrative division (initially from MITI and then from Toshiba), the director of the accounting division (from NEC), the director-general of the development department and director of development section 1 division (from the Electrotechnical Laboratory), and the director of development section 2 (from Fujitsu).

Most of the R&D was performed at each company's distributed research laboratory, which is part of SCRA. To put it concisely, the distributed research laboratories were formed at Oki Electric, Toshiba, NEC, Hitachi, Fujitsu, and Mitsubishi to carry out the project. At the same time, the Electrotechnical Laboratory took charge of the basic and leading research. Companies chose to carry out the research at distributed research laboratories because plans were already made for the supercomputer to be commercialized, and they didn't want to reveal the outcome of their research.

A technical committee was set up at the headquarters of SCRA. The technical committee meetings were held about once a month and the chairperson was chosen to be the successor of the person in charge of Fujitsu. The progress and outcomes that had been made at each distributed research laboratory were discussed at the technical committee meetings. Participating companies learned about the progress of the R&D, which was conducted by the distributed research laboratories of other companies through technical committee meetings, but they didn't learn about the core of the R&D. In this project, meetings on basic and common technical trends were often held, but there was little research exchange between the researchers from different distributed research laboratories.

However, MITI was in a position to know the research details and the progress of each distributed research laboratory because the outcome of the research and development was, in principle, to be reported to MITI. MITI didn't unveil the outcomes from the distributed research laboratories to the others because of the requirement for confidentiality. But they did give hints to the other companies, perhaps unintended, and created a spirit of competition among the companies. Through this type of management, MITI intended to obtain better results from the overall Supercomputer Project.

### *4.2.2. The central research laboratory and distributed research laboratories*

As mentioned in Section 4.1 above, MITI first planned to obtain revolutionary results using the accumulated outcome from the central research laboratories. The central research laboratory is a research and development system, which is suitable for executing fundamental research projects like the Fifth Generation Computing Project. However, the R&D of this project was only one step towards making it fit for practical use and each company had its own know-how concerning the technology. The companies didn't want to apply their expertise because they regarded it as a key benefit. Therefore, there was a possibility that the number of the participants in the project would decrease if MITI tried to force a central research laboratory system on the project. After all, the distributed research laboratory system was picked to carry out the project. Furthermore, the R&D of devices requires a large sum of money for capital investment, and so it would require a large expenditure to organize a central research laboratory. Therefore, it was more efficient to carry out R&D at a distributed research laboratory while making the best use of the existing facilities of each company, and purchasing facilities as the occasion demanded. Device production is very sensitive work and there is the danger of no repeatability when the laboratory changes even if the facilities are identical. The companies had to carry out R&D at their own laboratory to secure repeatability.

### *4.2.3. Total management of the R&D project*

The Supercomputer Project Sub-Committee (Chair: Tooru Motooka, a Tokyo University professor at that time, and from March 1986, Hideo Aiso, a Keio University professor) was established as a lower branch of the Committee of National Development Programs, and the members consisted of people from academia or with experience in the industrial communities, who discussed the fundamental plan of the project, the working plan, the conditions for each year, and so forth (Fig. 8).

With reference to the research of LSI technology in 1984 and 1985, the Intrim Evaluation Sub-committee for New Devices (Chair: Takuo Kanno, a Tokyo University professor at that time) was formed as a lower branch of the Supercomputer Project Sub-committee to examine the outline and objectives of the R&D, and thus completed reports in July 1986 and July 1987.

The members of the Liason Conference of the National Development Program (Chief: Director for Coordination of the Supercomputer Project) was composed of people from academia, related companies, associates of MITI, and the Electrotechnical Laboratory. They examined and ironed out the concrete matters of the R&D on the basis of a fundamental plan and each year's working plan for the project. As a lower organization of the plenary session, they set up JJ WG, GaAs WG, parallel processing WG and total system WG.

As the Supercomputer Project was completed, the Evaluation Sub-committee for the Supercomputer Project was set up under the Committee of National Development Programs to evaluate the project upon consideration of the results of the R&D and evaluation of the details of the related items.

