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VOLUME 2

NATURAL LANGUAGE PROCESSING AND ARTIFICIAL INTELLIGENCE: IMPLICATIONS OF NEW TECHNOLOGY THRUSTS

COGNOS

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NOTE

This report is the second volume in a series of reports addressing Natural Language Automated Processing and Artificial Intelligence. The reports in this series are:

- The State-of-the-Art
- Implications of New Technology Thrusts
- Possible Social and Economic Impacts
- Opportunities for Canada
- A Program Plan, and
- Priorities for Canada

EXECUTIVE SUMMARY

The Technology Thrusts Report examines the current state of world-wide efforts to push AI, expanding remarks from the State-of-the-Art Report. The technology thrusts are clearly exhibited in the analysis of various national and multi-national efforts in Japan, the United Kingdom, the United States, the Netherlands and the EEC. Particular attention is paid the the similarities and differences in their research and development programs as well as the institutional frameworks under which R&D activities are carried out. The broad centrally planned efforts of Japan and the United Kingdom are contrasted with the diverse and decentralized efforts in the United States. The complex relationships of the EEC are reviewed as are the narrowly focussed efforts of the Netherlands. Collectively, the thrusts and the institutional environments in which they are being carried out provide both a background and a real set of comparative approaches which can be used in identifying opportunities for Canada and organizational characteristics suitable to a Canadian program.

The level of international effort is significant. In the programs discussed in this report, most of them spanning 5 or less years, the allocated funding is estimated to be in excess of four billion dollars.

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1. IMPLICATIONS OF NEW TECHNOLOGY THRUSTS

1.1 HIGHLIGHTS OF THE STATE-OF-THE-ART REPORT

The State-of-the-Art Report focused on the fields of artificial intelligence (AI), machine translation (MT) and natural language processing (NLP). In particular the position of MT and NLP was expressed in the wider context of AI. This was accomplished by first examining the state-of-the-art in expert systems, speech recognition, optical character recognition and machine vision, graphic communications and the human-computer interface. This was done in order to set a tone for future research, development and commercialization opportunities with respect to both MT and the broader area of NLP. For example, much work in contemporary NLP has a direct lineage to less than state-of-the-art AI research. However, in the case of promising new developments in NLP the programming languages, representational data structures and search algorithms draw on techniques used in current AI research. This parallel is also true for MT systems. Most commercial MT systems tend to be based on an older and less sophisticated understanding of linguistic and artificial intelligence principles. However, current research in high performance MT systems is beginning to draw from contemporary AI principles.

This dichotomy, at least for MT, suggests an interesting commercial opportunity in the form of suboptimal approaches when the application domain, the research and development goals, and the necessary market needs are clearly defined. The consequence of such an awareness should assist in defining or at least separating short term and long term objectives with respect to both research and development of commercially viable products.

Allied to this approach is the need to take a broad view on issues outside MT and NLP as they relate to the handling of complex software, innovations in hardware technology, and cognitive processes associated with humans using MT and NLP systems.

From an AI, MT and NLP point of view the state-of-the-art report addressed a wide range of historical, current and planned activities in research, development and commercialization of products. Today, the net result is an intensely competitive international scene in which the Japanese announcement of the Fifth Generation Computer Project is generating strategic responses from many countries.

1.2 DEFINITION OF TECHNOLOGY THRUSTS

Within the context of this report 'technology thrusts' are defined in terms of an:

- engineering or technical breakthrough;
- advance in technological sophistication brought about by rapid transfer of scientific principles through technological know-how; and
- internationally accepted view within the technical community of promising commercial benefits to be gained from a technological innovation.

Within the domain of MT, NLP and allied areas of AI, we find a wide range of possible products based on current scientific principles and technological thrusts. As will be seen from this report, the marshalling of national and even international resources are creating considerable technological push in the development of new tools for the information processing industry. The stimulus for this push is coming from a very strong market-pull. The market is demanding more sophisticated, reliable and easier to use systems to assist in information processing.

1.3 TECHNOLOGY LIFE CYCLE OPTIONS

In recent years intense international competition for information technology products has forced both corporations and their national governments to adopt to new technology life cycle strategies as a means of keeping ahead. Five different strategies are identified in Exhibit 1-1. Each in its own right is capable of producing technology thrusts. However, the number and rate at which new thrusts are possible depends very much on the particular strategy adopted and the complexity of the end product. Each strategy in Exhibit 1-1 will now be considered in more detail.

