FIFTH GENERATION COMPUTER

Outline of Fifth Generation Computer Project

INSTITUTE FOR NEW GENERATION COMPUTER TECHNOLOGY

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1. OUTLINE OF THE FIFTH GENERATION COMPUTER SYSTEMS PROJECT

1. Background and Development of the Fifth Generation Computer

a. Provision for future computing needs

The information-oriented society

The Ministry of International Trade and Industry undertook such R & D studies as shown in Fig. 1 for implementing revolutionary new computers to serve as the tenchnological foundation of the information-oriented society of the 1990's. These studies seek to provide higher-level functions for new computers by using artificial intelligence techniques, and new software and hardware (architecture) technologies.

Realization of an easy-to-use computer system (natural language processing)

As computers are introduced into all areas of society and daily life, as well as into industry, future reliance on information in a broader range of areas can be expected. Technology that makes it possible for non-specialists to make full use of such machines is urgently needed. One aspect of such a technology is the development of man-machine dialogue in natural (human) language.

Use as a tool for intelligent activities

Computers will be increasingly relied upon as tools for supporting the creative process in industrial and social planning.

For instance, systems for use in decision support, as well as for support and execution of intelligent activities (non-standardized business operations, R & D, etc.), will become necessary.

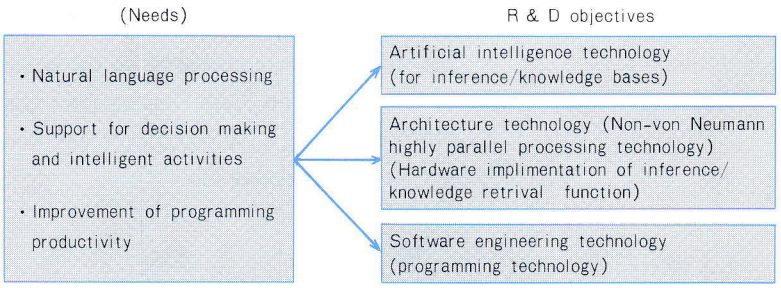

Fig. 1. R & D objectives for 5G computers to meet needs of the coming "Information Society"

INTRODUCTION

The Fifth Generation Computer Systems (FGCS) project was initiated in 1982 as part of a major program supported by Japan's Ministry of International Trade and Industry (MITI).

"Fifth Generation" computers, now under development, are intended to provide the basis for a revolutionary new kind of knowledge information processing by the early 1990's.

MITI's decision to support such a project was based on the realization that rapid advances in computer technology and radical changes in international economic and social environments have necessitated research and development on a new generation of computers aimed at coping with the information-oriented society of the 1990's.

As the central organization responsible for the execution of this national project, the Institute for New Generation Computer Technology (ICOT) was established in April, 1982. ICOT has mapped ont a research and development program that will span ten years: a three year initial stage ('82～'84), a four year intermediate stage ('85～'88), and a three year final stage ('89～'91). At present, the project is in the third year of the initial stage and research and development activities are proceeding as scheduled.

In the execution of the present project, valuable guidance and support have been received not only from the Ministry of International Trade and Industry, but also from various concerned parties in the academic and industrial sectors.

Reflecting the great importance placed on advanced technology , this research and development project has also evoked considerable reaction.

This pamphlet was prepared on the occasion of the International Conference on Fifth Generation Computer Systems held in November, 1984, to facilitate an understanding of the project's overall scope.

Maquinas operativas prolog tipo - PSI - Personal Sequential Inference machine

Δ (Delta). Delta Board

Fabrica Mitsubishi

Improvement of productivity in software development

With the growing sophistication and diversification of industrial and social activities, great increases in the demand for information processing are anticipated. To meet such rapidly expanding demand, technology for improving the efficiency of software development will be required.

b. The Limitations of Conventional Computer Architectures

The limitations of present-day computers

Present-day computer systems have significant limitations. None of them are capable of handling types of tasks in which the way to proceed is not explicitly specified. Complex sets of circumstances related to various aspects of the problem must first be understood, and based on this understanding, choices must be made. This is difficult to be done in conventional systems.

Human intellectual activities are complex and ambiguous

In the types of numerical calculations and routine job processing to which conventional systems are suited, the procedures that the computer is to perform must be clearly stated at the outset. In the vernacular of computer engineering, this is known as a "program".

In a large number of human intellectual activities, however, it often becomes necessary to alter the methods we normally use in complex ways, depending on the situation. For instance, terms of language activities, which are fundamental to other intelligent activities, the meaning of a particular word may change in a multitude of ways depending on the circumstances in which it is used. The sense of a word will vary depending on its relationship to adjacent words, and the meaning of a statement composed of such words will also depend on what the statement is actually about, and the context in which it is used.

In attempting to write a program to discriminate the meaning of any given word used in a sentence input to a conventional computer, the program itself would form a network that branched out ever more finely at each condition imposed. Such a program could never in reality be completed.

However, for the type of applications that will be required in the 1990's, it is precisely this kind of intelligent activity that will be demanded of computer systems. The problem lies in

how to implement such capabilities. The most promising answers to this question have come from research in the field of artificial intelligence.

Artificial intelligence research

Stated simply, artificial intelligence research strives to elicit from computer systems intelligent activity of the order demonstrated by human beings. Taking up concrete examples of such intelligent activities, such as "problem-solving," "inference," "learning" and "speaking and understanding words", attempts are being made to develop computer programs that can approximate these activities.

However, because of the limitations already described, the results of these research efforts have not been of adequate practical value when implemented on existing computer systems.

The Fifth Generation computer will, when developed, be able to compensate for the shortcomings of conventional computer systems.

2. Fifth Generation Computer Functions for the Needs in the 1990's

Computers have historically been based on various schemes with regard to their hardware structures: 1st generation—vacuum tubes; 2nd gen.—transistors; 3rd gen.—ICs; 3.5-th gen.—LSIs; 4th gen.—VLSIs). The 5G (5th generation) computer is being developed as a new system based on a technological scheme drastically different from those that have gone before.

Knowledge information processing

The Fifth Generation computer is aimed at the realization of knowledge information processing based on innovative theories and technologies.

In other words, to overcome the technological constraints of conventional computers, a knowledge information processing system must be developed. Such a system will require an intelligent conversation function and an inferential function employing a knowledge base, both of which are thought to be essential by the 1990's: applications in a far wider range of areas than has been possible with conventional systems will become feasible, using knowledge information processing systems (KIPS).

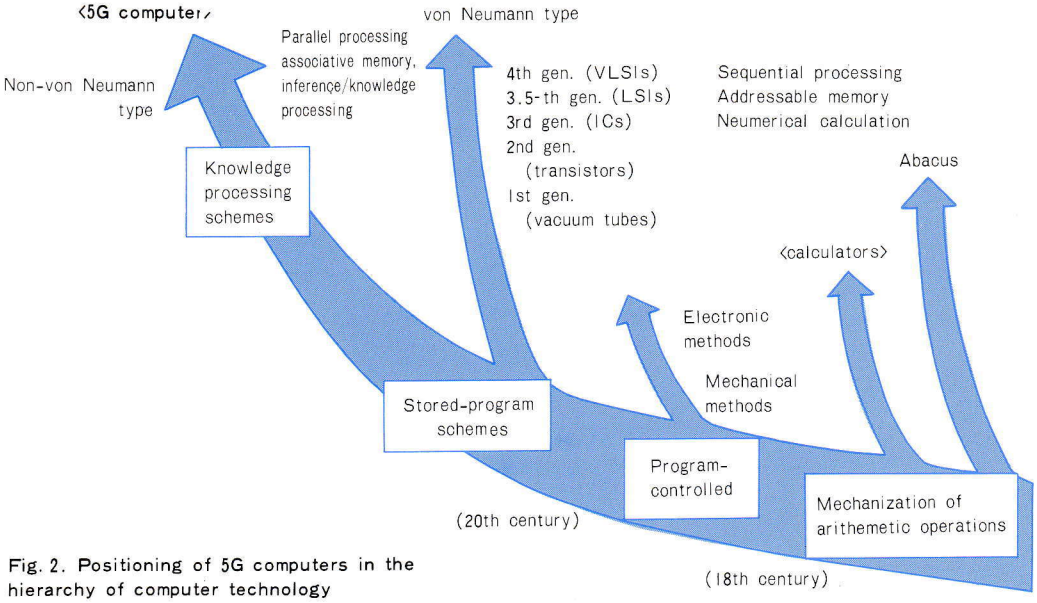

Fig. 2. Positioning of 5G computers in the hierarchy of computer technology

It is deemed necessary that the 5G computer be endowed with the four basic functions described below. In order to realize each of these, R&D on the corresponding technologies for hardware architecture, software engineering and artificial intelligence is to be carried out.