## 5. Outcome and evaluation of the Supercomputer Project

Qualitative analysis of the Supercomputer Project has been carried out a few times in the past. For example, Callon (1995) reported on the basis of interviews, "The Supercomputer consortium was unable to achieve its goals of creating new systems and new device technologies that would leapfrog the status quo".

However, very little quantitative analysis of this pro-

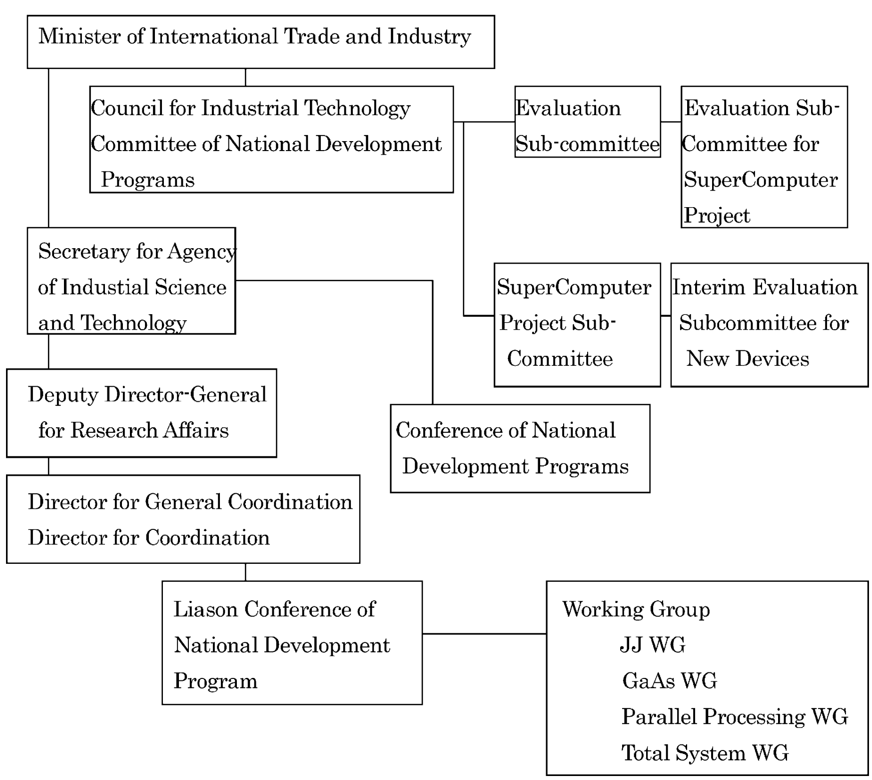


Fig. 8. Promotion organization.

Table 2
The number of patent applications of the Supercomputer Project

| | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| National Research Institutes | 12 | 8 | 4 | 17 | 3 | 5 | 4 | 6 | 5 | 64 |
| Entrusted companies | 11 | 78 | 64 | 87 | 96 | 79 | 51 | 59 | 0 | 525 |
| Total | 23 | 86 | 68 | 104 | 99 | 84 | 55 | 65 | 5 | 589 |

ject has been conducted.[9] And so in this section, I objectively evaluate the outcome of this project through quantitative analysis.

### 5.1. The number of the patent applications and research papers

The number of patent applications and research papers can generally be regarded as an index for evaluating the outcome of an R&D project. However, it is not fair to evaluate a research outcome without regarding the quality of the patents or papers as it does not consider the quality of the research outcome. After examining the trend in the number of patent applications and the number of papers, we considered the number of paper citations from the perspective of the quality of the results.

#### 5.1.1. The number of patent applications

There were 589 domestic applications for patents in nine years (Table 2). On average, there were about 65 applications for patents per year, a number double that of the Fifth Generation Computer Project, which had 32 applications for patents per year.

