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International Conference on Fifth Generation Computer Systems

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No. 49

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Preface

The Japanese economy is caught in the stream of international change and uncertainty, particularly as these are represented by the problems of energy and raw materials. At the same time, the nation is in the process of forming an information-oriented society wherein great importance is coming to be attached to the appropriate processing and utilization of information.

The computer has become an indispensable tool in our use of information. Still, over the next ten years, we are certain to find the need for even more highly sophisticated technology in overcoming the many problems we will come to face, and the realization of computer systems based on new theoretical foundations and technology will be much desired.

It was for these reasons that JIPDEC established a Committee for Study and Research on Fifth-Generation Computers (chairman, Tohru Moto-oka) which, beginning in 1979, set out on a two-year investigation into the most desirable types of computer systems for application in the 1990's (fifth-generation computers) and how the development projects aimed at the realization of these systems should be carried forward.

Presented here is a summary of the findings of the Committee (1979–1980) and the minutes of Panel Discussion III (Impact of Fifth Generation Computer Systems) of the International Conference on Fifth Generation Computer Systems held from October 19 to 22, 1981 at Keidan-Ren-Kaikan, Tokyo.

Summary (Preliminary Report on Study and Research on Fifth-Generation Computers, 1979–1980)

1 Background and significance

(1) Social requirements expected of computers in the 1990's

In the 1990's when it is expected that fifth generation computer systems will be in wide use, information processing systems will be central tools in all areas of social activity to include economics, industry, art and science, administration, international relations, education, culture and daily life and so forth. Such information processing systems will be required to meet those new needs generated by environmental changes and will not only be expected to play active roles in the resolving of anticipated social bottlenecks but also to advance society along a more desirable path through the effective utilization of their advanced capabilities.

Information processing systems in the 1990's will be expected to play the following roles:

1) To increase productivity in low-productivity areas

Although product quality and productivity in the secondary industries have been greatly improved through the adoption of computer controlled manufacturing processes and assembly lines, productivity in the primary industries such as agriculture and fishing and also in the tertiary industries such as goods distribution and public services, has remained little changed. This fact has been the cause of serious social imbalances. Cost reductions via increased efficiency as represented by industrialization and office automation can be expected in these fields as well, as a result of the effective employment of advanced computer systems.

2) To meet international competition and contribute toward international cooperation

Suffering from a shortage of land and natural resources, it is impossible for Japan to be fully self-sufficient in food, and her ability to supply her own energy and oil needs is the lowest among the developed countries. On the other hand, we do have one precious asset, that is, a highly educated, diligent and top quality labor force, our human resources. It is desirable to utilize this advantage to cultivate information itself as a new resource comparable to food and energy, and information related knowledge intensive industries should strongly be promoted to make possible the processing and management of information at will.

Such an effect would not only serve to help our country meet international competition, but would also enable us to make international contributions through knowledge-intensive technology.

3) To assist in saving energy and resources

One of the most important tasks facing mankind in this century is how to use our finite resources effectively. Paralleling the realization of minimization and optimization of energy consumption, improvement of energy conversion efficiency and simulators for use in developing new sources of energy through the use of computer technology, even the industrial system itself could be expected to change into a knowledge-intensive type information industry which would be typically non-energy consuming.

4) To cope with an aged society

Our society is aging at an unprecedented rate. Rapid increases in medical expenses and welfare costs together with the relative reduction in the labor force resulting from this aged society could lead to big social problems. Accordingly, utilization of fifth generation computers to prevent the occurrence of or to cope with such problems by way of developing streamlined medical and related information systems, health management systems and lifetime education systems for the aged etc. will be necessary.

(2) Technological background

Computer technology has, from its birth on, consistently and emphatically been aimed at high-speed operation and large capacity, and has been developed mainly for processing numerical calculations. As a result, computers have had significantly limited functions in terms of input and output processing that restricted their applications, and this has caused considerable inconvenience. As applications for computers have become widespread, from the initial scientific and technical computations to the more recent business data processing, there has arisen a strong need for freer input/output capabilities such as by speech or voice, images, graphics and the like, all of which are natural forms of information transmission for man.

The high cost of hardware up to now has not only minimized the number of functions capable of being carried out by it, but has also gradually increased dependence upon software, the proliferation of which has led to a situation called the "software crisis". This problem has had an undesirable side effect in that computer architecture has become stiff and inflexible due to the continued reliance on existing software and is believed to be unable to meet new applications as long as it continues to rely on existing technologies.

From the standpoint of seeds for the development of new technology, a technological basis permiting new architectures and new functions such as improved computer intelligence has matured. This includes VLSI technology which has rapidly advanced in the past few years, the realization of larger capacity memories, increased possibility for developing high-speed elements, promotion of research into artificial intelligence and pattern recognition technology and the technological fusion of communication and information processing among others.

Judging from the relationship between needs and seeds, it is quite natural to hope that information processing systems based on new conceptions and architectures which would prove to be a quantum leap in the computer technology of the past thirty years will appear in about ten years.

(3) Significance of the project

Japan had come to be considered an "economic power" by the other countries of the world. Thus, if we consider the direction in which our industries should proceed, it becomes clear that we no longer need chase the more developed countries, but instead should begin to set goals of leadership and creativity in research and development and to pioneer the promotion of such a project throughout the world.

The significance and effect of the research and development project for fifth generation computers is summarized as follows:

1) By promoting this project, Japan is playing a leading role worldwide in the field of computer technology development. This effort will not only help our computer industry foster more creative technology, but will also provide our country with a means of bargaining power. We can also fulfill our duty as an economic power expected to assume international responsibility by investing in the development of this leading field.

2) In addition to making our society a better, richer one by the 1990's, this project will also prove influential in other areas.

The fifth generation computer is expected to be beneficial in the solution of social bottlenecks such as the energy problem and problems related to an aging society etc. It is also expected to serve as a prime mover in the field of industry by helping those industires experiencing difficulty to improve their efficiency and thus their productivity. Further, society as a whole will become more affluent as computers are applied to increasingly new fields and areas.

3) Developments in heretofore unexplored fields will actively contribute to the progress of all humanity.

Through the promotion of research into artificial intelligence, a better understanding should be gained of the mechanisms of life which future research and development will then concentrate on. The realization of automatic translation into multiple languages will help promote mutual understanding between and among peoples of different tongues and thus aid in reducing trouble due to misunderstandings and ignorance.

With the construction of a knowledge base made possible, the knowledge which man has accumulated over the ages can be stored and effectively utilized, and new kinds of insights and perceptions can be more easily obtained by man with the aid of computers.

4) Experiments for advanced research and development organizations.

It is of great importance to conduct national tests of research and development organizations which have been in existence for a long period of time. The majority of national projects from now on will be required to be carried out by organizations for advanced research and development such as these. Thus tests of these organizations at the national level could be considered a kind of experimental project for future projects. Promotion of this kind of testing project will create an environment which will produce original research based around it.

2 Functional requirements

Fifth generation computer systems will be required to have an extremely wide variety of sophisticated functions to solve the numerous problems which todays computers have and to meet the social needs of the 1990's during which decade computerization is expected to find many more applications than nowadays.

As a whole, functions required of fifth generation computer systems will be as follows:

(1) Increased intelligence and ease of use so that they will be better able to assist man

1) Functions which enable inputting and outputting of information via speech or voice, graphics, images and documents

Enhancement of input/output functions which serve as the interface between man and computer is of prime importance in making computers easier to use.

In particular, since current computers are quite limited in their input/output functions, the ability to input and output information in a wide variety of forms such as speech or voice, graphics, images, documents and the like man's daily means of transmitting information will be of utmost necessity.

2) The ability to process information conversationally using everyday langauge

As computers penetrate further and further into every field of our society, there will be more opportunities for laymen to operate them and thus gain direct access to needed information. Therefore, the ability to communicate conversationally with a computer using everyday language will prove most beneficial.

3) The ability to put stored knowledge to practical use

The ability to handle information in speech, graph or natural language form does not end with the input function, but rather such a computer can only fulfill its purpose if backed up with the knowledge to comprehended that input information.

In order to be able to utilize computers more effectively as tools for solving various problems, they will have to be equipped with specialized knowledge i.e. knowledge bases, related to the fields in which they are employed. Then by putting these knowledge bases to practical use computers will be better able to lessen the burden on their human operators as well as serve a role as consultant systems for all mankind.

4) The functions of learning, associating and infering

So that computers have knowledge and can sufficiently use it for a desired purpose, they should be given in one form or another abilities of learning, associating and infering just like ours. With such abilities, computers would be able to clarify even vague requests given by man and using their vast ability to store information achieve new judgement facilities of their own which will help expand the capabilities of we humans as well.

(2) Lessening the burden of software generation

1) Automated processing based on the input description of requirement specifications

The cost of the development of software is now greater than that of hardware, and there will be increasing needs for software in the future. In such a situation, it is necessary to raise the proportion of automated programming in software development.

For example, an ideal process is one where a computer processing procedure is synthesized directly from requirement specifications described in a natural language, generated and performed.

2) Realization of a language capable of program verification and a suitable architecture

A programming language is a direct interface between man and machine in the development of a program. The ease with which the programming language can be used and language specifications functions greatly influence the degree of difficulty of software development. Moreover, it is desired that in future ultra high-level languages with a high degree of verifiability to enhance reliability of software appear, and a machine be realized which has architectures suitable for processing such languages.