EXHIBIT 1-1

CHOICE OF STRATEGY

RELATING TO TECHNOLOGY

LIFE-CYCLES*

STRATEGY	DESCRIPTION
Basic Research and Development	Object is to advance frontiers of knowledge. Concentration on discovery and invention.
Adopt	Imitation of foreign technology or purchase of patents or licences.
Adopt and Adapt	Emulation with improvement. Concentration on innovation.
Leap-Frog	Enhance a technology by superseding current limitations.
Paradigm Change	Skip an entire technology generation and go on to the next.

* adopted from Valaskakis et al. 1980

Traditionally basic research has as its purpose the probing of those aspects of nature's phenomena not yet clearly understood. This form of research usually produces theoretical and experimental results with potential value in many science and engineering applications. Over and above this, basic research seeks to answer fundamental questions about the laws of nature without regard to how they might be exploited in applied science and technology. Traditionally such research is carried out in government laboratories, universities and nonprofit research institutions. The results are expected to be disceminated through traditional scholarly reporting.

On the other hand, research carried out by a corporation is carefully selected to boost the effectiveness of the science and technology that apply to the product lines of the corporation. Although this research is expected to generate new knowledge, it is secondary to the mission of corporate research. The basic tenet is to focus on applied research with the expected outcome to be some form of invention.

More recently and with increasing rapidity new and aggressive strategies are coming into play which are deemed to give both corporations and their central governments leverage in bringing products to market. In each case these new approaches counter the competition by exploiting their efforts.

Adopting a foreign technology through patent rights, licensing or even mimicking can minimize both domestic penetration of a foreign product as well as reduce the market share of such a product should the adopted product be successfully marketed beyond domestic borders. This process circumvents the lead time necessary for discovery and invention. However it does not likely have any effect on prolonging the life of the product because there have been no enhancements made to the product. On the otherhand, adopting and adapting a foreign technology by innovating on the current product can create a wider market and a longer life for the product in the market place. Leap-frogging, or enhancing a technology by superseding its current limitations may arise from ongoing R&D or by carrying the adoption process well beyond the limits of competitive products. A final life cycle option is to change paradigms by skipping technology generation and going on the next. This step has associated with it a high overhead in new R&D efforts.

Information technology and in particular the broad arena of artificial intelligence technologies fall within all of these strategies. For example, dramatic advances in microelectronics and fundamental computer science are presenting immense opportunities for complex software systems to evolve to handle a wide range of natural language processing requirements. It is interesting to note that this situation has been made possible by a technology push in creating appropriate machine environments and a market pull seeking technological solutions to information processing problems for a vast user community.

In addition to changes in the fundamental strategies on how to capitalize on new technologies we are seeing serious attempts at evaluation of national strengths and missions among many technologically advanced nations. A major emphasis is being placed on so called strategic technologies such as information technology of which AI, NLP and MT are a part.

1.4 THE CAUSE FOR THE THRUSTS IN INFORMATION TECHNOLOGY

By the middle of the twentieth century a major shift was occurring in the fundamental structure of the global economy. The traditional strengths of the industrialized nations were shifting from a predominant manufacturing component to a major service oriented component. With this change came a dramatic need to process information. A tremendous market pull developed for products to support processing needs. The technological solution to these needs was the computer.

In a relatively rapid succession the computer was introduced, enhanced and proliferated. These processes were driven by both market pull and technological push. The computer's purpose was to support the data processing needs of organizations such that the information outputs could be used in decision making. However, from the beginning and up to today the computer has remained a tool at the hands of only specialists. The realization that applying linguistic theory, cognitive sciences, and artificial intelligence, among others, to both contemporary computers as well as computers with new and novel architectures has created an opportunity to address more complex analysis, production and control problems. Machine translation is a good example of a complex type of analysis problem suitable for current and emerging computers. In the area of NLP, the proliferation of both computerized workstations and microprocessor based computers are, for example, creating a potentially vast market for natural language interfaces to information systems. A result of such interfaces coupled with other general natural language computer based tools points in the direction of democratizing information.

2 THE INDUSTRIALIZATION OF ARTIFICIAL INTELLIGENCE

2.1 INTRODUCTION

Since the introduction of the first electronic computers in the 1940's the concept of rendering intelligence to the computer has been a continually sought after goal. Among the earliest endeavours were experiments in machine translation (MT). Naive approaches, limited computer 'power' and software failings led to rethinking the complexity of processing natural language. Meanwhile a revolution in computer hardware and software technologies continued through the nineteen fifties, sixties and seventies. Today both hardware and software are in their fourth generation. In addition, special purpose machines and artificial symbol manipulation languages have been developed to push out the frontier for creating intelligence in computer systems. The kernel to much of the new frontier work is in the area of natural language processing (NLP).