There were 271 patents from this project that were registered with the patent office as of September 1999 (Table 3).[10] This means that half of the patent applications were registered. We made an investigation to see if the registered patent had been utilized effectively. However, only four patents have been under contract for practical use. Though many patents were registered in this project, we can see that these patents were not utilized effectively. Incidentally, the above-mentioned four patents were all related to the parallel processor that was invented by Mitsubishi researchers, and the company that made a contract for all four patents was also Mitsubishi. This indicates that even for the patents for which contracts were made, the contracts were made in areas worked on by the contracting company's own researchers, indicating no spillover to other companies. Cray Research had already commercialized supercomputers before the Supercomputer Project was launched and so it was natural to think that the fundamental patents for supercomputers were already registered. Therefore, the patents from the Supercomputer Project were no more than peripheral patents and this was one of the reasons why there were fewer repercussion effects than expected.

#### 5.1.2. Trends in the number of research papers

In nine years, 1293 papers were submitted (Table 4). On average, 144 papers were submitted per year. For the Fifth Generation Computer Project, 2971 papers were submitted in 14 years (914 TR, 1457 TM), and the annual average was 169.

The Fifth Generation Computer Project put emphasis on fundamental research and set great store by report preparation. On the other hand, the Supercomputer Project was only one step towards being put into practical use and it placed more emphasis on obtaining patents than the papers.

#### 5.1.3. Comparison of the number of paper citations

As mentioned above, the number of papers and patents does not consider the quality of the outcome. Here I will examine more closely the quality of the research outcome by mentioning the number of paper citations. The number of paper citations could be a barometer for knowing how much influence a paper had on other papers. The data search in this section was done with SCI-SEARCH, which is a database made by the Institute for Scientific Information (ISI) to provide international and academic information on the papers related to science, technology, and biomedical science.

First of all, I elicited eight researchers from the Supercomputer Project who had submitted the most papers.

[9] The Mitsubishi Research Institute once performed a quantitative analysis on technology. The Mitsubishi Research Institute (1999) analyzed the effectiveness of the Supercomputer Project by using the method of Bach and Lambert (1992). Specifically, they divided the effectiveness to improve the R&D capability, the economic effectiveness, and the effectiveness for improving a citizen's living standard and social standing, and analyzed the accumulated effectiveness that could be determined at the periods of five and then ten years after the end of the project. The economic impact of the project's effectiveness was calculated using the equation: Market creation effect=Sales volume of the product×Degree of the project's contribution. As a result, the accumulated effectiveness for five years after the project ended turned out to be 100 billion-yen, and 290 billion-yen for ten years after. It was a challenging attempt that evaluated a national-scale project quantitatively, but the consequence of the analysis itself is shaky.

[10] The patents, which were registered through this project, were intellectual property obtained upon commission from the government. Therefore, it was thought that all rights would be restored to the government.

Table 3
The number of registered patents of the Supercomputer Project[a]

| | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| National Research Institutes | 9(0) | 6(0) | 3(0) | 16(0) | 3(0) | 3(0) | 3(0) | 5(0) | 5(0) | 53(0) |
| Entrusted companies | 8(0) | 51(0) | 34(1) | 40(1) | 39(2) | 29(0) | 15(0) | 11(0) | 0(0) | 218(4) |
| Total | 17(0) | 57(0) | 37(1) | 56(1) | 42(2) | 23(0) | 18(0) | 16(0) | 5(0) | 271(4) |

[a] The figures in parentheses indicate the number of registered patents that one company contracted to use.

Table 4
The number of papers of the Supercomputer Project

| | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| National Research Institutes | 51 | 54 | 66 | 70 | 45 | 43 | 43 | 48 | 4 | 424 |
| Entrusted companies | 3 | 62 | 93 | 131 | 123 | 142 | 172 | 136 | 7 | 869 |
| Total | 54 | 116 | 159 | 201 | 168 | 185 | 215 | 184 | 11 | 1293 |

As a comparison, I also elicited eight researchers each from the Fifth Generation Computer Project and the Real World Computing Program who had submitted the most papers.

Next, the search time period was set. Only eight years have passed since the realization of the Real World Computing Program, and so a search period of eight years was set for the Supercomputer Project and the Fifth Generation Computing Project. The search was conducted in the limited field of computers.