Four basic functions

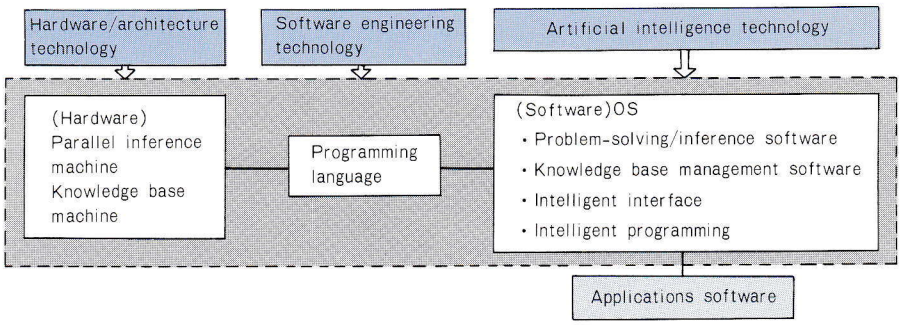

Fig. 3. R & D of 5G computers

1) Problem-solving and inference function

In order to solve problems, rigorous deductive inference and inductive inference, including conjectures based on incomplete knowledge, will be employed.

2) Knowledge base management function

A system to perform acquisition, accumulation and utilization of various types of knowledge will be required for inference processing.

3) Intelligent interface function

A flexible, interactive man-machine interface will be developed with capabilities for using natural language (both written and spoken), graphics, images and other types of input data.

4) Intelligent programming function

Application problems will be automatically converted into efficient computer programs.

3. Examples of Applications and Impact of 5G Computers

Some examples of 5G computer applications are given in Table 1. As shown in Fig. 4, the impact of the 5G computers is anticipated to extend to a wide range of areas in industry and society.

Industrial areas	• Design (VLSI-CAD) : Designing large-scale computers in a short period of time • Production processes (intelligent robots) : replacement of human labores in "dirty" jobs or under extreme conditions • Development : expert systems for efficient development of chemical and pharmaceuticals • Management (management diagnosis expert systems) : support for optimum management decisions based on changes in society and the economy • Office work (intelligent OA) : word processors using voice input, document preparation support • Manitenance (remote diagnosis of malfuncions) : automated diagnosis of various plant malfunctions
Social areas	• Education (CAI) : realization of individual instruction with menus geared to the student's level of understanding • Clinical (automated nursing systems) : nighttime surveillance of patients in intensive care units, support for measures to cope with sudden changes in conditions
International	• Translation (automatic translation systems) : automation of effective translation between several laguages at the semantic level

Table.1. Examples of 5G computer applications

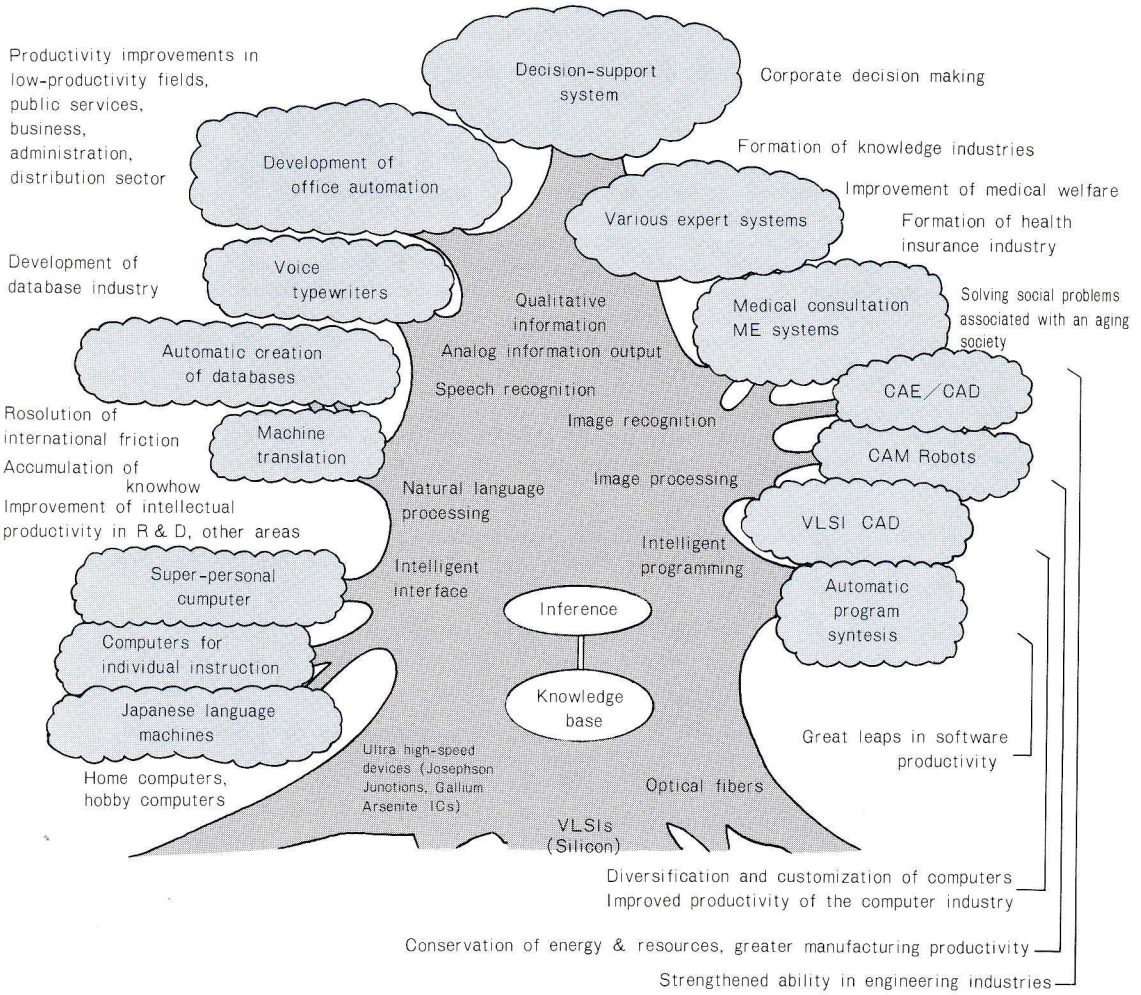

Fig. 4. Social impacts of 5G computers

4. Major International Computer R & D Projects

Research and development on advanced computer systems is presently being conducted by various research organizations in the other industrially advanced nations. The U. S., Great Britain and other countries have recently begun to vigorously promote new projects.

Plans for new projects are being advanced other countries as well.

Japan, aware of its role in promoting international contributions to the field of advanced computer techology, seeks to

encourage international cooperation for mutual benefit among projects that share mutual research interests.

Table.2. Major R & D Project in other countries

US : DARPA (Defence Advanced Research Project Agency) of the Department of Defence, has initiated a program called the Strategic Computing and Survivability Project. Developmnet will be carried out over a ten-year period, beginning 1984 under a charter from the U.S Government (AI, expert systems, parallel processing architecture, etc.). A joint research project (on computers and semiconductors) by private firms is also underway. A Consortium called MCC (Microelectronics Computer Technology) was established, whose work is to be performed over approximately 10 years starting 1983. (CAD/CAM, AI, new architectures, advanced IC packaging, etc.)

Great Britain : The Ministry of Commerce and Industry has initiated a project for advanced information technology (the AIT project). A steering conmittee was established within the Ministry, in June, 1983 and research and development was begun in April 1984. (Knowledge base system, man-machine interfaces, software engineering, VLSIs, etc.)

France : Committees of experts within national research organizations are presently studying possible projects corresponding to the FGCS project, and will make recommendations to the Government. (AI, knowledge base management, intelligent interfaces, etc.)