3) Improvement of environments for programming and realization of intelligent interfaces

To improve programming productivity, not only language would be improved, but also programming environments should greatly be improved to provide intelligent interfaces between users and systems. Such requirements are common in every form of computer access such as data base access for retrieving desired information out of a great amount of information, or a knowledge base access for gaining a new perception to cope with an unknown problem

4) Utilization of existing software assets

As computer functions and performance are improved, new applications will increase to the point where conventional computers will not be able to deal with them. However, it will be desirable to utilize software developed to date as much as possible. To this end, systems will be preferred which are flexible enough to run software based on conventional architectures.

(3) Improved overall functions and perfromance to meet social needs

1) Improved cost/performance

It is a common principle to all industrial products that technological progress improve the cost/performance of products. In the 1990's, the cost/performance of hardware and software combined should be improved significantly.

2) Light, compact computers

Computers are expected to be lighter and smaller as the technology of integration of devices progresses. The 1990's should find portable, high-function computers, multilingual translating machines, and industrial products equipped with high-performance computers.

3) High-speed, large-capacity computers to meet new applications

It can be said that demands on speed of processing and memory capacity as basic computer abilities are and will be limitless. Many problems that are considered unprocessable by conventional machines will appear as new applications as processing speed and memory capacity increase. Realization of the intelligent system, described above, is dependent on great improvements in these basic performances. With these improvements, unknown situations can be simulated with high precision to assist in widening our ability to solve problems.

4) Increased diversification and adaptability

Up to now general-purpose computers with fixed hardware have been in the mainstream, but computer systems in the 1990's will be required to have much wider diversification and purpose-oriented adaptability and flexibility. Hardware and software both should have their basic components modularized for free system adaptability and rearrangeability to suit various purposes.

5) Highly reliable functions

As computers find their way into more and more field area of our society, they are likely to cause much more damage when they get malfunction. Therefore, constructing highlyreliable systems is an absolute requisite for future society. Computer systems should not only be equipped with functions to automatically detect and repair their own malfunctions, but should also be capable of preventing the danger of a runaway computer by means of malfunction prevention devices and the aforementioned improved machine intelligence.

6) Sophisticated function for the protection of secrets

Social computer systems will be largely expected to serve as social utilities and thus will have to be equipped with sophisticated functions for the protection of secrets. These systems will also be required to have built-in mechanisms for preventing computer crimes and unauthorized use of computers.

3 Objective and image

The Fifth Generation Computer Systems will be knowledge information processing systems based on innovative theories and technologies that can offer the advanced functions expected to be required in the 1990's, overcoming the technical limitations inherent in conventional computers.

3.1 Basic concept

The Fifth Generation Computer Systems will be knowledge information processing systems having problem-solving functions of a very high level. In these systems, intelligence will be greatly imporved to approach that of a human being, and when compared with conventional systems, man-machine interface will become closer to the human system. Figure 1 shows a conceptual diagram of the Fifth Generation Computer Systems. As shown in the figure, a powerful problem—solving mechanism based on problem understanding and inference functions, knowledge bases, etc. are found between the human system and the conventional machine functions. In addition to that models will be realized principally through software, and the machine principally through hardware, and the Fifth Generation Computer Systems will perform the following functions as integrated capacities;

1) Understanding of problem de-

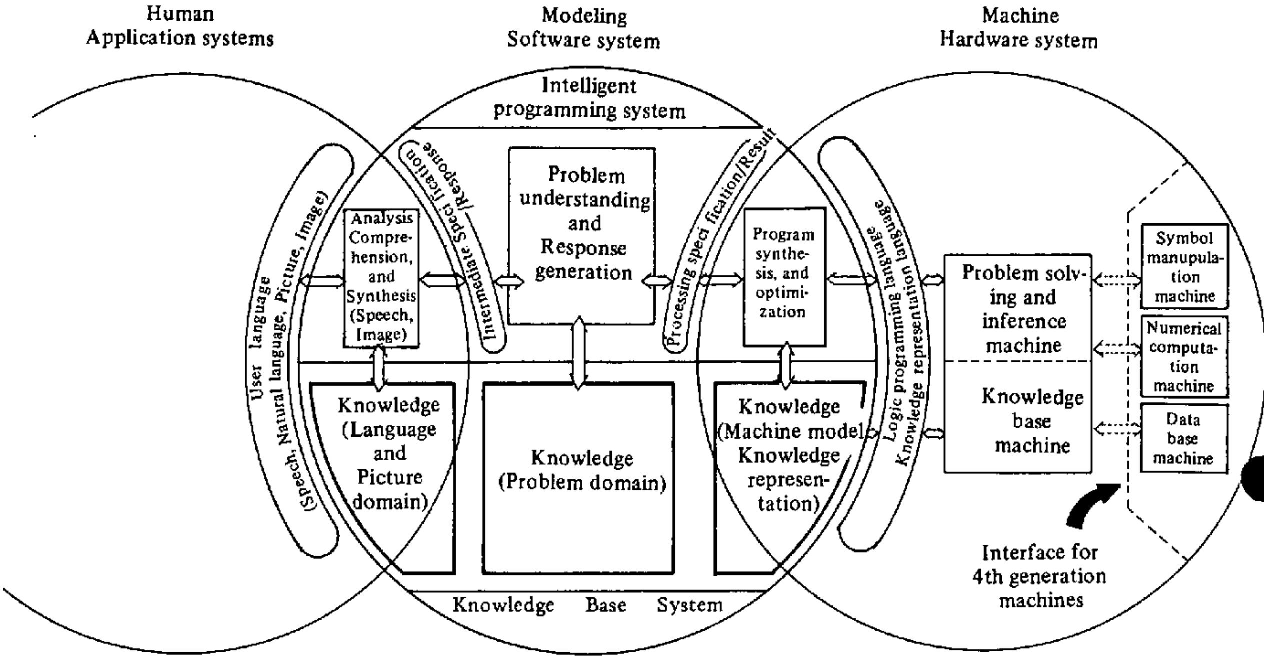

Fig. 1 Conceptual diagram of the fifth generation computer systems

scription and requirement specifications

2) Synthesizing processing procedures
3) Optimization between machine system and processing procedures
4) Synthesizing response based on outputs from machine system
5) Intelligent interface functions capable of understanding speech, image and natural language, etc.

The knowledge bases tht support the above functions will contain knowledge of the following types:

1) Knowledge of the languages to be used for man machine communication
2) Knowledge on the problem areas to be solved
3) Knowledge on the machine systems

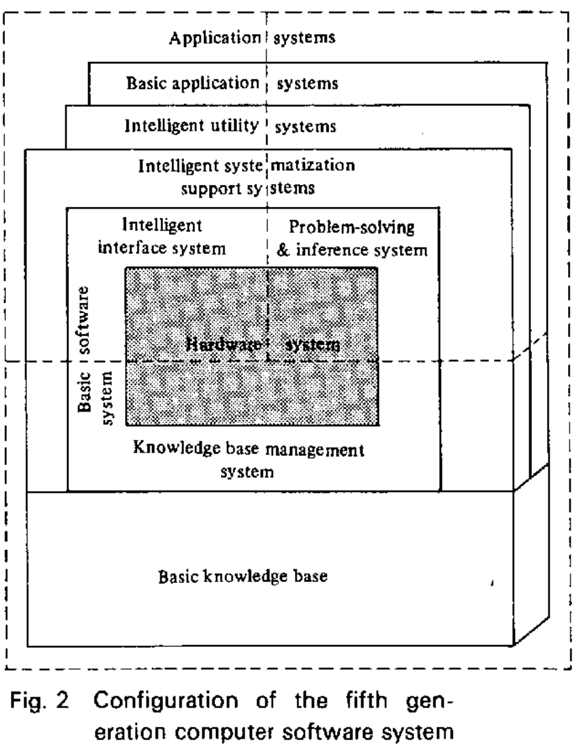

Fig. 2 Configuration of the fifth generation computer software system

3.2 Constituent elements of software system

Figure 2 shows the system configuration image.

These constituent elements perform the following functions:

(1) Basic software system

The basic software system forms the core of the software system, and consists of the three subsystems of Problem-solving and inference, Knowledge base management and Intelligent interface which are the basic function of the Fifth Generation Computer Systems.

(2) Intelligent systematization support system

The system provides the human designer intelligent functions to strongly support systematization work based on the knowledge base contents and it consists of three subsystems of Intelligent programming, Knowledge base designing and Intelligent VLSI designing.

(3) Intelligent utility system

This system has such functions as to enable the user easy of the entire computer system and make the system highly reliable.

These include programs to support the portability of software and database from other machines, user guidance functions, and automatic inspection and repair functions for the prevention and detection of failures.

(4) Basic knowledge base

The basic knowledge base supports the operation of the system itself in addition to containing the accumulated valid and universal knowledge necessary to the user. Generally, there are three types; the general knowledge base that mainly relates to the understanding of natural languages, the system knowledge base related to the system itself and the applied knowledge base containing specialized knowledge for various applications.

(5) Basic application system

The following types of basic application systems can be cited:

- Machine translation system
- Question-answering system
- Applied speech understanding system
- Applied picture and image understanding system
- Applied problem solving system

(6) Application systems

The following systems can be thought of as examples of knowledge information processing application systems:

- Intelligent CAE/CAD system(Note)
- Intelligent CAI system
- Intelligent OA system
- Intelligent Robot

3.3 Configuration image of the hardware system

The Fifth Generation Computer Systems should consist of all levels, from small to large scale machines, in order to process diversified applications. The machines of all

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(Note)

CAE:	Computer Aided Engineering
CAD:	Computer Aided Design
CAI:	Computer Assisted Instruction
OA:	Office Automation

performance levels must have common languages as well as the following three basic functions. The remarks in parentheses indicate the correspondence with conventional computer systems.