And third, along with searching the number of papers recorded by the researchers of each organization, a search was also made of the number of paper citations under the above conditions.

Of the three projects, the Supercomputer Project was at the bottom in terms of the number of papers and the number of paper citations (Table 5). This indicates that the Supercomputer Project had less of a spillover effect than the other projects. One reason for the low spillover effect is that the productivity level of this project was low because there were no researchers who specialized in doing research for this project. Another reason was that the project was designed for R&D up to one step before practical use, unlike the other projects, resulting in relatively smaller number of papers and content.

The reason the Real World Computing Project resulted in a relatively high number of papers and paper citations was because it resulted in a far larger number of papers recorded within the applicable time period in the computer field.[11]

### 5.2. Technical outcome of the Supercomputer Project

This evaluation of the technical aspects of the results of the Supercomputer Project was done under a survey by the Council for Industrial Technology Committee (1990).

#### 5.2.1. Research and development of new high-speed and highly integrated devices

*5.2.1.1. EJJ devices* At the beginning, research and development was carried out mainly using lead-based

[11] The number of submitted computer-related papers during the research period of the Real World Computing Program from 1992 to 1999 was 81,958, three times as many as other projects. For example, 30,426 papers were submitted during the Supercomputer Project from 1982 to 1989, and 27,583 papers were submitted during the Fifth Generation Computing Project from 1983 to 1990.

Table 5
The number of research papers and citations by the researchers of the Supercomputer Project and other projects

| Projects | Term | No. of researchers examined | No. of papers | | No. of citations | |
|---|---|---|---|---|---|---|
| | | | Total | Per researcher | Total | Per researcher |
| Supercomputer project | 1982–1989 | 8 | 9 | 1.13 | 33 | 4.13 |
| Fifth generation computing project | 1983–1990 | 8 | 21 | 2.63 | 79 | 8.2 |
| Real world computing program | 1992–1999 | 8 | 23 | 2.88 | 94 | 11.75 |

alloy, but after IBM withdrew from the research, the lead-based alloy was immediately replaced by niobium and certain results were obtained. Moreover, an experimental small-scale computer was manufactured and shown to have high-speed efficiency. In the end, enough JJ devices couldn't be mounted on the computer for the necessary accumulation, but this led the way for development towards SQUID.

*5.2.1.2. HEMT devices* It was shown that high-speed operation and savings in electricity with the HEMT devices gives a decided advantage over silicon devices. In the end, not enough HEMT devices could be accumulated to mount on computers, but they were applied to very high-speed optical communication devices.

*5.2.1.3. GaAs devices* Considering the accumulation level, the number for mounting on systems, and the operation, it was possible to develop the world's highest level of GaAs devices but the accumulation level was not sufficient for mounting on computers. However, they were applied to portable telephones and antennas for satellite broadcasting as high-speed communication devices.

### *5.2.2. R&D of parallel computer architecture and parallel software*

*5.2.2.1. Parallel processing architecture* With high speed parallel processing architecture, the parallel operating effect has been improved. Owing to the establishment of this technique, a system to connect tens of vector processors was also developed.

As for the dedicated parallel processing architecture, three types of specialized architecture were introduced with high expectations for practical use. The possibility of supplementation of general computers and the development of new uses based on the various characteristics was also suggested.

The world's first data flow supercomputer (SIGMA-1) was developed and its effective speed wasn't beaten by 170 MFLOPS and the existing vector supercomputer.

*5.2.2.2. Parallel processing software* A unique higher-level language (PARAGRAM) and other various computer languages and the supporting software for efficient parallel operation were developed and obtained excellent results.

### *5.2.3. Integrated system (construction of the final high-speed system)*

A high-speed parallel processor successfully set 10.92GFLOPS in maximum processing speed with a multi-processor of four linked processors, a computer with theoretically a 2.11 to 3.78 times higher performance compared with the theoretical maximum performance of four times.

A large capacity high-speed memory system was handy and convenient for users by saving labor in programming and maintenance because they would not have to give definite instructions to control each memory system as in the past.