W. Germany : The Government has instituted a policy for the comprehensive promotion of improvements of the information industry. In a five-year sector research on semiconductors and next-generation computers. (AI, expert systems, parallel processing architecture)

European Countries : With the development of more advanced information technology as its goal, the EC Committee recently approved plans for software technology, VLSI-CAD, etc.) ECRC (European Computer-Industry Research Center) was established in January 1984 by Bull, ICL and Siemens. (Next-generation computer architecture, man-machine interfaces, etc.)

2

FIFTH GENERATION COMPUTER DEVELOPMENT PLANS

1. Aims of the Fifth Generation Computer Systems Project

The ultimate goal of the Fifth Generation Computer Project is the realization of a computer system possessing a wide range of intelligent capabilities, making feasible its use in the new applications of the 1990's. A more concrete breakdown of the goals of the project is given in Table 3.

A new world of applications will be opened up by the 5G computer. The form that the new type of information processing will take is referred to as "knowledge information processing." A large part of the technology for realizing knowledge in formation processing systems (KIPS) will make use of the results of artificial intelligence research. In order to integrate these results into a single system, it will be necessary to selectively combine results to form a consistent whole, while augmenting underdeveloped parts of AI technologies.

Knowledge information processing system (KIPS)

Knowledge information processing programs will be very large and complex. It would be difficult or impossible to try to implement such programs in presently existing programming environments. In order to overcome such problems, it has become necessary to introduce an entirely new type of programming language, based on entirely new principles. A programming environment that reduces the cognitive demands on human beings will be created. Under such an environment, it is hoped that people with no expert knowledge will be able to write programs with ease on the foundation of this new programming language, by efficiently using the capabilities of the computer system.

Establishing a programming technology for large and complex programs

Of course, it need hardly be said that programming is itself a type of intelligent human activity. Thus, by making programming the object of knowledge information processing, much of the burden may be transferred to the computer. This has already been taken up as a goal of artificial intelligence, and forms the field of research known as automatic programming. But, efforts based on existing computer systems are rather difficult to produce results that can be practically applied. Hopes are thus placed on Fifth Generation systems to make such practical applications possible as well.

Realization of very high performance hardware

If such extremely voluminous and complex programs should become possible, the remaining problems amount to how to build a computer powerful enough to execute them.

Judging from the past results of artificial intelligence research, it appears necessary to make the operating speeds of 5G machines faster than those of existing computer systems by about two orders of magnitude. In order to realize such tremendous processing speeds, the concept of highly parallel processing must be introduced, in which several hundred processors employed simultaneously to execute a single program.

Fortunately, thanks to advances in VLSI technology, the use of a large number of processors will probably not lead to serious cost problems. However, highly parallel processing is not applicable to all programs. An appropriate programming language must be chosen, and an architecture suited to the language must be developed.

2. Approaches to 5G Computer Systems

Programming suited to descriptions of intelligent activities

The first task to be performed in concretely defining the goals of the FGCS project is the discovery of a programming language suitable for describing the intelligent activities to be executed by the computer. To this end, it is essential to understand the principles underlying the intelligent activities that the language is to express. In contrast, existing computer architechures embody the basic arithmetic operations, which form the underlying principles of numerical calculations.

Predicate logic

For the 5G computer, logic, and predicate logic in particular, has been adopted as best expressing the principles underlying intelligent activity. Logic is in general regarded as the universal law governing reasoning processes. There are various forms of logic, and predicate logic is that form which is most closely related to natural language. Thus, aside from the initial apprehension we all feel toward anything so strict and rigid, such logic can be manipulated by anyone.

While predicate logic alone is not capable of handling all intelligent activities, there is no doubt that predicate logic is the most powerful means available in terms of description.

"Inference", the basic mechanism of logic

Inference is the mechanism fundamental to logic; by the rigid procedure of inference, knowledge is used to extract from

known information what was previously not known explicitly. When human beings attempt to understand the meaning of something, whether they are conscious of it or not, inference plays a central role in the process. The possession of knowledge and the execution of inference procedures together comprise the fundamental conditions for intelligent activity.

Syllogisms

Inference is carried out according to a set of inference rules. The most basic of these rules are syllogisms, in which A→B and B→C leads to A→C. One method by which computers may be made to reason by inference is to build such inference rules into the hardware, in order to make automatic execution possible. This is, in fact, the approach taken in research on the 5G computer.

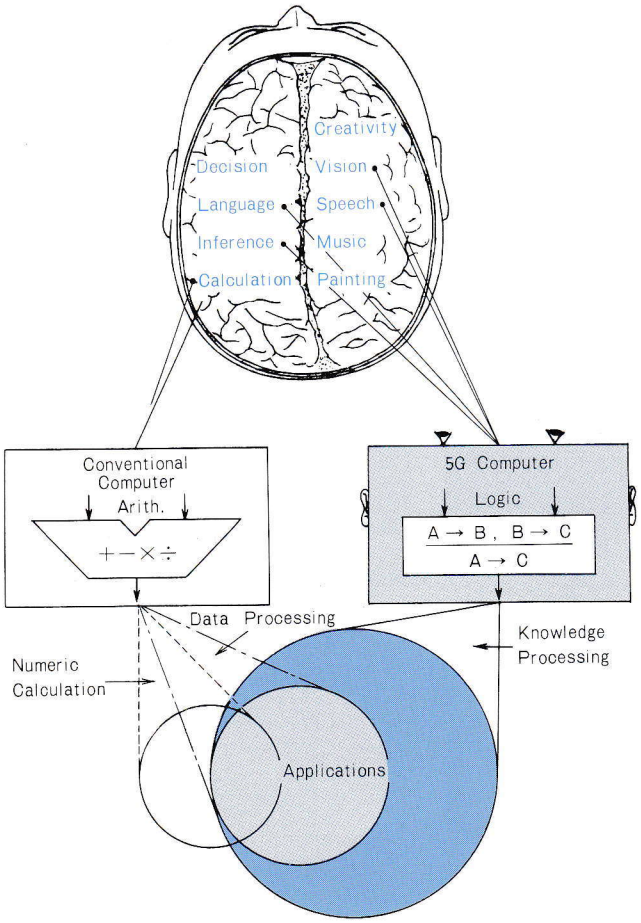

Fig. 5. Aims of the 5G Computer

The method by which programs are expressed in logical form and executed with inference functions is called logic programming. Programs in logic programming correspond to, say, the expression of an arithmetic problem as a system of simultaneous linear equations. Inference operations would then correspond to solving such a problem by cancellation. Thus a large part of the program consists of the knowledge that is to be used in the inference operation.

Relational database

Assuming that such logic programming is employed, much of the knowledge accumulated within the computer system must be expressed in the form of predicate logic. This format may be made to correspond almost exactly with the relational descriptions in existing relational databases. Thus, in constructing a knowledge base, existing relational database technology may be directly utilized as a springboard.

Parallel processing

In addition, prarallel processing of programs employing predicate logic is possible. This is similar to solving in parallel for each unknown of a system of linear equations.

The above description is summarized in Fig. 6.

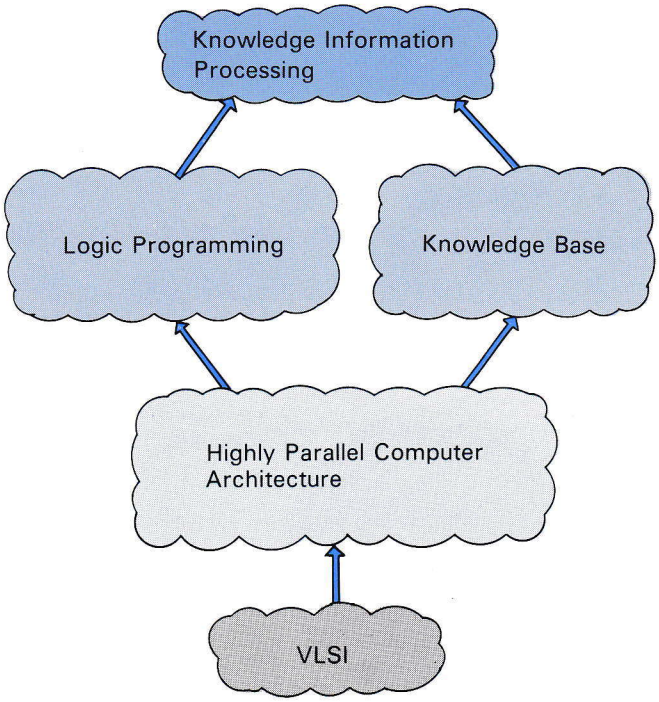

Fig.6 Approach in Development of Fifth Generation Computer

3. Configuration of the 5G Computer

Configuration of the 5G computer

Fig. 7 presents the targetted configuration of the 5G computer.