1) Problem -solving and inference machine (Central processing unit)
2) Knowledge base machine (Main memory with virtual memory facilities and file system)
3) Intelligent interface machine (Input/output channels and Input/output devices)

There will be machines of several performance levels in each of these small to large computer systems, to permit system configurations which emphasize any of the several functions by application or purpose of use.

Figure 3 shows a configuration image of the Fifth Generation Computer Systems. The machines are to be structured according to function on various new architectures, including a data flow machine, which are based on VLSI architecture and each system is to be a combinatin of machines suitable for various individual applications or needs.

Furthermore, from a macro configuration point of view, having the system shown in the figure–3 as one of the principal elements, a multiple system form of usage where this would be connected to a local or global network and the whole network then be utilized as a large-scale distributed processing system, is also being envisions.

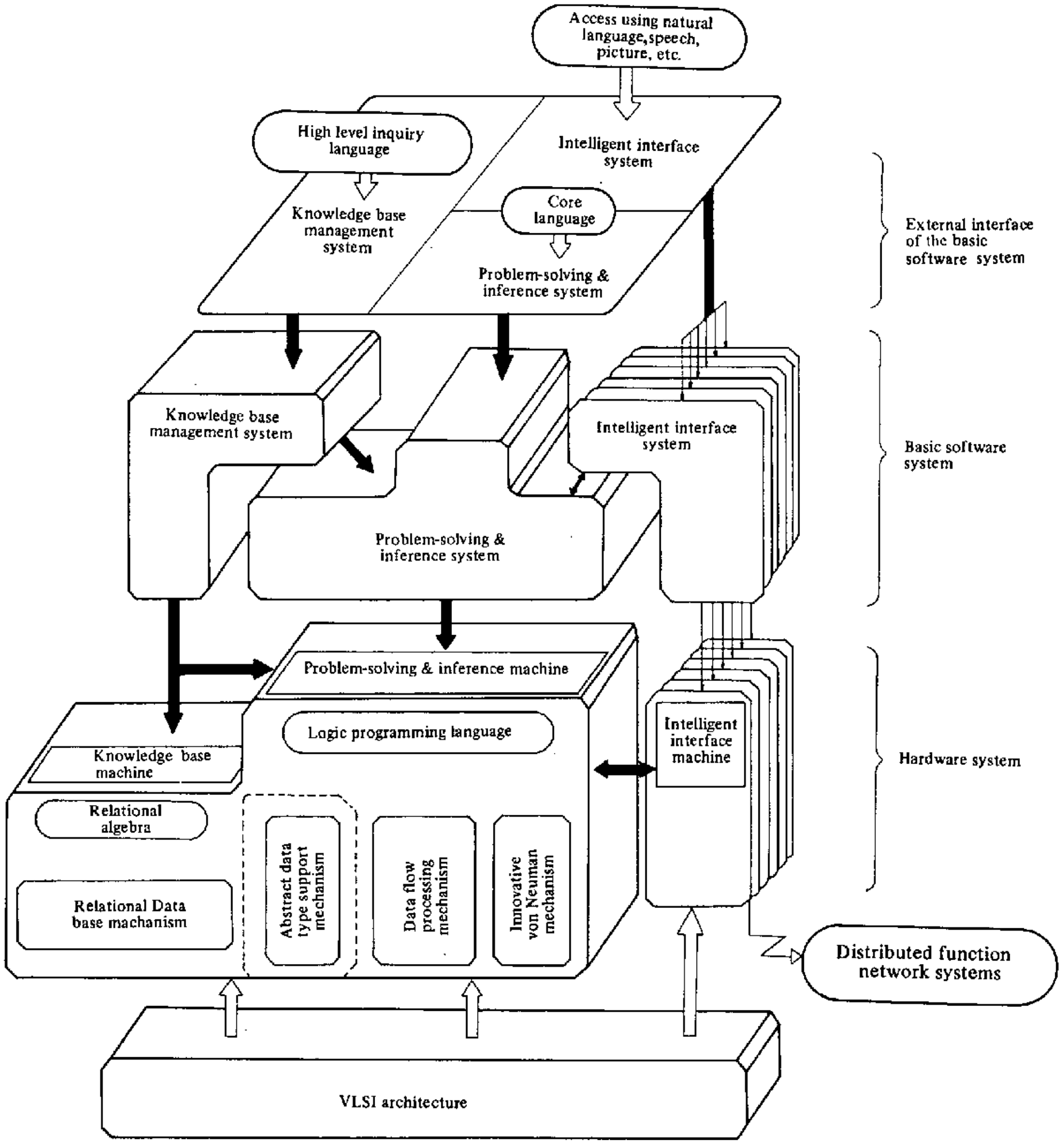

Fig. 3 Basic configuration image of the fifth generation computer systems

Technical Program of the International Conference on Fifth Gereration Computer Systems

19 October (Monday)

Opening Ceremony Chairman *T. Tejima*
13:30–14:00 Declaration of Opening
T. Tejima, Executive Director, JIPDEC
Welcome Address
Y. Shimada, President, JIPDEC
Address
R. Tanaka, Minister, International Trade and Industry

Keynote Speech
14:00–14:50 Challenge for Knowledge Information Processing Systems
T. Moto-oka, University of Tokyo

Overview Report Chairman *T. Moto-oka*
15:05–17:30 What is Required of the Fifth Generation Computer - Social Needs and its Impact
H. Karatsu, Technology Consultant
Aiming for Knowledge Information Processing Systems
K. Fuchi, Electrotechnical Laboratory (ETL)
Fifth Generation Computer Architecture
H. Aiso, Keio University

20 October (Tuesday)

Knowledge Information Processing Research Plan Chairman *K. Fuchi*
9:30–10:15 Problem Solving and Inference Mechanisms
K. Furukawa, ETL
10:15–11:00 Knowledge Base Mechanisms
M. Suwa, ETL
11:15–12:00 Intelligent Man-Machine Interface
Ho. Tanaka, ETL

Knowledge Information Processing Research Plan (Cont.) Chairman *Ho. Tanaka*
13:30–14:15 Logic Programming and a Dedicated High-performance Personal Computer
T. Yokoi, ETL

Invited Lecture
14:15–15:15 Innovation in Symbol Manipulation in the Fifth Generation Computer Systems
E. A. Feigenbaum, Stanford University (USA)

Invited Lectures Charman *K. Fuchi*
15:30–16:30 Logic Program Synthesis
W. Bibel, Die Technische Universität München (FRG)
16:30–17:30 The Scope of Symbolic Computation
G. Kahn, INRIA (France)

21 October (Wednesday)

Architecture Research Plan Chairman *H. Aiso*

9:30–10:15 New Architectures for Inference Mechanisms
S. Uchida, ETL

10:15–11:00 New Architecture for Knowledge Base Mecahnisms
M. Amamiya, Musashino Electrical Communication Lab. NTT

11:15–12:00 VLSI and System Architecture - The Development of System 5G
K. Sakamura, University of Tokyo

Lunch

Architecture Research Plan (Cont.) Chairman *H. Aiso*

13:30–14:15 The Preliminary Research on Data Flow Machine and Data Base Machine as the Basic Architecture of Fifth Generation Computer Systems
Hi. Tanaka, University of Tokyo

Invited Lecture

14:15–15:15 A Congnitive Architecture for Computer Vision
B. H. McCormick, University of Illinois (USA)

Panel Discussion I

15:30–17:30 Knowledge Information Processing Chairamn *K. Fuchi*

Panelists:
E. A. Feigenbaum, Stanford University (USA)
W. Bibel, Die Technische Universität München (FRG)
G. Kahn, INRIA (France)
M. Nagao, Kyoto University (Japan)
S. Osuga, University of Tokyo (Japan)
K. Furukawa, ETL (Japan)

22 October (Thursday)

Invited Lectures Chairman *Hi. Tanaka*

9:30–10:30 Fifth Generation Computer Architecture Analysis
P. C. Treleaven, University of Newcastle Upon Tyne (UK)

10:45–11:45 Algorithms, Architecture, and Technology
J. Allen, MIT (USA)

Panel Discussion II

13:15–15:15 Fifth Generation Computer Architecture Chairman *H. Aiso*

Panelists:
B. H. McCormick, University of Illinois (USA)
P. C. Treleaven, University of Newcastle Upon Tyne (UK)
J. Allen, MIT (USA)
E. Goto, University of Tokyo (Japan)
S. Uchida, ETL (Japan)
T. Uraki, Hitachi (Japan)

Panel Discussion III

15:30–17:30 Impact of Fifth Generation Computer Systems Chairman *T. Moto-oka*

Panelists:
J–L Lions, INRIA (France)
N. Szyperski, G. M. D. (FRG)
C. Read, Inter-Bank Research Organization (UK)
P. J. Riganati, National Bureau of Standards (USA)
S. Okamatsu, MITI (Japan)
I. Toda, Yokosuka Electrical Communication Lab., NTT (Japan)

International Conference on Fifth Generation Computer Systems, Panel Discussion III

Impact of Fifth Generation Computer Systems

OCT. 22, 1981

Chairman: T. Moto-oka, University of Tokyo (Japan)

Panelists: J–L Lions, INRIA (France)
N. Szyperski, G. M. D. (FRG)
C. Read, Inter-Bank Research Organization (UK)
P. J. Riganati, NBS (USA)
S. Okamatsu, MITI (Japan)
I. Toda, Yokosuka Electrical Communication Lab. NTT (Japan)

Moto-oka: Now let us open the last session. To begin with, I would like to introduce the panelists. From right to left, Mr. C. Read. Mr. Read is director of IBRO, a research organization jointly owned by the major British banks. His background is social science and economics and he has been doing research on the use of information technology in management sciences and other applications. He is also involved with numerous government committees and is an adviser on information technology to Prime Minister Thatcher.