As for generation data processors, which were made by the combination of high-speed parallel processors and a large capacity high speed memory system, research into a large-scale problem processing system was conducted, and the world's largest simulation program in the nuclear power field was successfully operating in a relatively short time.

A resource satellite data processor, which was a demonstration system of the dedicated parallel processing system, demonstrated very high-speed processing, higher than had ever been achieved with existing all-purpose computers.

Individually speaking, the Supercomputer Project produced excellent results. The research and development of HEMT devices and GaAs devices, particularly, resulted in unexpected outcomes applied to very high-speed optical communication devices, portable telephones, and antennas for satellite broadcasting. However, the research outcome for the logic devices and memory devices couldn't be directly helpful to supercomputers for practical use. From the point of view of the devices for computer use, the technology evolution of silicon devices produced unexpected and remarkable results, helping to make the silicon devices faster and less expensive. The non-silicon devices such as JJ devices, HEMT devices, and GaAs devices, which were under research and development, couldn't surpass silicon devices in processing speed and prices. Therefore, non-silicon devices were never installed in the commercialized supercomputer in Japan after the project was launched with a single exception.[12] As for integrated systems, success was made in demonstrating 10GFLOPS at the maximum speed using a simple program and it is not entirely clear whether or not the goal was achieved. The integrated system of this project was structured by putting each company's machine together, but the fundamental efficiency of each company was never revealed to others to protect company secrets. Therefore, they weren't able to integrate the system efficiently. The integrated system of this project was no more than a temporary system and it didn't contribute much towards a supercomputer fit for practical use.

### *5.3. Evaluation of the Supercomputer Project based on a questionnaire survey*

In this section, various evaluations of the Supercomputer Project are presented and each evaluation is based

[12] The VPP500, commercialized by Fujitsu in September 1992, was loaded with GaAs devices. However, Fujitsu did not take part in the

Table 6
Foresight and validity of the Supercomputer Project

| Research scope | Large-scale program | Supercomputer project |
|---|---|---|
| Wide | 21.4 | 15.4 |
| Neutral | 67.9 | 69.2 |
| Narrow | 10.7 | 15.4 |
| **Adjustment of the needs between society and industry** | **Large-scale program** | **Supercomputer project** |
| Top-shelf | 54.8 | 38.5 |
| Neutral | 38.6 | 30.8 |
| Out-of-date | 54.8 | 30.8 |
| **Level of objective** | **Large-scale program** | **Supercomputer project** |
| High | 46.9 | 30.8 |
| Neutral | 49.7 | 53.8 |
| Low | 3.4 | 30.8 |
| **R&D expenses compared with objective** | **Large-scale program** | **Supercomputer project** |
| Great | 1.7 | 0 |
| Neutral | 62.4 | 53.8 |
| Small | 35.9 | 46.2 |
| **Overroll evaluation** | **Large-scale program** | **Supercomputer project** |
| Success | 56.2 | 61.5 |
| Neutral | 33.2 | 30.8 |
| Failure | 10.5 | 7.7 |

on the questionnaire survey conducted by The Japan Machinery Federation and Japan Industrial Technology Association (1995). Thirteen people from the relative companies, the Electrotechnical Laboratory, and the Research Association were surveyed. We discuss here a comparison of the results from the questionnaire surveys of 19 other large-scale projects.[13]

### 5.3.1. *Foresight and validity of the Supercomputer Project (Table 6)*

The research scope, the adjustment of the needs between society and industry, and the level of objective provide good indications of the character of the Supercomputer Project. The research scope was limited, compared to other large scale projects, and the level of objectivity wasn't thought to be high because the R&D of the project was only one step towards practical use. For example, the performance objective of the entire project was 10GFLOPS as the maximum speed, but when the project was being completed, a level sufficient for commercial use had already been achieved.

As for R&D expenses, the project expenses were estimated at 23 billion-yen at first, but ended up being 18.7 billion-yen. At that time, even commercialized computers with the efficiency of 1GFLOPS had a cost of 60 billion-yen for each company. This is why the R&D expenses of this project are thought to be low compared to other large-scale projects. At the end of the project, each company put their R&D results together and operated an integrated system. However, they had to borrow a supercomputer parallel processor because they couldn't afford one.