With the programming language (Kernel Languages) at the center of the figure acting as interfaces, the 5G software unfolds upward, and the hardware downward.

In terms of present software levels, the software scheme consists of a demonstration system for basic software and the basic software system, with very-high-level programming languages intervening between the two.

Demonstration system for basic software

The demonstration system for basic software consists of a number of application-oriented systems constructed to test knowledge information processing concepts. Once the 5G computer is completed, it is expected that a large number of full-scale application systems will be developed by commercial vendors.

Problem-solving and inference software module

The basic software system is the most important element in the software hierarchy, forming as it does the basis for knowledge information processing. The problem-solving and inference software module is, in terms of existing computer systems, the operating system. It makes possible effective use of the inference machine by constructing higher-order inferences from simple syllogisms, and ensuring that a variety of different types of problems may be solved efficiently in a manner convenient to users.

Knowledge base management software module

The knowledge base management software module corresponds in principle to database management systems, but because it handles knowledge instead of data, far greater intelligent functions will be required of it. One example of this might be a learning function, by which the module could determine whether information was significant. The system could accumulate knowledge based on such decisions.

Intelligent interface software module

Simply put, the intelligent interface software module will make it possible for the computer to understand human language: to "speak" and "hear", and to converse through figures.

Intelligent programming software module

The intelligent programming software module will employ advanced software engineering technology to reduce to the absolute minimun burden imposed on human programmers, with the ultimate goal of automatic programming.

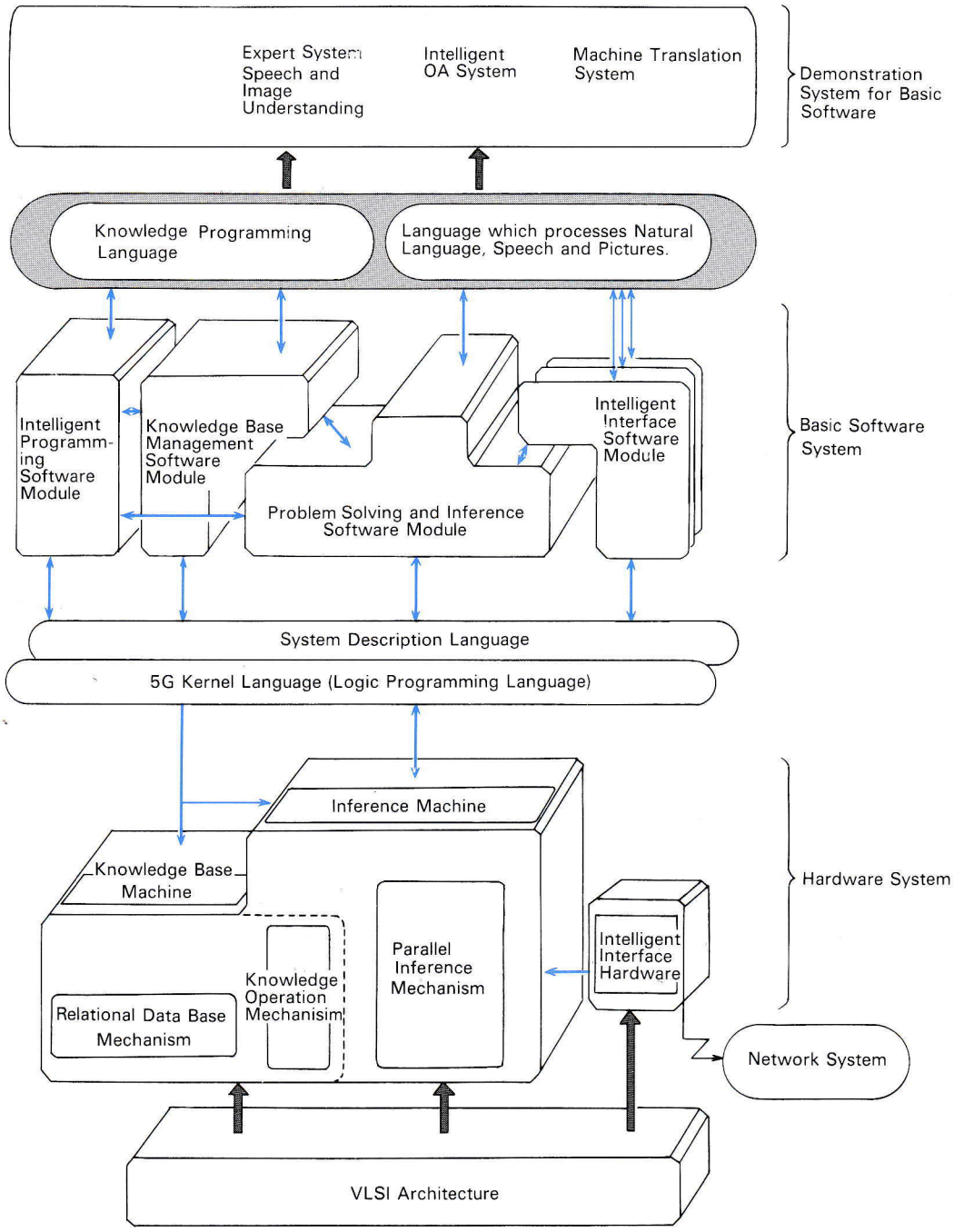

Fig.7 Basic Configuration Image of the Fifth Generation Computer Systems

Hardware

The hardware of the 5G computer will consist of three subsystems; in future, however, an integration of these in one form or another is anticipated.

Inference machine

Using basic functions, such as those for syllogisms, the inference machine directly executes programs written in the Kernel Language.

Knowledge base machine

The knowledge base machine carries out high-level processing of knowledge expressed in a variety of complex forms.

Interface hardware

The intelligent interface hardware is in charge of executing basic functions for speech and image processing. All of these make use of advanced parallel processing technology, the goal of which is ultra-high speed performance. As regards to element technology, VLSI device technology will be employed.

VLSI technology

4. Steps in the Development of the 5G Computer

Ten years for research and development

Because R&D on 5G computers incurs a high level of risk, involving as it does a large number of unkowns, a relatively long period—ten years—has been allotted for the project.

This ten-year period will be divided in to several stages: three years for the initial stage, four years for the intermediate stage, and three years for the final stage.

〈Initial stage〉

The initial stage of R & D is being conducted with emphasis placed on the fundamental technological elements required to build of a 5G system.

〈Intermediate stage〉

In the intermediate stage, the algorithms and basic architecture to be used in subsystems that will constitute the foundation of 5G systems will be determined based on the results of the initial stage. Following this, a small-to medium-scale system will be developed using various subsystems as components.

〈Final stage〉

The final stage of research and development has as its goal the completion of a prototype 5G system, completely integrating all the results of research performed up to this point.

Research and development tools

In addition, a primary objective of this project is the in-house development of R&D tools; this work will be carried out from the initial through the intermediate project stages.

Because the 5G system will be based on revolutionary new programming languages, software development could not be expected to proceed efficiently using conventional computer

systems. Existing technology is being employed in the development of these high-performance tools for software development in order to complete in a short time.