Next to Mr. Read is Professor Lions from France. Professor Lions is a member of the Academy of Science in Paris, a professor at the college de France, president of INRIA, and secretary-general of the International Mathematical Union. Next to him is Dr. Riganati from the U.S. Dr. Riganati is division chief of the Institute of Computer Science and Technology (ICST) of the U.S. National Bureau of Standards.

ICST is the division responsible for research and development of government-related computers. Dr. Riganati has had a varied career. He worked for Rockwell International, GE and IBM and teaches college graduate courses. Next is Mr. Szypersky from Germany. Mr. Szypersky is now chairman of GMD, the society of mathematics and data processing. An expert in economics and business administration, he has been doing research on computer applications in these fields. Mr. Szypersky is also professor of planning theory at Cologne University. Next to him is Dr. Toda from Japan. Dr. Toda is now data communication research division manager at the Yokosuka Electrical Communications Laboratory of the Nippon Telegraph & Telephone Public Corporation (NTT). He has been involved in computer-related work ever since graduating from college. At present, he is supervising the development of a network architecture called DCNA which is being conducted under the leadership of NTT. Last is Mr. Okamatsu. Mr. Okamatsu is director of the electronics policy department at the Machinery and Information Industries Bureau of the Ministry of International Trade and Industry. The Ministry is, as it were, sponsor of this project. The subject we are going to discuss is "Impacts of the Fifth Generation Computer System." Since this is the last session, I hope the panelists will discuss all aspects of this project as well as the immediate subject. Now, Mr. Read would you please lead off?

Read: Thank you, Mr Chairman. I should perhaps first make clear that these are my personal views and not my colleagues' in the UK, nor Mrs Thatcher's. I am speaking as a user of this technology and, unlike most of you, I am not an engineer.

Every technology development can be used to produce good and it can equally be used to produce evil. That is exactly what has happened in the past. Gunpowder can be used to make pretty patterns in the sky, and it can be used to kill people. Motor cars provide many benefits, but they pollute and jam our cities making them most unpleasant places for people to live in. And they consume scarce energy. If we had foreseen the undesirable effects of motor cars, do you think we would have followed the policies which we did in fact adopt?

Information technology is no exception. In fact, it is a more extreme case. So far, new technologies have largely affected only our physical environment. Now we have the ability to affect our mental environment, and to make radical changes in the structure of society and the quality of individual lives. Even with information technology at its present state of development, there are already many problems. I would like to summarize some which I think most important.

1 Extensive bureaucratic use of information about people, by government and by companies, threatens not just the privacy of individual citizens, but their liberty. New laws have been enacted to deal with this in many countries, but I would like to remind you that those laws do not concern themselves very much with the technology of how it is done. Their purpose is to control *what* is done, *who* should be allowed to do it, and for *what purposes*. And they are about the right of individual citizens to know who is doing what with the information about them.

2 Information technology makes possible very efficient control and surveillance. Improving the efficiency of police and other investigators, including those from financial institutions can reach a level of efficiency that is very dangerous. I am in favour of a certain amount of deliberately engineered bureaucratic *in* efficiency. It is the best protection of my liberty that I know about.

3 Information technology is changing the role of traditional institutions, and destroying the value of specialist know-how, by providing the know-how to everyone. It is destroying the need for many forms of intermediation, by providing direct contact between original buyer and seller, for example.

4 The labour required for many of the

functions to be performed, given information technology, is radically changed both in quantity and in structure. In most parts of the world, the unemployment threat is very real. And no-one knows of a satisfactory solution. When labour migrated from agriculture as a result of technical invention, it was able to go to manufacture. When it migrates from manufacturing with improved efficiency there, it goes into the service industries. Now, we are beginning to apply technology to the service industries, and if labour is taken out from there, there is nowhere for it to go. What will be the result? Will we manage that successfully? Will society perhaps become polarised, so that there are highly trained experts working very hard, while less able people have nothing to do? Or shall we arrange things differently so that we all work a four or three day week? Do we have the right physical facilities for working a four and three day week? I wonder how popular a four day week would be in Japan?

5 Information technology has made many changes in power structures. For example, automation in banking has given industrial power to labour unions so now we have bank strikes. This did not happen before because non-automated systems were not so easily disrupted by the withdrawal of labour.

The big lessons from the past, it seems to me, are these: Allowing ourselves to be led by technology and by the unthinking enthusiasm of its engineers is very unwise. We have to choose the kind of society we want, and to give guidance to the engineers on what uses we do and do not want to make of the new technology. I agree strongly with Professor Feigenbaum: that it is needs we should look to, not opportunities. Many opportunities are evil.

Making those choices for society, in my opinion, cannot be left to economists and market forces. Least cost solutions, or maximum productivity are not desirable in themselves. Indeed they are often very harmful. In assessing the quality of life, there are many other matters to be taken into account. These matters have no price tag. And therefore they do not exist in the minds of economists and accountants who, in my view, have done more damage to society in the past few decades than any other professions.

High productivity and least cost criteria have led to many undesirable effects already, even without better technology. For example, the combination of self-service shopping and banking plus the motor car as a means of getting to the self-service location, leads to a point where you can do all that you need to do without speaking to a single human being. This process is assisted by information distribution via television and radio where again there is no need to speak to a human being. Social interaction is being eliminated. The result is that people are isolated and lonely. And this is a most undesirable condition for most people. But do they have the choice to pay for a higher cost solution that would be socially more desirable? The answer to that question in most cases is "No".

I find it sad that these unwise, undesirable and narrow economic views are included in the social objectives for the fifth generation computer system. I would like to suggest that the opposite view could be taken and should be taken. If the fifth generation does all that is hoped for, it will make it possible for us to make proper use of non-numeric information. Many speeches have explained how this is hoped to be achieved. If we can do that, then we can use qualitative value judgments in our decision making, and we can at last counteract the false high value currently placed on numeric data, and the false truths contained in many economic doctrines. If that could be done, that alone would justify the fifth generation computer. I believe that would be the intellectual and technical development that could have the greatest benefit to society, by improving the quality of decision making, particularly by our governments.

The third lesson I would draw from the past is this-and other speeches have referred to it. Often the greatest benefit from the application of information technology to human and organisation problems has come from the discipline which it imposes. We have had to clean and organise our data, our procedures and our objectives. In many cases, 90% of the benefit could have been achieved without actually buying the computer or writing a single line of code. This will also apply in the same way to non-numeric data and to the associated intellectual concepts. Indeed, it could be even more beneficial. We must convince the world that the fifth generation machine can be a reality before it is fully engineered and we must get everyone to work upon disciplining their non-numeric knowledge to achieve these splendid benefits which can be realised no matter what form the fifth generation machine finally takes.

The fifth generation system, if realised, will indeed give us greater potential for good and, equally, greater potential for evil than we have ever had before, It is therefore essential, in my opinion, to begin work now, and in parallel with the engineering research, on the social engineering which must accompany it. Social objectives must be set in clear, specific and well-defined areas, not in general 'motherhood' statements that no-one can disagree with. Priorities must be determined among social needs. The wide opportunities must be reviewed and a choice must be made of which areas to work on in the light of what we want to do to society. New laws and regulations to control and to ensure the beneficial use of the technology, and the beneficial use of our telecommunication systems need to be established quickly.

As many people have already pointed out, work on organising the information to be used in expert systems must be started at once, or we may find we have the technical tools and no organised information to work on. Equally, work must be started now on how to change the education of management, of doctors, of lawyers and of all other professionals, including government officials, so that they might learn how best to use the new tools and the new approaches to better quality decision making which they will facilitate.

I would like to suggest another concept for study. I wish to introduce the term '*in*-expert systems'. Half of the population of the world is below average ability and, in many countries, the average ability, unlike Japan, is not very great. Information technology can be used to devise many simple jobs each within the limited capability of such people and structured within a system which can bring together each of their small contributions to make an effective joint effort in a complex task and creating at the same time a social environment of working together. Since hardware is becoming cheap and powerful, it could be extensively used to make jobs people-shaped. Isn't that a better idea than causing unemployment? And isn't that more likely to fit the needs of the third world countries? I have done this once in the Middle East, where available clerical labour was of poor quality. It worked well although the hardware and software were very expensive then. With present technology, and particularly with the fifth generation, I believe the future for *in-expert systems* could be very bright. You can see a parallel to this in other technologies. For example more good has been done to medical health in this world by the simple engineering of water supplies and sewage than by all of the high technology used in surgical operations.

Isn't this the sort of thing that senior politicians might like to hear this week at the Cancun conference? I am pleading for the more responsible and more appropriate use of the technology.

I would conclude by saying this. If only the engineering work on the fifth generation system goes ahead, I personally have grave reservations about the desirability of that plan. But if, in addition to this engineering work parallel studies are undertaken of the uses to which the new technology could and should be put, I could support the whole project most enthusiastically.

Thank you gentlemen.

Lions: I speak here on an individual basis, and I am not expressing any official views. I am sure to express the views of all French participants in thanking our Japanese hosts for their splendid organization of this meeting. Now I am here in a rather strange situation, part of my work has been on numerical analysis and here I hear of non-numerical knowledge and I am secretary-general of the International Mathematical Union and I hear many implicit criticisms on the possible danger of using too much mathematics. But nevertheless, I must say that I entirely agree with most of the ideas and goals of the fifth generation project. Concerning the topics of this afternoon session, i.e. the impact of the fifth generation project, I would like to confine myself to six simple remarks.