The overall project was evaluated highly in comparison to the other large-scale projects, taking account of the achievement of the project's performance objective of 10GFLOPS as a matter of form. However, the trade negotiation about supercomputers between Japan and the United States became obvious and all the results of the project weren't fully declared to the world.

### 5.3.2. *Evaluation of the management of the Supercomputer Project (Table 7)*

The project had to use a single-year budget system in the same way as the other projects, and although the

R&D of the devices in the Supercomputer Project, and had no direct relation to the outcome from the Supercomputer Project.

[13] There are 19 categories for large scale projects: two for new materials, four for electric information, six for mechanical aeronautics, four for resources, and three for human lifestyle.

Table 7
Evaluation of the management of the Supercomputer Project

| Flexibility of plan change | Large-scale program | Supercomputer project |
|---|---|---|
| Rigid | 39.1 | 53.8 |
| Neutral | 36.7 | 23.1 |
| Flexible | 24.2 | 23.1 |
| Limit on use of the budget | Large-scale program | Supercomputer project |
| Loose | 13.2 | 23.1 |
| Neutral | 35.6 | 30.8 |
| Tight | 51.2 | 46.2 |
| Degree of coordination | Large-scale program | Supercomputer project |
| Permissive | 10 | 9.1 |
| Neutral | 70 | 63.6 |
| Much interfering | 20 | 27.3 |
| Degree of information exchange | Large-scale program | Supercomputer project |
| Little | 10.3 | 16.7 |
| Neutral | 75.6 | 58.3 |
| Great | 14.1 | 25 |
| Burden of office work | Large-scale program | Supercomputer project |
| Little | 3.1 | 0 |
| Neutral | 18.4 | 18.2 |
| Great | 78.5 | 81.8 |

limits on use of the budget were tight, there appears to have been relatively sufficient funding.

However, the Supercomputer Project had less flexibility for modification compared to other projects. For example, when IBM announced their decision to end R&D of JJ devices, the participating companies wanted to stop R&D of the JJ devices and put emphasis on other areas, but MITI continued this research to the end. There was increasing dissatisfaction with the situation by the participating companies. As for the degree of coordination, there had been more interference than with other large-scale projects.

Regarding the degree of information exchange, many of the respondents said that the project presented fewer opportunities to exchange information among the companies compared to other large-scale projects because the R&D was executed only at the distributed research laboratories, and the only way to exchange information was through superficial information from the monthly technical committees.

Several respondents also replied that the participants in the project had to shoulder more of the burden of office work than in other large-scale projects because the MITI officials in charge of the project changed every two years, resulting in a change of policy and an increase in office work.

### 5.4. *Effectiveness of the Supercomputer Project*

We made an analysis focused on JJ devices, which was one of the subjects of the Supercomputer Project, in order to examine the effectiveness of the project.

Using the database of the Institute for Scientific Information (ISI) -SCISEARCH-, we added up the number of papers submitted each year by the researchers who were engaged in the research and development of JJ devices, and the number of papers concerning JJ devices in the world, in Japan, and by the participating companies. Table 8 shows the change in the percentage of the number of papers concerning JJ devices submitted by the Japanese companies that engaged in the Supercomputer Project in all papers related to JJ devices in Japan and the percentage of Japanese papers concerning JJ devices to the total number in the world.

The percentage of the number of papers concerning JJ devices submitted by the companies participating in the Supercomputer Project to the total number of papers concerning JJ devices in Japan was not very high during the project, with the exception of 1986. However, after the project came to an end, the percentage was stable, reaching a peak in 1992. Participation in the project became a trigger for the companies to continue the research and development of JJ devices even after the

Table 8
Number of papers concerning JJ devices

| | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Papers by the researchers that engaged in the supercomputer project/Japanese papers | 0 | 8 | 0 | 0 | 25 | 9 | 0 | 5 | 7 | 16 | 19 | 9 | 8 | 13 | 9 | 8 | 6 | 19 |
| Japanese papers/total number in the world | 21 | 30 | 12 | 13 | 14 | 12 | 11 | 8 | 9 | 14 | 9 | 16 | 13 | 16 | 18 | 18 | 18 | 15 |

project was over. The papers from the project had been prepared mainly by the researchers of national laboratories and universities, and this might be the reason why the share of participating companies was so low.