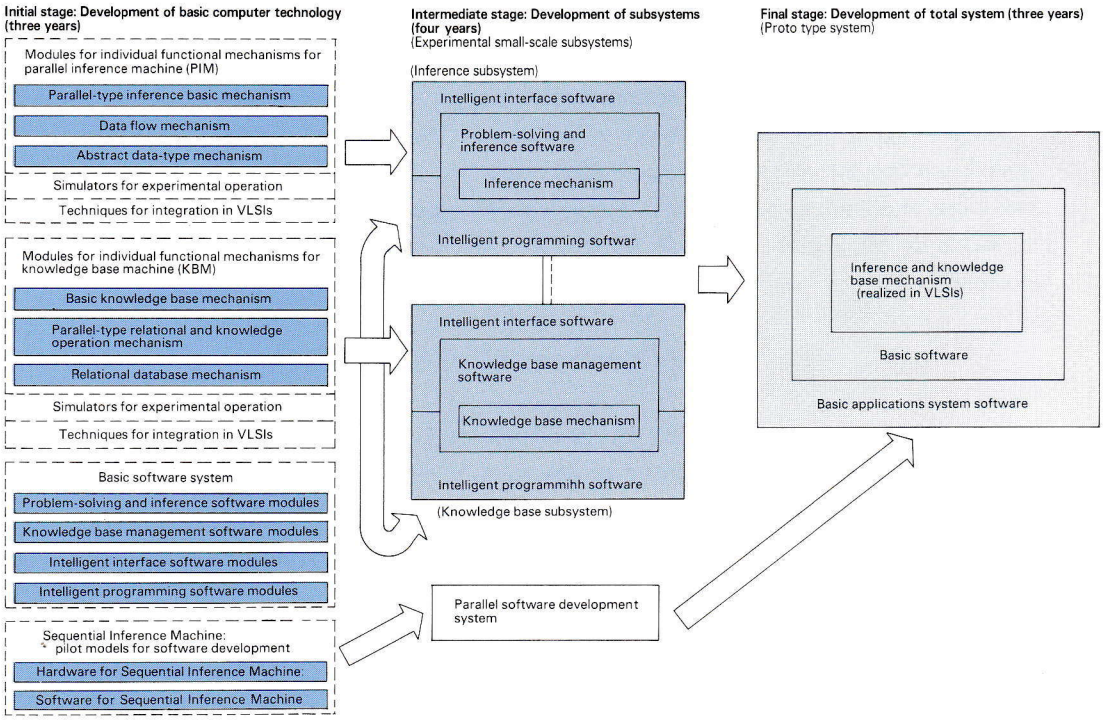

Fig.8 Stages of Fifth Generation Computer reseach and development

3 RESEARCH & DEVELOPMENT THEMES AND STATE OF PROGRESS

1. R & D Areas in the Initial Stage

A summary of the R & D areas of the initial three-year stage, as well as the interrelations between them, is presented in Fig. 9.

The four basic areas for R & D are listed below; each of these is further subdivided into research themes (see Appendix 1,"Research and Development Subjects for the Initial Stage").

1) Inference subsystem
2) Knowledge base subsystem
3) Basic software system
4) Pilot models for software development

The demonstration system for basic software shown in Fig. 9 will not, however, be taken up directly in the initial stage.

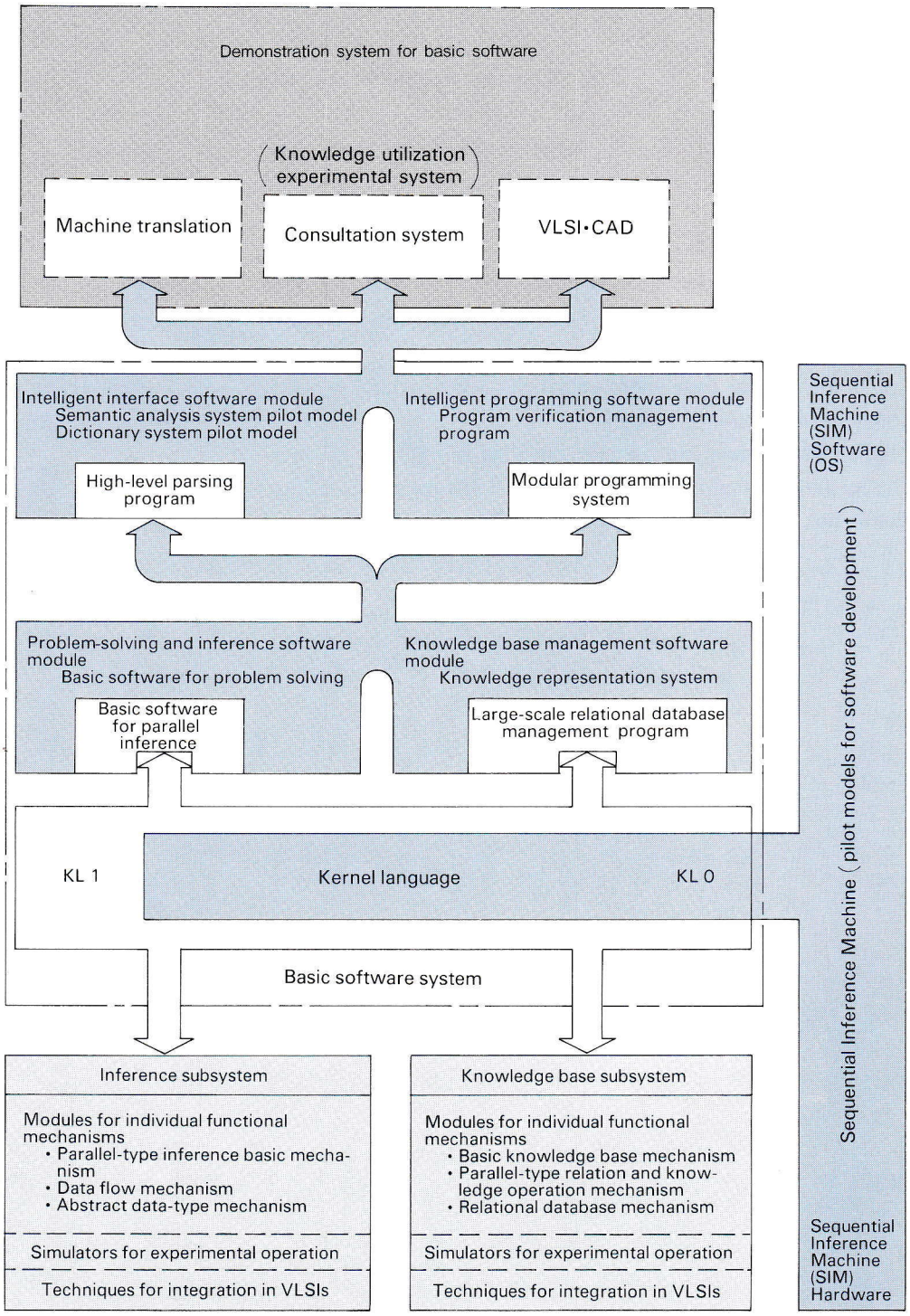

Fig.9 Overview of research and development in the initial stage

2. Major Results of the Initial Stage

The major results of R & D anticipated in the initial stage may be listed as follows.

1) Inference subsystem
   a. Investigation of various parallel inference schemes (data flow scheme, reduction scheme, clause unit scheme, complete copying scheme)
   b. Trial-fabrication of hardware simulators.
   c. Accumulation and evaluation of design data
2) Knowledge base subsystem
   a. Development of a parallel-type relational database machine (Delta)
   b. Establishment of specifications for a tightly-coupled interface with the inference machine.