First a remark on the scientific impact. This is maybe something which has not been emphasized enough, in my opinion. Assuming that this project is successful, and certainly at least some parts will be successful and extremely interesting, it seems to me that this is going to have a very important impact, maybe a fundemantal one, on all sciences: chemistry, biology, and to speak on things which I know better, very difficult problems like turbulence, combustion. This project can have a very strong impact on fundamental basic research.

Second remark: how to find experts. This is not a criticism, but a remark which has already been made: how are you going to find the experts? I would like to remark that when you start having such ambitious and appealing projects, certainly this is going to motivate young people to work along these lines and certainly this will be a part of the solution of finding experts. Young people are to be motivated by a huge project, it seems to me, a very appealing one, very ambitious. I think this is very interesting for young people. (and for older people as well!).

Remark three. Training and education. I am wondering if this is something which has been studied in Japan, and I would be very interested to hear some comments on that: it is obvious that such an important project, even if only partly successful, well have an extremely important impact on high schools and the teaching of children. After all, children who are ten now will be twenty at the end of this project, so maybe one should start thinking about them now. And I would be curious to know if there has already been something done in this country along these lines and what conclusions or preliminary conclusions you have.

Remark four. (The only part where I am criticizing the approach.) It seems to me that the users have not been consulted enough. But maybe this impression is due to the fact that I am very far from grasping all parts of this project and maybe consultations have taken place.

Fifth remark, on the international aspects (some of the previous remarks are also valid on an international basis. For example, the first remark of the scientific impact is certainly not national but completely international). It is clear that the impact of this project will be international, it will have an international visibility, so it will motivate young people and maybe new projects will start, and therefore it can certainly motivate cooperation on some of the basic aspects of the project.

Sixth and last remark. This is more a question: if cooperation is achieved between a given country and Japan, at this point it is not clear to me whether the whole results of the Japanese programs will be available to this country. And also what will be the situation when we come down to maybe pre-industrial developments? This is a question which we will have to consider at one stage or the other. Thank you Mr. Chairman.

Moto-oka: Dr. Riganati, please.

Riganati: Thank you Mr. Chairman. I would also like to join my colleagues in thanking the organizers of this conference for this rare opportunity to comment at the planning stage of a major new project. I hope that the comments by foreign workers will be taken constructively and will lay a good foundation for similar cooperation in the future. I would also like to say that since, during this conference, it has been announced that Dr. Fukui has won the Nobel prize in Chemistry, I'm sure that I speak for all of the foreign participants in congratulating Dr. Fukui and Japan for this outstanding work which is recognized by this prize.

My observations and comments are divided into three parts. First, since FGCS appears to me to be a rather grand theme or movement for the "informationalization" of society, I simply can't resist making light or amateur philosophical observations. Second, I have some comments on the social impact of FGCS including some brief comparisons between the United States and Japan. Third, I'll discuss some specific suggestions for the future conduct of FGCS.

The "philosophical" observations

The first point relates to a set of theorems with which I'm sure many of you are familiar. They originated in the early 1930's with the work of Kurt Godel and Alfred Tarski. Briefly stated, in any axiomatic system at least as complicated as elementary arithmetic: 1) there can always be statements which can neither be proved nor disproved, which are neither true nor false, or which may in fact be both; 2) true assertions can be expressed which cannot be deduced from the axioms; and 3) the axioms cannot be shown in advance to be without internal contradictions. For example, an infinite recursion, which has been discussed in many contexts, is illustrated by the statement: "I am a liar". This statement is neither true nor false. Perhaps it is both. Perhaps our reasoning and logic processes are simply incapable of reasolving this statement. Jacob Bronowski in a very readable article in the *American Scientist* (Spring 1966) summarized this concept in an article called "The Logic of the Mind."* He says: "In short a logical system which has any richness can never be complete yet cannot be guaranteed to be consistent". I think the design of FGCS should bear in mind these concepts, especially as they are developed by Dr. Bronowski in this article.

The second point relates to analogy and symmetry. These are two very powerful procedures for human reasoning. I quite agree with Professor McCormick that the biological world provides keen insight for us in exploring possible solutions to very complex knowledge-based problems. While man does not fiy by building machines that flap wings, we ignore these biological solutions at our own peril. The fact that the number of elements in large computer networks is today on the order of magnitude of the number of elements of the human brain, is a very significant statement. If we look to the notion of symmetry in the biological world, we find the right brain-left brain duality. In fact, there are those who conjecture that the inspirational, or the inference mechanism has something to do with the synchronization between the left brain and the right brain. This is the "Ah hah!" "Now I understand" reflex. Perhaps we should look to this notion for architectual symmetry and perhaps take into account the symmetries which nature has found so useful. As a very light aside, a science fiction novel, by Robert Heinlein, called the *Moon is a Harsh Mistress* discusses the concept of a computer which occupies most of the surface, or the undersurface, of the moon, suddenly waking up and becoming aware of itself.

I would like to pose, perhaps as a rhetorical question for Professor McCormick or others, the following notion: if we build sensors for computers which are similar to biological sensors, perhaps we're talking about, in the seventh generation or beyond, the concept of *real* computer vision, where a computer, using biological sensors, can have vision very similar to what we find in the biological world!!

The third brief "philosophical" observation relates to the fact that, on this earth of ours, there are approximately 3,500 natural languages. There are those who think that we in the computer sciences are very intent on creating at least that number of artificial

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*The Phi Beta Kappa-Sigma Xi Lecture, delivered to the American Association for the Advancement of Science at Berkeley, California, December 29, 1965. Reprinted in the book *The Identity of Man* by Jacob Bronowski.

languages! On this concept, written some 400 years ago, the essays of Michel de Montaigne relate some very interesting and apparently timeless truths.

The fourth and last philosophical point is related to the nature of ambiguity. Ambiguity is a fundamental concept which is important to the entire theme of Fifth Generation Computer Systems. Information, of course, is the property of an element in set, that is, in context. The continuity between prose, poetry, and music and the richness that we find in that progression owes, in part, its significance to increasing ambiquity. Leonard Bernstein in a sixpart lecture on "Whither Music", some five or six years ago, discussed this concept from the point of view of music and meaning. Today we can create computers which can synthesize music by rule. Tomorrow, if the Fifth Generation Computer System realizes its lofty goals, perhaps we will have computers which can compose creative music whose structure of ambiguity is exquisitely tuned in ways we have never heard before. A classic book which discusses these notions in the literary context is William Empson's *Seven Types of Ambiguity*.

Comments on Social Impact of FGCS

The influence of social values on the impact of FGCS cannot be underestimated. The concept of the fifth generation and beyond systems, is not restricted by national boundaries. This conference is an attempt to focus the effort in Japan. In the United States, the desire for FGCS-like systems is no less intense but the methods are very different. The U.S. House of Representatives, Science and Technology Committee, for example, recently asked for a twenty year look ahead from our Institute concerning the directions in which the information society is likely to procede. Many such forecasts exist. They will go to very different uses in the United States than in Japan because there are some fundamental differences in our respective society's values. I would like to quote Dr. Lewis Branscomb, who was formerly Director of the National Bureau of Standards and is currently vice-president and chief scientist of IBM, in a lecture he gave at NBS, on its eightieth anniversary this year: "The number of lawyers in the city of Boston is approximately equal to the number of lawyers in the entire country of Japan." This illustrates one fundamental difference in the nature of the focus of the two societies. The effects of such social values on the impact of fifth generation systems will be very different.

The second point relates to the influence of population distribution. Historically, civilization has developed along transportation routes—in early Italy along the Po river valley; in California, along freeways; in Japan, from what I can observe in Tokyo, there is no discernable pattern to me as a foreigner, but I suspect outside the city the transporation routes play a key role in where people live. If aspects of FGCS related to personal computers and networking, especially large distributed networking, are successful, the concept of cottage industries may actually see a significant rebirth worldwide. The change in lifestyle which will result is something that those of us sitting in this room today, will find as difficult to imagine as the city factory was to those who worked in isolated farm houses before the industrial revolution.

The privacy issue in the United States has been for some time extremely important. We have legislation and we have specific enforcement procedures. I understand that it is currently a significant issue in France and in much of Europe and is becoming an issue in Japan. Information access is power. The realization of FGCS will certainly transform society in unexpected ways. The issues of privacy, security, transborder data flows information exchange between countries, are key issues that FGCS will face head on if it comes close to being successful.

My final point on social impacts deals with population characterization. In the United States in the 1970's, there was a popular book. The title was *Working* by an author named Studs Terkel. What he did was interview many people in a wide range of professions, in some detail. His book tells their story the way they tell it about what they do. For many of us living in the United States, that book contains much new information, even though we thought we knew what a steelworker did or what a cab driver did, and what he thought of himself. It turns out for me, I had no idea. I don't know if the comparable literature exists in Japan, and I simply pose a question. Do the planners of this FGCS project have the bottom up knowledge of the society which they are going to transform by this "informationalization"?

Suggestions for proceeding with the development of FGCS

Now we come to some specific suggestions for FGCS. The first one relates to the open systems interconnection reference model. I believe I will take just a very quick aside to explain this model. The International Standards Organization (ISO) has been working for some two years or so to develop a model for open systems interconnection. This is a functional hierarchy consisting of seven layers beginning with the physical layer. For those of you familar, on the right, in the figure, are some of the existing protocols. Above the physical layer are the link layer, and the network, transport, session, presentation and application layers. An open system is one which can communicate with any other open system. Historically, the structure has been to think of the basic communications protocol and to build on top of them such things as a file transfer protocol, a virtual terminal protocol, graphics, or whatever special applications you have in mind. The notion of 'open system' leads to separating out functionally what is common to these, and to creating functional layers as high up in the application as you can possibly go. The transport layer, session layer, and others that are shown here.