The proliferation of the computer and its emerging prevasiveness in government, business, educational institutions and the home is producing a market pull for enhanced software products that make the computer a more flexible and useful tool. This need is clearly seen in progressive Data Processing shops where the computer user community demands greater ease of use and more powerful applications software to meet the changing profile of the user community as applications building and applications complexity shifts from centralized computer professional services to decentralized and independant applications users who in the main are not computer specialists. NLP is key to providing the man-computer communications where the intent is to create machines that can communicate with people rather than train people to communicate with machines.

Allied with NLP is a rising awareness among both government and industry for the need to re-evaluate machine translation as a vehicle to support the burgeoning demands being put on human translators be it for the translation of official government texts such as in Canada and the European Economic Community or in industries for such things as manuals associated with complex technologies.

During the last few decades slow and steady progress has been made in establishing principles of NLP and MT. Most of the work has been carried out in universities, predominantly in the United States. Thus, today, both the hardware and software technologies as well as fundamental principles of NLP and MT are sufficiently advanced that a new synergy is in the offing.

2.2 THE INTERNATIONAL ENVIRONMENT

The structural change taking place among industrial economies in their shift from manufacturing to information and service based activities is tantamount to a switch from brawn power to brain power. Consequently, this offers further potential for industrial restructuring in response to accelerating worldwide competition to supply information technology in support of this shift.

The energy shocks of the nineteen seventies and the recession of the early eighties adversely affected much of the manufacturing and service industries and caused severe reprecussions in employment and productivity. Productivity improvement and growth are inextricably linked. Therefore, a return to more favorable economic conditions may result in a rapid growth in new information technologies to aid in developing improved efficiency in manufacturing and service industries. On the other hand, continuation of recessionary times will likely see an even greater demand for productivity improvements and cost efficiencies as mature industries in the developed countries decline in the face of new industrial states emerging from the 'Third World'. In such an environment innovation in information technology will likely focus on productivity improvements without much opportunity to service the broader requirements of the emerging information society such as wide spread national language access to databases or wide spread machine translation systems.

Regardless of the sway in the global economic condition, information technology is going to be critically important. The emerging attitude in industrialized countries towards 'brain power needs' will provide considerable impetus for an expanding interest in artificial intelligence based products. In fact, a key implication of this scenario for AI applications is the emphasis it will tend to place on evaluating new technologies according to their ability to enhance productivity.

2.3 THE EMERGENCE OF NATIONAL EFFORTS

Basic and applied research in artificial intelligence and allied fields has been on going for some thirty years. The majority of this effort has originated in the United States where most of the research has been sponsored by the Defense Advanced Research Projects Agency (DARPA) and other defense research granting agencies. Universities and nonprofit corporations have been the main benefactors.

Historically, other nations involved in artificial intelligence research such as the United Kingdom, Canada and France have supported their efforts through government sponsored granting agencies and departments. Again the majority of funding going to universities. This pattern of basic research and development has remained relatively static until recently. In the autumn of 1981 a dramatic shift took place which continues to generate repercusions throughout the industrialized world. Japan announced a ten year plan to develop the fifth generation computer. This constitutes a paradigm shift to the next generation of technology. At the heart of this plan is artificial intelligence and new hardware designs appropriate to supporting sophisticated information processing.

In the following sections we will examine in some detail the key thrusts within a number of 'national efforts'. The analysis will start with Japan.

2.3.1 The Japanese Plan

In late 1978 the Japanese Ministry of International Trade and Industry (MITI) initiated an effort to define a project to develop computer systems for the 1990's. The broad terms of reference required that the project should avoid direct competition with IBM, provide Japan with considerable economic advantage and enhance Japan's international prestige. This task was assigned to the Japanese National Electrotechnical Laboratory (ETL).

After investing some one hundred man-years in planning, a strategy to develop over a 10 year period the fifth generation of computer technology was publicly announced at a specially convened international conference in October 1981. In the Spring of 1982 the program was officially launched under the auspecies of the Institute for New Generation Computer Technology (ICOT).

The aim of the project is to create computers that meet the following functional requirements:

- display intelligence and portray ease of use that they will be better able to assist man;
- lesson the burden of software generation; and

- incorporate functional capabilities and performance characteristics which make them useful in meeting social needs.

In concept form the fifth generation computer will utilize knowledge information processing systems having very high-level problem solving capabilities.

Justification for the 10 year plan, as presented at the October 1981 meeting, placed emphasis on:

- the social requirements expected of computers in the 1990's;

- the technological background leading to the development of the fifth generation computer; and

- the significance of the project from a Japanese perspective.