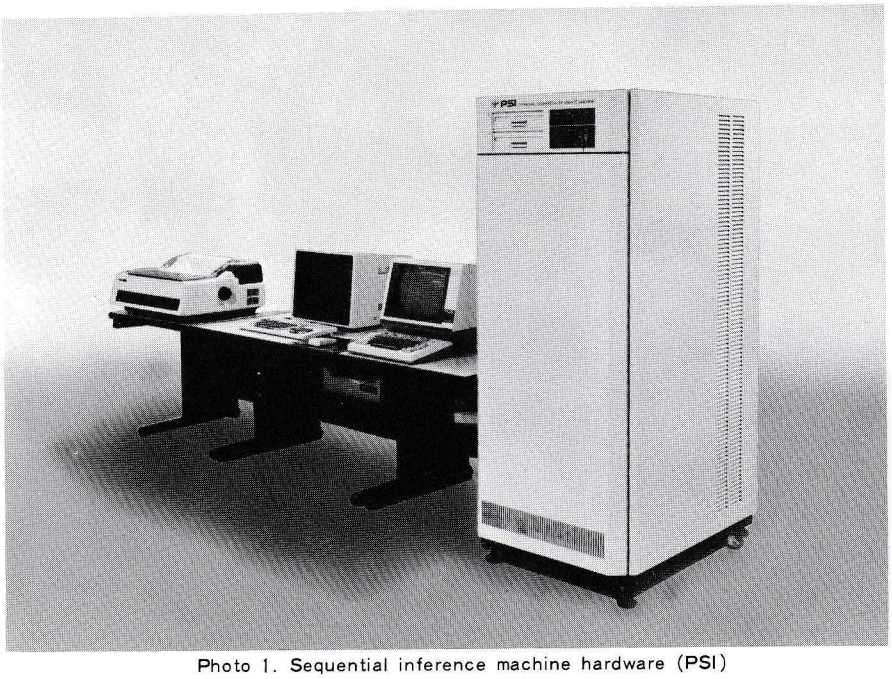

Photo 1. Sequential inference machine hardware (PSI)

3) Basic software system
   a. Establishment of parallel-type logic programming language (KL1) Specifications
   b. Development of the basic specifications for a knowledge programming language (Mandala)
   c. Development of a large-scale relational database management program (KAISER)
   d. Partial prototyping of a knowledge utilization system -Japanese proofreader support system, etc.)
   e. Development of an advanced syntactic analysis program (BUP)
   f. Trial-fabrication of an experimental semantic analysis program
   g. Development of a modular programming system (for use with SIM)
   h. Trial-fabrication of an experimental software verification management program
4) Pilot models for software development
   a. Development of sequential logic programming languages (KL0, ESP)
   b. Development of SIM hardware (PSI)
   c. Development of SIM software (SIMPOS)

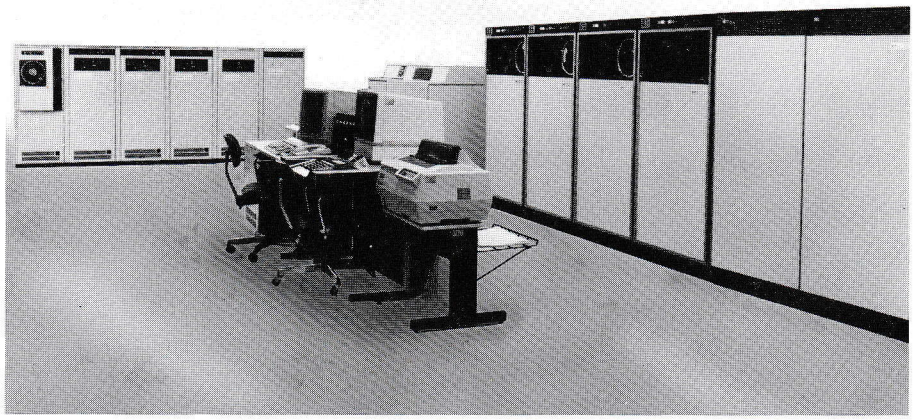

Photo 2. Parallel type relational data base machine (Delta)

3. R&D Subjects in the Intermediate Stage

Verification of R&D results thru. practical use

In the intermediate stage, while development at the subsystem level is being carried out based on the results of the initial three-year stage, R&D results will be verified in terms of practical utilization. This stage may be regarded as a period crucial to determining the final outcome of the Fifth Generation Computer Systems Project as a whole.

Two subsystems

The central area for R&D in the intermediate stage will be development and prototype fabrication of two subsystems with problem-solving and inference functions, and a knowledge base management function.

Trial-fabrication of a demonstration system for basic software

Knowledge information processing technology will be applied to real-world situations to attempt to verify related research results. The results of these applications will be evaluated and fed back into the project for use in work on each of the research themes. At the same time, a demonstration system for basic software will be constructed. Also, in order to support R&D on software technology based on parallel processing, work on a machine for parallel software development will be carried out.

Parallel software development system

The objectives of each R&D area are as follows (for details, see Appendix 2,"Proposed Research and Development Subjects for Intermediate Stage").

1) Inference subsystem

The architecture of a parallel inference machine (with about 100 processing elements) capable of efficient execution of programs written in Kernel Language version 1 (KL1) will be established, and experimental hardware will be fabricated.

2) Knowledge base subsystem

While clarifying the technology for implementing the type of knowledge operations that will be required by knowledge base machines, as well as establishing the parallel architecture specifications for the knowledge base machine, concrete details of the hardware will also be determined.

3) Basic software system

a. 5G kernel language

Themes include improvement of the first version of the Kernel Language (KL1), raising the system processing

speed, and determining the specifications of Kernel Language version 2 (KL2).

b. Problem-solving and inference software module

In a parallel processing environment (with a parallelism factor of about 100), attempts will be made to realize higher-level inference functions, such as those for inductive reasoning and analogy and to implement cooperative problem-solving functions.

c. Knowledge base management software module

Central themes for research are a distributed knowledge base and a knowledge representation language.

d. Intelligent interface software module

Research themes include an experimental semantic analysis system, electronic dictionaries, and an experimental interactive speech processing system.

e. Intelligent programming software module

Themes include design of a specification description language and an experimental design support system.

f. Demonstration system for basic software

In order to evaluate the validity of R&D results, an integrated evaluation system employing each of the basic software modules will be trial-fabricated.

4) Development support system

In order to increase R&D efficiency, a system for developing parallel software will be implemented.

This system will employ several closely coupled SIM machines. A local areas network will also be implemented.

4 SUMMARY OF THE ORGANIZATION OF ICOT

1. Establishment

The Institute for New Generation Computer Technology (ICOT) was established in April of 1982 as the central organization responsible for promoting the Fifth Generation Computer Systems Project: its research center was opened for operation in June of the same year.

2. Organization

ICOT is divided into research laboratories and general affairs offices. At present approximately 50 researchers and 10 administrative staff are employed at the institute.

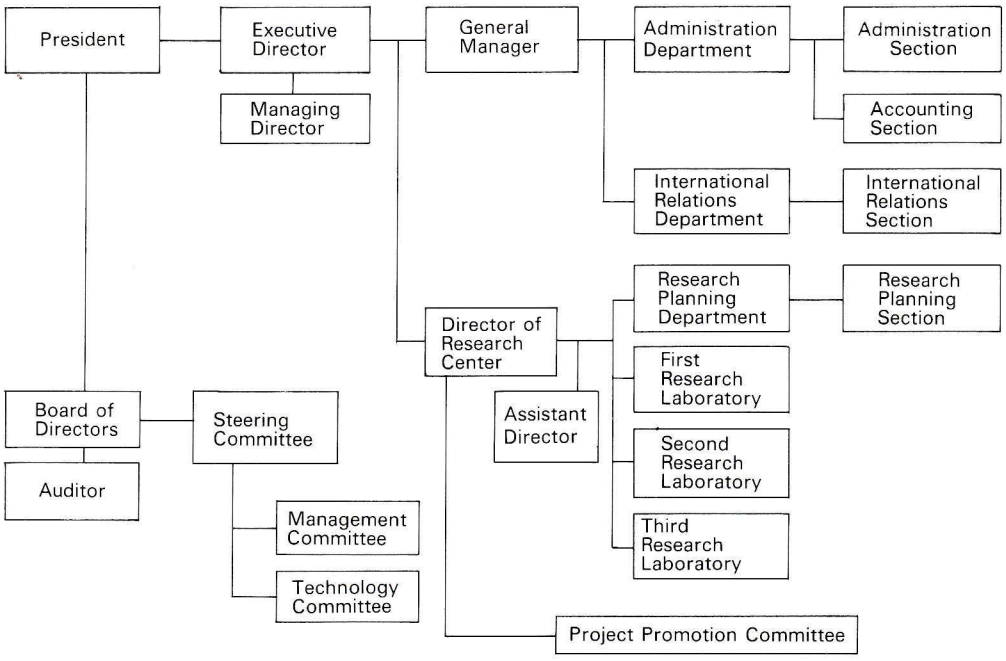

Fig.10 ICOT Organization

3. Activities

1) Research and development on the 5G computer

R&D activities on the 5G computer are being carried out under the auspices of the Ministry of International Trade and Industry, with funds alloted to the project amounting to ¥400 million in 1982, ¥2.7 billion in 1983, and ¥5.1 billion in 1984.