This concept has been developed from the telecommunications point of view. Proposals exist currently to extend this model which takes into account viewpoints from storage and retrieval, process transaction, resource management, information representation and systems management. My suggestion here—and I am /vare of Professor Motooka's leading role in CCITT, but I would like to emphasize it as a very important point—is that FGCS staff should interact closely with this international effort and should think of it as an integral part of the FGCS project.

The second point relates to the man-machine interface and specifically to image and speech I/O. Everyone who works in the field of input/output related to image processing or speech processing must create a data base. However, if many researchers worldwide are to work and compare algorithms and procedures carefully, what is needed is a large *well characterized*, widely available data base. Many data bases exist but few satisfy all the conditions. In Japan the PIPS project created data bases which had some of these characteristics. Time varying imagery, multiple languages, the Japanese language, and many other examples, in my opinion, have not been adequately covered. I suggest the FGCS staff should work for international agreement for formated data bases which would be used for man-machine I/O algorithms, so that the maximum number of researchers can bring their efforts to bear on these problems.

This next point is one which has been discussed many different ways. It was suggested to me early in this conference by my colleague Dr. Russell Kirsch. The question is: is this FGCS project, as currently conceived, too broad? Or too narrow? We've heard many comments that it is too broad. But that judgement cannot be made independent of resources. Does the project intend to pursue basic research in neural science, physiology, cognitive sciences, linguistics, etc.? And how will the resources by focused? There is a critical need for FGCS planners to carefully consider the tradeoffs between engineering judgement and scientific curiousity. I personally think the notion of motivating society to pursue these basic areas is an excellent one. We learn in science as much or more from failures as we do from successes. Certainly FGCS will have significant successes if it is well designed. It will also have significant failures from which much also will be learned. If this dialogue that we have begun this week is to continue, I suggest 1) that a formal list of what FGCS is *not*, from the point of view of the planners, might be compiled; 2) that the detailed rational for the choices (on which we have had excellent discussion in the question and answer sessions) be formalized and distributed to attendees for careful written critique; and 3) that the entire set be published for worldwide distribution. This would continue the theme of openness which was begun here.

The last suggestion is in agreement with Dr. Sakamura who, in his clear and insightful presentation, stressed the need to not separate hardware and software at the early stages, and to develop uniform and standardized interfaces. I would like to state that, from my experience, those statements are extremely true. Thank you very much Mr. Chairman.

Moto-oka: Thank you. Your turn, Mr. Szyperski.

Szyperski: I don't think I have to say that I'm just speaking on my own and in my own right. Anyhow I'm sitting on the other side with my Japanese friends so its hard to say on whose behalf I'm speaking.

Now I'm still puzzling a little bit over what the role could be we are supposed to play right now. Being a viewer requires more detailed information as to your proceedings as well as your goals. On the other hand I think it is worthwhile to take up your challenge and try to respond to some of your FGCS ideas. I will do that in light of my personal impressions and the changing world I can see around me.

Let me make first some introductory remarks. I think the name fifth generation computer systems is a very good marketing idea, because it is not too far away from what was called the third generation, and it is open enough for anything which might be in between and it should be clear that there is nothing like the fifth generation going to appear before 1990. And that of course is a very good approach. So what I learned in the meantime is that the project really is a mixture of a program, a project, and what I would like to call a philosophy of technological changes within that special field. I am really impressed by the way you have presented it. I'm not fully convinced by all of the design assumptions that have been outlined. And I think that is because it is not just a question of running a project.

On the other hand, I can't believe that the Japanese information technology industry will wait ten years to bring out challenging products and systems. I believe that the ambitious goals and objectives evident in your project, show what is already in the industrial development stage. And so that's very interesting too. That's a very good marketing approach, and in any case it gives us quite an idea of what's going on in the industrial research and development work.

So I would say that FGCS is not only a big venture, but in other respects, might be something like big business, too. So I think talking about international cooperation, about relations in the first or second stage, or even the third stage, asks really for special rules as to, how to handle such cooperation. There are many examples around us, where international cooperation in the research world was really accomplished. We can look at space research, we can look into other areas, and we can see that there are not only international relations between universities, and research organizations, but of course between international industries and companies, too. Let me come to some maybe more basic observations and responses.

As I understood your program, there are actually four different, very interesting areas you would like to strive for. First, there is VLSI CAD. Then, second, the area of computer architecture related to the special conditions and requirements and programming rules. Third, the idea of knowledge-base information, and fourth, the multi-media intelligence interfaces. Now could we go over these four subsets and ask what is the impact on the academic world, on the professional world, industry, economy, the social world, politics, and of course on the individual. I won't be able to do that in ten minutes, but I would like to pick out some aspects. Looking at the academic world, I think that your project has a direct influence, of course, on . . . admissions and on computer science and what surrounds it. But there are also many indirect aspects of what was mentioned right here on such fields as cognition, linguistics, and psychology. And the question really is, can we see academic development and the development in science in isolation or in waves. And in some particular way stimulated and promoted by one or the other disciplines. Physics promoted for quite a while many aspects of many other sciences. And I can see that computer science is now doing projects and programs similar to that.

On the other hand, looking into the professional areas, I think we have to ask what is a cognitive style and what are the attitudes of professionals in different professions? Are they open to help? Are they ready to get some help? Would they like to have some help?

I think it was brought up at the very outset of the conference that raising the quality of the less qualified and less developed professionals is a necessity in a developing society. And I would say that, without trained and qualified professionals, we won't solve the problems of the poor in the world either. So the North/South dialogue is not just a dialogue with peoples trying to become equal again in the sense that we try to meet at the poorest level. I think we have a duty to try to use our capacity in order to do that. But let's see at what professional level special schemes for adapting technologies and adapting techniques are necessary in order to meet the given conditions in various cultures. And that I think is the main task, and I feel that the tools that are being developed or planned here are flexible enough to meet these conditions.

On the other hand, of course, instruments are only as good as the people using them, so we have to train ourselves in order to adapt to the real conditions.

Looking into the industries, you will find that developments like your fifth generation computer systems are really asking for changes in the way products are sold. I think that's a basic idea of systems selling, which is now quite a problem in many other areas of our industries, and will be more and more of a problem in the computer industry too. That means, not only hardware and software training, but knowledge basis and progress diffusion. Different fields of engineering and the supply of hard and software to go with it must be realized, like you find it in many industries today. Now if this is true, you will find in our economies of course more differentiation within the information, technological and technical markets.

I want to try to put my thinking on the social world, and I guess you can say that there will be many questions and we have to pay more attention to the social aspects of changing technologies. Especially those aspects corresponding to our current policies. I think the conflict between innovation on one side and contribution to global problems on the other is really a striking problem. It is very hard for politicians to find the right way for getting more innovation within their own country and trying to have a better support and a better contribution for what is really asked for.

On the other hand, you won't be able to do that, without same type of strategic analysis as far as your own national situation is concerned. So asking what the basic positions are, you have to look at the resources and you have to ask what are the natural resources . . . what are the human resources, what are the financial resources, and in general, what are the information resources we can make use of within our nations? And asking that question of my own country West Germany, I find the answer is not too different from your situation. Our main resources are not natural resources either, but mostly information resources.

So in order to go through impact analysis not as I did it, but in a much broader sense, we have to reason why we don't have nunerous choices to pursue in one way or the other. I am not talking about such questions as what is the right architecture, what is the best language? I don't think that is the main problem. The main problem of the project is, as far as I can see it, that there is a national need to cooperate and to bring together a variety of manpowers and resources, and there are different ways to do it. Of course, the centralized plan way might work, and the market way might work, as it works in our country. So the wise use of marketing powers and the risk of more planning might help overcome problems we have to face, and if I take the European and German position, I would say we have to accept your new challenge. I would say that our position is not too bad. Some will say it is so bad that we should not try to work in this field anymore, but I don't believe that. Among the groups working around the world right now no single one will finally succeed on its own. Cooperation at the international level is a matter of course. And that is not too bad a position. Rather I would say it is convenient to live with.

Now regarding the expectations associated with the development, I won't try to repeat what you brought up in the very beginning in the first or the second papers that were presented here. Let me finally say, I would like to congratulate you for your openness, and the wisdom for talking about these problems so openly. It is helpful for you and I think it is helpful for all of us attending the conference. Thank you so much.
much.

Moto-oka: Thank you. I would like Dr. Toda to speak next.

Toda: Thank you. It is a privilege for me to be present at this session.

The fifth generation computer system project is a very important and ambitious one. I feel it is most important that we spare no efforts in making it a success and thus add a new page to computer history. I would like to take this opportunity to comment on the project from two standpoints. One concerns our philosophy or policy on FGCS and the other, the management of FGCS.

First, I would like to look back on the evolution of computers. This slide shows the evolution of computers as viewed from a functional standpoint. As you know, the first computers did nothing but compute. Subsequently EDVAC and EDSAC appeared, bringing with them the concepts of memory and programs. Some time later computers were equipped with a communications capability to meet online processing and TSS requirements.

Computers these days have come to have some perceptive capability thanks to character recognition, voice recognition and sensor technologies.

The question is what kind of capability should the computer be given next. Many keywords are being talked about, such as understanding, inference, learning, judgement, and imagination. As I see it, a characteristic of the fifth generation computer project is that it points out rather explicitly that inference is the next capability which must be built into the computer.