As for the percentage of the number of Japanese papers concerning JJ devices to the total number in the world, the share was high when the project was launched because the project received considerable attention. However the share declined as the project came to an end. After 1991, the share stabilized. The participating companies, as well as the rest of Japan, secured a certain share, and so we can judge that a certain spillover effect was achieved.

## 6. Conclusions and the ideal style for a government-sponsored R&D project in the future

There was not much need for the government to carry out the Supercomputer Project on a national-scale because three companies had already decided to introduce supercomputers, and they were ready to implement the R&D for practical use when the national project was inaugurated. There was not much space in which the government could intervene. However, the R&D about devices, such as JJ devices to serve as substitutes for silicon, had a high uncertainty, and so there was space for the government to intervene in the R&D in this area.

An analysis of the quality of the project based on the number of paper citations shows that the Supercomputer Project was quoted fewer times than other similar computer projects, and so the effectiveness from the project could be judged relatively small.

We can also see the spillover of this project by examining where the patents gained from this project are actually being used. As a result of the project, 271 patents were registered, but contracts to use only four of them were made, and all with one company that provided researchers to the Supercomputer Project. Therefore, as far as can be seen from the patents, there was almost no spillover to other companies that didn't take part in the project.

However, in order to see the spillover effect of this project in regards to JJ devices, the percentage of the number of submitted Japanese papers concerning JJ devices to the total number of papers in the same field in the world could be an indication that the share increased after the project, not only among the participating companies of the project but throughout Japan. For this reason, it can be said that the research and development of JJ devices had a certain effectiveness.

As for the degree of information exchange, the project presented fewer opportunities for information exchange among the companies compared to other large-scale projects because R&D was executed only at the distributed research laboratories, and the only way to exchange information was through the superficial information from the monthly technical committees.

The target of this project, to make a prototype high-speed computer with 10GFLOPS, was achieved by using a simple program. And so while the target was achieved, there is still doubt as to whether the goal was actually achieved.

As for the devices such as HEMT devices, GaAs devices, and JJ devices, which were included in this R&D project, all of them were ultimately unable to obtain a level of accumulation good enough for installation in computers. However, because the project was directed by the government, it was learned that while these devices were not suitable for computer use, they have been applied to use in portable phones and high-speed devices for satellite broadcasting, resulting in a considerable profit. When evaluating an R&D project, it is important to evaluate accomplishment of the objective, which was set before the project was launched, but the indirect results, which are unpredictable, must also be highly evaluated.

Based on the above evaluation of this project, the method for conducting government-sponsored R&D projects will now be considered.

Many of the government sponsored R&D projects have been done through the mission system. It's a system that integrates separately developed researches like the Supercomputer Project. Using this method, the differences in individual R&D progress results in the slow projects pulling down the other projects, making overall integration impossible. Additionally, it becomes necessary to conduct research into areas that are relatively unimportant, making focused investment for R&D impossible. Therefore, the government should focus on non mission style R&D.

Furthermore, if the project needs several decades to complete, the original objective of the project has a tendency to become out of date by the time the project is concluded. Therefore, project management should be more flexible so that the objective can be altered to meet the demands of the times, and so the project itself can be canceled if it becomes dated. As mentioned above, when evaluating the outcome of a project, we should set a high valuate on not only the direct effects, such as the accomplishment of the objective, but also on the indirect effects.

Once a government-sponsored project is launched, the participating companies tend to engage in R&D, bearing the expenses without regard for the available budget, and with this project as a trigger, the participating companies make a concentrated investment in the field. Therefore, rapid progress in a short time in the R&D in this field can be achieved. When the government selects a theme of government-sponsored R&D, they have to carefully make a selection that shows promise, with reference to not only the national budget but also to the possibility of investment from the participating companies.

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