The work on basic technology for the 5G computer is performed by project teams consisting of members of the ICOT laboratories. In addition, a project promotion committee and working groups including acknowledged outside authorities have been formed to advise on the project and to exchange opinions with the ICOT research teams.

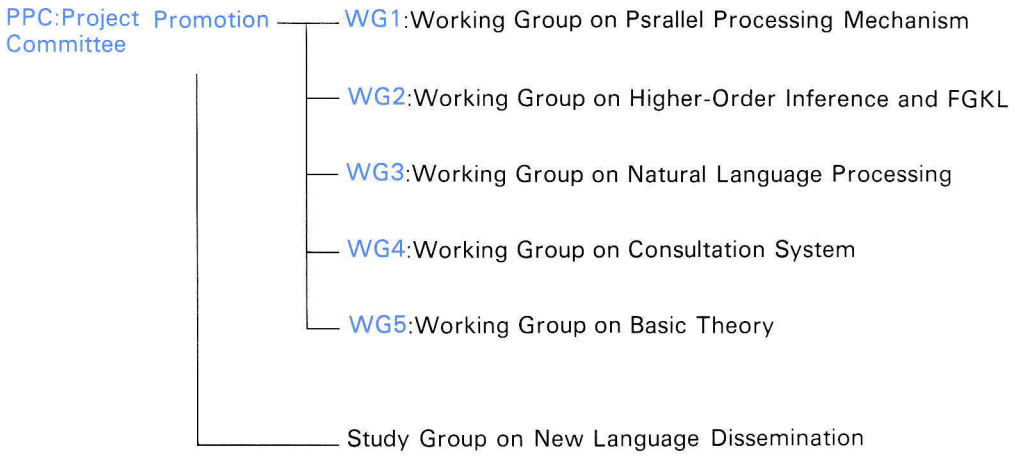

Fig.11 Organization of PPC

As the present R&D effort has as its object advanced technology, research workers are sent to advanced research organizations in the U.S. and Europe,to survey the latest technology and to exchange opinions. Experts from other countries are invited to Japan for short periods of time for purposes of research interchange.

2) Survey studies related to advanced computers

As one step toward promoting R&D on the 5G computer, survey studies are being conducted on trends in related technology both in Japan and abroad. These surveys, conducted by

committees of experts from various fields, seek to identify promising areas for fifth-generation applications and to evaluate the impact of new developments.

3) Promotion of international cooperation in R&D on 5G computers

In order to facilitate international exchanges related to R&D, the following activities are being executed.

(1) Dispatch of university and other researchers and specialists to the U. S. and Europe

(2) Preparation and distribution of English-language technical journals (such as the ICOT Journal and various Technical Reports)

4) Propagation and publicization of project results

ICOT sponsors a symposium each year to announce and explain the results of project R&D.

In addition, ICOT also issues a number of publications, such as the ICOT Technical Reports, Technical Memos, and the ICOT Journal, and through these makes positive efforts to transmit the results of its research.

5) Sponsorship of the International Conferences on Fifth Generation Computer Systems

In October of 1981, the International Conference on Fifth Generation Computer Systems (FGCS) was held in Tokyo, with approximately 300 persons attending from Japan and abroad; enthusiastic discussions of technical possibilities and problems took place. In November, 1984, the third year of the initial R&D stage, the international conference, called FGCS' 84, was held.

Through these international conferences on Fifth Generation Computer Systems, we at ICOT hope for fruitful exchange of opinions on the significance, goals and results of advanced technical development in this promising field.

Research and Development Subjects in the Initial Stage (FY 1982-1984)

Research & Development Subject	Details
Parallel Interence Machine (PIM)	The paralell inference machine, together with the knowledge base machine, forms the nucleus of the Fifth Generation Computer hardware. In the initial stage, an evaluation will be made of the basic inference module configuration. This module will consist of the following: (1) A parallel inference basic mechanism to manage the parallel execution of inference operations. (2) A data flow mechanism to execute inference operations and rapidly determine solutions. (3) An abstract data-type mechanism to consolidate detailed inference operations into several groups and control them by group.
Modules for Individual Functional Mechanisms for PIM	The parallel inference basic mechanism, data flow mechanism, and abstract data-type mechanism each consist of functional sub-modules. Initially, prototypes of these submodules will be constructed. These prototype sub-modules will then be integrated to construct a prototype module for each of the three functional mechanisms.
Simulators for Experimental Operation	Prototype simulators for experimental operation will be built to simulate module configurations using different combinations of sub-modules. They will also be used to determine the optimum configuration of the modules for the three functional mechanisms and also of the inference basic module, which these sub-modules will constitute.
Techniques for Integration in VLSIs	Prototype software will be developed to evaluate VLSI-convertibility for each of the sub-module circuits designed.
Knowledge Base Machine (KBM)	The knowledge base machine, together with the parallel inference machine, forms the nucleus of the Fifth Generation Computer hardware. In the initial stage, an evaluative study will de made on the configuration of the basic knowledge base module, which will consist of the following: (1) A basic knowledge base mechanism to provide overall management of the execution of basic knowledge base operations. (2) A parallel relation and knowledge operation mechanism to streamline knowledge accumulation, retrieval and updating, data, conversion, etc. (3) A relational data base mechanism to provide large-capacity knowledge accumulation, storage and management.
Modules for Individual KBM Functional Mechanisms	The basic knowledge base mechanism, parallel relation and knowledge operation mechanism, and relational data base mechanism each consist of functional sub-modules. Prototypes of these sub-modules will be constructed in the initial stage. These prototype sub-modules will be subsepuently combined to produce a prototype module for each of the three functional mechanisms.

Research & Development Subject	Details
Simulators for Experimental Operation	Prototype simulators for operational testing will be built to simulate module configuration using different number and combinations of sub-modules. They will also be used to determine the optimum configuration of the modules for the three functional mechanisms and also for the basic knowledge base module, which these sub-modules will constitute.
Techniques for Integration in VLSIs	Prototype software will be developed to evaluate VLSI convertibility for each of the sub-modules circuits designed.
Basic Software System	The basic software system forms the nucleus of the Fifth Generation Computer software, and is composed of the following four softwere module for knowledge information processing: 1. Problem-solving and inference software module 2. Knowledge base management software module 3. Intelligent interface software module 4. Intelligent programming software module An extended Fifth Generation Kernel Language, required for the intermediate stage, will be developed by organizing the knowledge, obtained through designing and breadboarding the basic software system. A prototype software system will be produced to test the specifications and to validate their accuracy.
Fifth Generation (5G) Kernel Language	The Fifth Generation Kernel Language, the base language for all other modules, will define interfaces between FGCS hardware and software. Development and evaluation of prototype Kernel Language version 0, (based on Prolog), is planned for the initial stage of the project. This will be followed by specification design and development of prototype Kernel Language version 1, oriented to parallel execution.
Problem-Solving and Inference Software Module	The problem-solving and inference software module has capabilities for deductive inference, inductive inference (including conjecture based on incomplete knowledge), and inference by mutual complementation of knowledge. The development of prototype basic parallel inference software is planned for the initial stage for use in high-speed execution of deductive inference and basic software for problem-solving to determine efficient solutions to problems.
Knowledge Base Management Software Module	The knowledge base management software module has capabilities for knowledge accumulation, distributed-knowledge source utilization, and knowledge acquisition. The development of a prototype knowledge representation system is planned for the initial stage in order to define knowledge representation methods. A large-scale relational data base management program is also planned to accumulate and manage a large volume of data represented as knowledge.
Intelligent Interface Software Module	The intelligent interface software module is for flexible interaction between human and computer. The development of a prototype of an advanced syntactic analysis program is planned for the initial stage. The aim is to achieve high-speed syntactic analysis and simplified algorithms for natural language understanding, which is critical to man-machine interaction. Basic techniques for semantic analysis and a pilot model of a dictionary system will also be developed.

Research & Development Subject	Details
Intelligent Programming Software Module	The intelligent programming software module will automatically convert a given problem into an efficient computer program (at the Kernel Language level). A program module management system capable of extracting component modules, and verifying program facilities is planned for development in the initial stage. Here, the aim is to establish modular programming, which is basis to intelligent programming, extraction of the necessary program, and program verification.
Sequential Inference Machines (SIM): Pilot Models for Software Development	Pilot models (prototype sequential inference machine will be implementd) for efficient development of software for the Fifth Generation Computer Systems. These models will be developed by modifying a selected language suitable for inference and by partly modifying existing von Neumann architecture.