There are two sides to computer structure: architecture and hardware technology, that is, component and packaging technology. Over the years computer components have evolved from vacuum tubes to transistors, ICs, LSIs and VLSIs. As you know, we are now on the threshold of the VLSI age. Architecture is determined by the trade-off between computer functions and hardware technology and has a very close bearing on the evolution of the two.

I feel there is a major difference between the evolution of computer functions and that of component technology as shown here. Computer functions have evolved by accumulation, whereas components evolved by successive generations, replacing their predecessors.

New computer functions have been introduced one after another, but this does not mean that the old functions disappeared. There has been an evolving coexistence of old and new functions. By contrast, component technology has evolved by replacement: for example, the advent of transistors made vacuum tubes almost completely obsolete.

The fifth generation computer system project as I understand it will center around research on inference mechanisms. While the importance of that research is quite obvious, I think it is also of vital importance to do research on how to achieve such capabilities as a whole using VLSIs working on the basis that they should naturally be components in the fifth generation computer. My second comment concerns the question of whether the fifth generation computer system should be general-purpose or application-specific. Current computer applications can be broadly divided into information processing, communications, and control. Control applications in particular have been quickly spreading into all industrial fields since the development of microcomputers. There are numerous possible impacts of the fifth generation computer system, but I would like to concentrate on the introduction of inference capability. It is a foregone conclusion that inference capability will be applied to the information processing field, but as has been discussed from the beginning of this conference, inference capability is also expected to greatly help various professional people to use computer systems as extensions of their expertise. Toward this end, I think it is important for experts in different fields to combine their efforts to build numerous expert systems. In the area of communication, inference capability will play a role somewhat similar to the "inexpert system" mentioned by Mr. Read a little while ago. I think it will be effective in improving man-machine interfaces.

Inference capability will also be related to a very wide range of industrial fields. I have the impression that the biggest objective of the fifth generation computer project may be to achieve a general-purpose inference mechanism, suitable for such a wide range of applications. From my experience, I think it is extremely difficult to try to design a general-purpose machine from the outset in an area where there is not an adequate accumulation of experience. On the other hand, I do not think it is a good approach to build different machines independent of each other, Given that it is necessary to proceed bearing in mind the eventual need to develop a universal machine, it would seem practical to devote efforts to developing application-specific systems for the immediate future.

From this process, the framework for a general purpose machine will gradually emerge. I think this may be the right approach to follow.

Now I would like to touch on the management of the project. From the point of view of project management, the fifth generation computer project is of tremendous size in terms of cost, personnel, and range of research subjects. Second, it has an awful lot of basic-research elements. Third, it is an international project as can be seen from the variety of nationalities represented here. These are the major characteristics of the project from the standpoint of project management.

In this light, it would seem necessary to consider making preparations for technical transfer in advance. As I said a little while ago, the computer is a tool for man to use, and adding inference capability should expand the range of its applications quickly.

To commercialize the results of basic research will require more than ten times as much effort as the basic research, though it will be functionally different. Accordingly, for rapid feed back to society of the results of research into the fifth generation computer project, it will be necessary to ensure that the widest possible range of interested people have easy access to the research results.

The next point I would like to make is that a flexible research setup must be constructed. Since the project will continue for as long as ten years, its nature as defined at the outset will have changed by the time it ends.

For example, the first part of the project, which will place enphasis on feasibility studies and the like, will require divergent management because many alternatives will be developed in parallel. Conversely, the latter part of the project will need convergent management since it will involve developing selected alternatives on a priority basis. There will be a need for a management setup of coping with these changes in project results and nature.

The development of an inference system in general and its evaluation in particular will require the cooperation of many experts in various fields.

The cooperation of experts in diverse industrial fields will be also vital to the development of the "inexpert system" mentioned earlier. To proceed with the fifth generation computer project, it will be imperative that computer experts in government, universities, and industry cooperate closely, but I think it will also be essential to create an environment which will encourage non-computer experts as well to cooperate willingly in the project. I also think that ensuring smooth international cooperation is a major challenge from the standpoint of project management. As I see it, the fifth generation computer project is ambitious and challenging in terms of technological objectives. From the standpoint of R&D program management also, it presents us with many entirely new challenges. I hope that through the fifth generation computer project we will gain not only technological knowledge but plenty of new and valuable experience in R&D management techniques. Thank you.

Moto-oka: Thank you. Now, Mr. Okamatsu, your turn.

Okamatsu: I am from the Ministry of International Trade and Industry (MITI). Perhaps some policy makers should have been present at some of the earlier sessions, but since the subjects discussed at these sessions were too complex and technical for the likes of us, I am participating only in this panel discussion. On behalf of MITI as promoter of this project, I wish to express our sincere appreciation for the tremendous participation from overseas in this international symposium on fifth generation computers. As you will have no doubt understood from the four days of discussions including today, the fifth generation computer project is aimed at exploring various possibilities and developing concepts which will have important impacts on the computer systems of the future.

In this sense, this symposium may have been a slight disappointment to those who participated in it with the hope that it would provide clear-cut answers to the question of the nature of the fifth generation computer system. The aim of holding this international conference was, however, to exchange technical opinions with overseas countries on this Japanese project from its planning stage and to discuss visions of the fifth generation computer system, which is expected to have far-reaching effects.

Since this project is the first of its kind for us and for Japan, it is very challenging. I would like you to understand this first of all.

The subject of this panel discussion is impacts of the fifth generation computer system, and I would like to take this opportunity to briefly explain MITI's ideas on the fifth generation computer system in the context of policy—making.

This will also answer the questions about its social impacts asked by other panelists earlier. Our approach to policy-making for the 1980s started with discussions on what the objectives for the decade would be. As a result, we concluded that there are three basic objectives MITI policies must achieve in view of the international environment Japan finds herself in.

One is to make international contributions now that this country, accounting for 10% of world GNP, has become an economic power. The second has to do with our limited resources. Japan is very poor in natural resources and has as many as 113 million people living on its limited land. The country must support itself by means of its technology in future. Accordingly, to promote technology is the second objective. At the same time, we must build a vigorous and comfortable society partly because in the past we may have tended to give too much consideration to technology, industry or economics at the expense of the quality of life, this is our third objective.

By the way, as we see it, effective use of information technology means increasing the flow of information. In Japan's case, information flow has increased mainly in industry, notably manufacturing, in the 1970s. Needless to say, this has underpinned the international competitiveness of Japanese industry. From now on, the utilization of information will spread widely into society and consumer life.

In other words, information technology should not only help improve industrial productivity, it should also contribute greatly to resource conservation and energy saving, which are of vital importance to Japan. It should also help solve a diversity of social problems confronting our society or, for that matter, any other industrialized country, such as health care, education, transportation and urban problems.

Moreover, it should permit us to broaden the scope of human activity further. We think it is important to build a vigorous and comfortable society making the best use of information technology.

The next step in our policy-making approach was to consider what policy to establish to achieve the objectives mentioned just now. We set a policy goal of building an affluent information society. To build such a society requires improving our social and regulatory foundations. This has a bearing on the problem of social impacts referred to earlier. One area we must address is computer security.

Specifically, as computer use spreads more widely in industry and consumer life, we must consider how to meet the problem of system security or system failure and, furthermore, computer crime, which is, to our regret, on the increase here in Japan, too. We see computer security as a major challenge. Privacy is another area to consider. A short time ago some panelists touched on the area of privacy. It is not yet a hot issue in this country, but we have studies now under way at the government level to improve our regulations in line with the recommendations made by the OECD committee.

Another major impact of increased computerization will be, as Mr. Read pointed out, unemployment. Fortunately, Japan, unlike Western nations, does not have a serious unemployment problem for now. We must, however, pay due consideration to this in future since our society is quickly aging.

At the same time we must note the fact that in this country, too, there are emerging fears that computerization may lead to an over-managed society or something which might be termed "computer allergy". To meet the situation, we must consider how to cope with the problem of education and training pointed out earlier as well as the various problems I referred to a moment ago.

Also, from the standpoint that the progress of computer technology, or natural science, should not be held back by lags in social science, we think we must take steps so that the lagging sections of our social infrastructure can keep up. A case in point is communication lines. As of now, the use of communication lines in this country is strictly regulated. Since, however, technological advances have made online and distributed information processing possible, we consider it necessary to get the most out of them in order to build a desirable information society. On this also, we have various studies now under way at the government level.

So far I have discussed at some length the challenge of laying the foundations of an information society. Another challenge we are tackling in parallel with it is to promote information technology, that is, to encourage research and development of this technology. I would like you to understand that our overall policy framework is built on a well-balanced approach to these two challenges. In technological development, the question is what fields the government should be involved in. Our basic thinking is this: government involvement is needed in projects which have the potential of producing tremendous ripple effects but require a long period for commercial application and which involve great risks and financial burdens. Involvement is also needed in fields which concern urgent social demands which must be met immediately. In a nutshell, these are R&D fields which would be slow in making progress if left to the private sector or the price mechanism. As you can understand from what I have just explained, government support is limited to basic R&D fields. The fifth generation computer system is one of these important R&D fields. Our government policy for information technology has so far been one of catch-up, that is, developing technologies after they have been announced in overseas countries. The fifth generation computer project marks a complete departure from the past in the sense that we are intending to conduct creative, leading-edge technology development. The aim of the project, as already discussed, is to solve by new technologies those major problems which could not be solved by existing computers. In view of the magnitude of its expected ripple effects and the risks involved, we believe it requires positive government involvement for the reasons I stated earlier.

Now I would like to be specific about how we intend to proceed with the project. As has been repeatedly mentioned, the project will be implemented in three phases. As a preliminary step, the government made a budget appropriation of only ¥15 million for fifth generation computer research and development this year, that is, fiscal 1981. The appropriation was to cover the cost of investigating three subjects.

One is what are the important technological requirements on which the government should concentrate R&D efforts and which of these efforts the government should fund. The second is how to schedule the R&D project. The third is what form of setup should be adopted for fifth generation computer system development. The investigation is now under way, and I understand that final conclusions will be drawn up at the end of the current fiscal year, in other words next March. Thereafter, we are planning to implement the project in the three phases I mentioned a little while ago.

Phase 1, extending over the first three years, will develop the basic technology.

For the first project year, we have requested an appropriation of about ¥500 million from the government budget for next fiscal year. We think phase 1, or the first three years, of the project will need a government budget appropriation of some ¥10,000 million, including the ¥500 million.

Phase 2 will be devoted to developing subsystems over a four-year period. These subsystems will be integrated into a total system in phase 3, that is, the last three years. To sum up, the project is aimed at building a prototype fifth generation computer system in ten years. I mentioned appropriations of ¥500 million and ¥10,000 million, but these are actually only what MITI has planned. We are now negotiating for them with the Ministry of Finance. Similar to what you will no doubt have experienced in your own countries, our Ministry of Finance wants to trim government spending as much as possible especially because, for the past three years, they have been striving to put the nation's financial house in order. For our part, we want to do our best to get the appropriations from the standpoint that investment in information technology is something bearing on the very foundation of society. Accordingly, we have been carrying on a heated debate with the finance people day after day. Thus, I hope you understand that the said figures are not yet incorporated in the government's budget estimate but are only what MITI has in mind. As for the staffing to carry out the project, we are considering setting up a new external organization and staffing it with appropriate people.

Finally, I would like to touch on the international cooperation aspect of the project. The project aims at developing the basic technology. It is very large in scale and is expected to have very far-reaching effects. Furthermore, our policy adopts the stand that we must make international contributions. Taking these and other factors into consideration, we think we must enlist some form of international cooperation in the project.

The first step in this direction is this international conference. How to proceed with the project will be made clear by the investigations now under way. We intend to create opportunities for internationally releasing information about the project in some form on a continuing basis.

I hear that there is, if anything, more pessimism than optimism about economic growth hn the industrialized West. We will be most happy if we can contribute toward revitalizing the world economy through this leading-edge project. Thank you.

Moto-oka: Thank you. Now the first round of speeches is over. Are there any panelists who wish to comment? Then, any questions from the floor?

Q (JAPANESE, Floor): It was reported that there were as many as 100 miners killed in an accident at a Hokkaido coal mine. How about developing a computer-aided mining system under which miners would not have to go into pits or other places where working conditions are adverse but could sit in front of television monitors and operate robots to do the actual digging?

Japan accounts for only 0.3% of the world's land area. So if you consider Japan alone, it might seem there would not be much demand for computerized mining. But the need for Japan to play a greater role in the international arena was mentioned just now. 99.7% of the mines in the world are somewhere other than in Japan, and there miners are doing very dangerous work underground. If the project works well, mining would also come under MITI's sway. . . .(laughter) Please let me hear your comments on this. Presumably the same is true of all countries around the world.

Karatsu: You are right. On the first day I suggested making intelligent robots to do dirty work. On that occasion I cited work on the seabeds and in very dangerous fields as examples of work to be done by robots because it happened to be before the coal mine explosion took place. Our subcommittee is also of the opinion that great efforts should be made to develop intelligent robots. And I think this is incorporated somewhere in the project.

Moto-oka: Professor Lions took up the problem of training and education as an important impact. Mr. Karatsu, I believe you are well-informed about this field.

Karatsu: I think I said on the first day that the problem of dropouts will be greatly eased by computerization. The problem of inference was addressed a little while ago. What is generally called CAI is still at a rudimentary stage. If computers can handle inference then this will greatly alleviate the problem of dropouts.

More important, the increasing number of elderly people is a big problem, especially in Japan. It means the employment structure will have to change substantially.

Considering these two things leads us to the question of lifetime education. I think the fifth generation computer system will go a long way toward performing this education efficiently. And I have proposed that it be covered in the project.

Probably it will have considerable effects. Transfer of this technology will have a great significance not only for industrialized countries but also particularly for developing countries.

Foreigner: It would be very helpful if some of us could provide you with the benefits of our experience in computer science and engineering; but none of us has more than three decades, thirty years of experience. We're very fortunate however that we do have some recommendations from the President of the United States. The President of the United States, who I am about to quote, was the President two hundred years ago, shortly after Mr Read's government and my government had a short dispute which resulted in the formation of the United States. I would like to quote for you, from President John Adams something that he wrote in the year 1780.

"I must study the art of politics and war so that my sons may have the liberty to study science and engineering. So that their sons may have the liberty to study music, art, sculpture, dance and philosophy." That's the end of the quotation from President John Adams in the year 1780. In some of our fortunate countries, our societies are about to enter the third generation; wouldn't it be fortunate, if those of us in computer science and enginering, as we enter the fifth generation of computers, could help society enter its third generation? Thank you.

Moto-oka: We have a lot of requests to ask the opinions of people from industry, who are present here in large numbers. In particular, there are many people from U.S. industry, including IBM: would any of them like to give us some comments?

Schorr: Well we're happy to be invited. As it has been expressed by other people, we're very impressed with your openness, and the thoroughness of your plans. I think some of the comments you have made have summarized the situation quite well. It's a very forward looking project, and I think you've done a very interesting planning exercise, and I think some of the things that have been said about the project, have been expressed by yourself and Professor Fuchi. You have a starting point for a project on basic research, a good plan, we hope. It's the manufacturer's who tend to be a bit more conservative, as we saw in some of the remarks repeated by the Hitachi, Fujitsu people, but I come from the research division so I can be a little more appreciative of the progressive nature of what you are attempting. I think you have a project that has been stated over and over again in basic research which is high risk, I think a lot of things will succeed and we will be prepared for some things to fail. I think that should be expected. I look forward to coming back in one or two years, whenever you're ready to present some more results, and I would be happy to see what those are.

Q: As long as you've asked. As Professor Feigenbaum mentioned, Digital is currently using expert systems and internal industrial application. I might say personally, not as a representative of DEC, or of Mr. Reagan, that I respect the organization of this project, its clear goals, checkpoints, and perhaps most importantly, a vision that allows many people to contribute in a coherent way, to a major undertaking. I marvel at the ambition of the goals, even though I am from a manufacturer, I suspect that even partial success will be significant. And lastly for whatever use it may have, a suggestion: The relative benefits of theoretic and pragmatic approaches to expert systems aren't clear to me, but if I may add a small voice to Dr. Feigenbaum's, it does seem very beneficial to very soon execute a reasonably large number of expert systems, in order to more clearly see what is more critical and what is not. That's all.

Q: I think in this session, it would be very logical to express the fears of the third world. I was once asked by a reporter in my country, what I felt was the state of electronics, and as to how we seem to be doing on the world scene. My comparison to him was that of a long distance runner, something like perhaps 1600 meters, something like that, going around the track, and by the time we have done a quarter of the track, and find the other guy taking us over again. What I'm trying to say is this: it has been pretty demoralizing for a typical third world country to notice that technology is advancing by leaps and bounds and that they have neither the resources nor the skills to benefit from that technology. We in the third world feel that a great deal of international cooperation is required on this course. Because to go back to the comment of Mr. John Adams, which was quoted a little while ago, now one is expected to learn a new art in keeping up with changing economic realities. I'm attempting to caution that, society, as Mr. Read pointed out, has migrated in its world course from agriculture to industry to service. And we don't know what will become of it all if all the service sector functions were to be automated. Thank you.

Q: Since this is almost the close of a very inspiring meeting, and the close is dealing with social impact, and since Russel Kirsch has quoted a president long dead, I would like to quote a computer scientist alive and well at Stanford. My college professor, Dr. McCarthy. When I get mired down in the details of work on knowledge engineering, I sometimes think of one of Dr. McCarthy's statements for inspiration. Which is, what will the world be like when we will be able to put one hundred year's thought into every decision? And that, it seems to me, is the overriding benefit. Perhaps with fifth generation computers we'll be able to find out the answer to that question.

Moto-oka: Thank you. I wish I could ask the opinions of many more people, but there is only a little time left. I would like to close this session now.

Finally, on behalf of the organizers of this conference, I wish to sincerly thank the many people present here for participating in this conference and giving various and very constructive opinions on our project. There were many opinions expressed on the application aspect of the project. Needless to say, we are also well aware that what the fifth generation computer system will be used for is a very important question.

However, our lack of resources prevents us from broadening the project too much. Accordingly, it looks as if the project has not taken the application fields into consideration. This seems to me to be the main criticism made about the project. How to compromise on this aspect will, it appears, be a major question from here on.

If you will allow me to exaggerate a little, this project aims to be the space shuttle of the knowledge world. As I see it, the space shuttle project was planned with the aim of conducting various experiments in space and creating something new through them but also with the idea of proving the economic viability of challenging the unknown. The space shuttle is very easy to understand because it is related to a space we can visualize, outer space. This project of ours, however, may include many points difficult to understand because it is related to what, in the knowledge world, might be called artificial or virtual space.

When it came to international cooperation in the space shuttle project, suggestions were invited from the world over about what experiments to conduct using the space shuttle. I understand that Japanese proposals are to the included in the space shuttle some years from now. Throughout the conference I have been thinking of the possibility of such forms of international cooperation in this project.

Now I would like to declare the conference closed. Thank you all very much.

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