Proposed Research and Development Subjectives for the Intermediate Stage

Research & Development Subjective	Details
Hardware Systems	The two subsystems which will form the nucleus of the Fifth Generation Computer hardware will be trial-fabricated. (1) In order to effectively execute programs written in Kernel Language version 1, about 100 processing element modules will be linked to form a prototype inference subsystem. (2) Knowledge processing implementation schemes will be investigated, and a number of processing element modules incorporating knowledge operation mechanisms will be linked to form a knowledge base subsystem.
Inference Subsystem	In order to implement the inference subsystem, R&D on the following five items will be carried out. (1) The dynamic characteristics of the parallel inference machine will be analyzed and evaluated, and the parallel inference machine architecture will be determined by means of simulations. (2) Prototypes of data flow, reduction and other mechanisms will be developed based on component modules. Each will make use of the highly parallel execution of KL1 programs. (3) A parallel inference machine architecture will be developed from about 100 processing elements linked in a network to form an experimental parallel inference machine. (4) R&D of a software system for controlling, testing and evaluating the parallel inference machine architecture and component modules. (5) In preparation for scaling-up the parallel inference machine (to about 1000 processing elements), studies will be made of large-scale parallel inference machine architecture, including fusion with machine models, VLSI architecture and knowledge base machines.

Research & Development Subjective		Details
	Knowledge Base Subsystem	In order to implement a knowledge base subsystem, R&D will be performed on the following five items: (1) Analysis and evaluation of the dynamic characteristics of knowledge base machines, and development of a knowledge base model to determine the architecture. (2) Further improvement and miniaturization of relational database machines (RDBMs), through adoption of VLSI components, and development of a knowledge base machine architecture to form the nucleus of the knowledge base machine. (3) Establishment of technology for configuring a distributed RDBM, centered on models of distributed relational database machines and control algorithms. (4) Investigation of schemes for integrating inference engines within RDBM machines, establishment of connection mechanisms for such schemes, and trial construction; also, research on knowledge base parallel control mechanisms to support parallel processing in knowledge base machines and the realization of knowledge operations. (5) In preparation for large-scale knowledge base machines, research will be conducted on large-scale knowledge base machine architecture, with a view toward implementation of machine models, VLSI architecture and knowledge acquisition and systematization mechanisms.
Basic Software System		The baic software systems will form the nucleus of the Fifth Generation Computer system, and will be composed of the following five modules for knowledge information processing: 1. Problem-solving and inference software module 2. Knowledge base management software module 3. Intelligent interface software module 4. Intelligent programming software module 5. Demonstration system for basic software Through the design and trial construction of the basic software system, the results gained will be consolidated and, based on these, version 2 of the Kernel Language will be specified for the final stage. In addition, software for use in actual verification of specifications will be created, experiments performed, and the specifications clarified further.
	Fifth Generation (5G) Kernel Language	The 5G kernel language, the base language for all other modules, will define interfaces between FGCS hardware and software. In the intermediate stage, design of specifications for KL2, which will become the language of the FGCS prototype system, will be completed. The processor and programming system of KL1, the specifications of which were determined in the initial stage, will be prototyped.
	Problem-Solving and Inference Software Module	The problem-solving and inference software module has capabilities for duductive inference, inductive inference (including conjecture based on incomplete knowledge), and inference by mutual complementation of knowledge. In the intermediate stage, the following four kinds of software will be developed. (1) Parallel inference software that operates on the basis of an advanced parallel processing algorithm, to perform high-speed deductive inference and problem solving. (2) Basic high level inference software, that is, experimental software that performs advanced inferences such as those for induction and analogy, and basic software for studying a learning function.

Research & Development Subjective		Details
		(3) Basic cooperative problem-solving software, that is, experimental software in which a number of problem-solving programs are made to cooperate to realize an inference function through mutual complementation of knowledge. (4) Demonstrative problem-solving and inference software, by which the results of research and development may be applied directly to actual fields of application, to verify the validity of the results, and also as a means for testing by feeding back evaluation results into the development of each type of software.
	Knowledge Base Management Software Module	The knowledge base management software module has capabilities for knowledge accumulation, distributed-knowledge source utilization and knowledge acquisition. In the intermediate stage, the following four kinds of software will be trial-fabricated. (1) A knowledge representation/utilization system, which not only includes functions for representation and accumulation of knowledge and for effective use of the knowledge gained using appropriate inference facilities, but which also contains tools for construction and support of knowledge bases. (2) Basic knowledge acquisition software, experimental software based on inductive inference, equipped with functions for acquiring knowledge. (3) Basic software for distributed knowledge base management, which manages a number of knowledge bases as a logically unified whole. (4) Demonstrative knowledge base management software, by which the results of research and development may be applied directly to actual fields of application, to verify the validity of the results, and also as a means for testing by feeding back evaluation results into the development of each type of software.
Intelligent Interface Software Module		The intelligent interface software module is for flexible interaction between human and computer. In the intermediate stage, the following five kinds of software will be trial-fabricated. (1) A semantic dictionary/semantic analysis system: analyzes meanings using a thesaurus (of Japanese, English, etc.) in knowledge-base form. (2) Basic software for sentence analysis and synthesis: experimental software that has sentence analysis and synthesis functions, which are basic to text understanding. (3) A conversational system pilot model: an experimental system offering comprehensive functions for smooth interaction via natural language. (4) A pilot model for an interactive speech processing system, to be trial-fabricated by studying techniques for analysis and understanding of conversational language; containing a large number of ellipses and which depends greatly on context; and based on technology for speech understanding and synthesis. (5) A pilot model for an interactive graphics and image processing system. Studies will center on techniques for representation of graphic and image data, and on unification with natural language. An experimental system will be created based on functions for graphic/image understanding and synthesis, in which large amount of information are to be exchanged. (6) Demonstrative intelligent interface software, by which the results of research and development may be applied directly to

Research & Development Subjective	Details
	actual fields of application, to verify the validity of the results, and also as a means for testing by feeding back evaluation results into the development of each type of software.
Intelligent Programming Software Module	Goals for the intelligent programming software module include automation of the basic operations involved in writing programs, developing and maintaining software, and the realization of integrated high-level support for all processes. In the intermediate stage, the following five kinds of software will be developed. (1) A specification description and verification system, in which high-level specification descriptions using natural or formal languages, as well as advanced program testing based on this, are performed. (2) A software knowledge management system, that organizes various programs developed on SIM machines into knowledge bases, and provides intelligent program development support. (3) Basic software for program transformation, verification and synthesis, experimental software that transforms programs with logical strictness using optimization and other factors as a measure, verifies the correctness of the transformation, and synthesizes software based on the transformation. (4) Experimental software for pilot model of a software design, production and maintenance system, by which all processes from software development through maintenance are consistently managed and supported. (5) Demonstrative intelligent programming software, by which the results of research and development may be applied directly to actual fields of application, to verify the validity of the results, and also as a means for testing by feeding back evaluation results into the development of each type of software.
Demonstration system for basic software	An demonstration system for basic software will be developed, by which results of each R&D subject may be applied directly to actual fields of application, to verify the validity of the results, and also as a means for testing by feeding back evaluation results into the development of each type of software.
Development support systems	In any advanced R&D project, appropriate development support systems are essential; in the initial stage, the SIM computer is being developed for use as a software development tool. In the intermediate stage, in order to facilitate R&D efforts, the following two systems will be developed: 1. A pilot model machine for parallel software development 2. A network system for development support.
Pilot model for parallel software development	The following will be developed for use in the system for parallel software development. (1) A machine for parallel software development, which will be capable of efficient development of parallel software, such as software for processing parallel KL1 programs and other parallel inference software. (2) A sequential inference machine (improved version), to be implemented by miniaturization and improvement of the hardware of the SIM developed in the initial stage, and for enhancing software functions.

Research & Development Subjective	Details
Network System for Development Support	A network system for supporting development efforts, to enable efficiently use of R&D results.

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