This project combines research for a number of areas of computer science and artificial intelligence. Specifically it is proposing to develop an integrated computer system containing and supporting the following principle components:

- knowledge bases

- knowledge base query

- inferencing machine

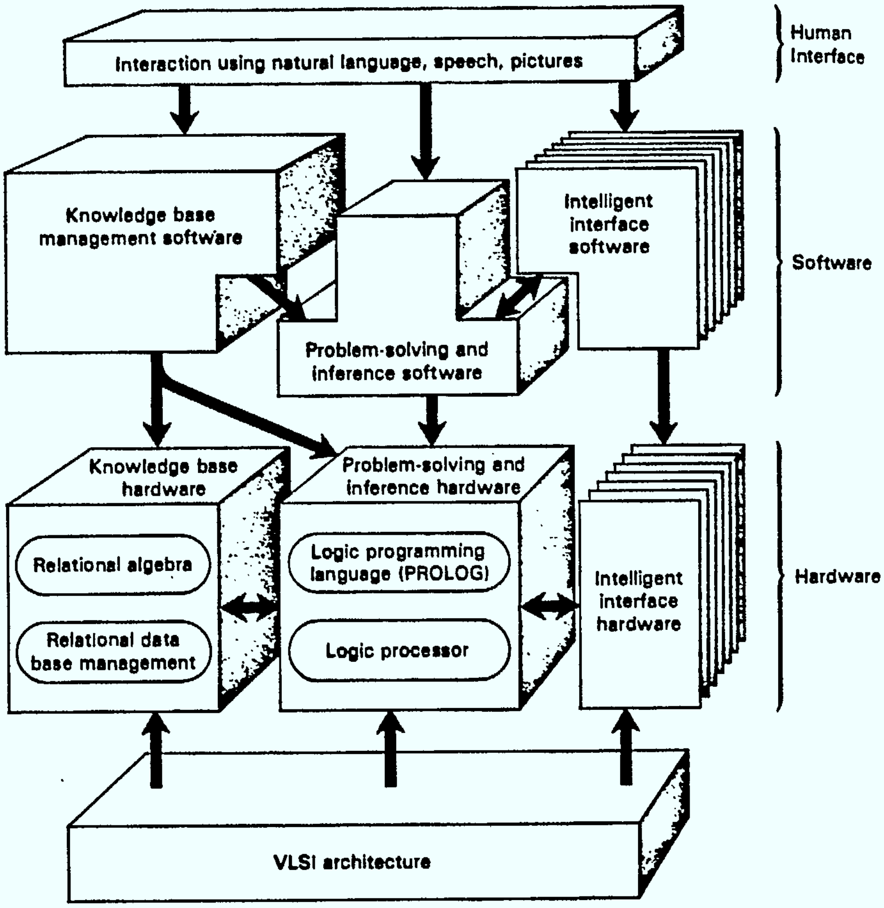
- natural language query, and

- expert systems.

In schematic view the fifth generation computer system is characterized by Exhibit 2-1 in which the proposed computer system is portrayed in three layers identified as the human interface, software and hardware.

EXHIBIT 2-1

Fifth-Generation Computer Systems



The human interface layer is intended to permit interaction between the machine and users through such facilities as natural language, speech and pictures. The software layer would include the knowledge base management software, problemsolving and interface software, and intelligent interface software. The third layer represents the hardware environment. It is intended to be comprised of specialized hardware subsystems specifically designed to support software systems. Each of these subsystems would be based on very large scale integration (VLSI) architecture.

Some of the ambitious themes and targets established for this project are presented in Exhibit 2-2. These are further borken down into 26 research and development themes as illustrated in Exhibit 2-3.

EXHIBIT 2-2

Themes and Targets of Basic Application Systems
For the Japanese Fifth Generation Computer Project

Machine translation system

- Multi-lingual translation
- Word capacity: 100,000 words
- Translations should be 90% accurate, with the remaining 10% processed (edited) by humans
- Should be an integrated system capable of taking part in each of the processes from compilation of the text to the printing of the translated documents
- The entire cost of translation should be 30% or less than those made by humans

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Question answering system

- Should be a system prototype for answering questions in a variety of professional fields
- Word capacity: 5,000 words or more
- The number of inference rules: 10,000 or more

Applied speech understanding system

- Phonetic (voice inputting) typewriter:
  Should handle 10,000 words, posses a meaning analyzing function, be capable of correcting errors in speech by itself, and output sentences easy to understand
- Speech-responding system:

EXHIBIT 2-2 (cont'd)

Themes and Targets of Basic Application Systems For the Japanese Fifth Generation Computer Project

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Applied speech understanding system (cont'd)

Should handle 10,000 words, be able to grasp the meaning of responses and thus be capable of natural conversation

- Speaker identification system:
  Should be able to handle a few hundred people or more and identify speakers within a practical interval of time

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Applied picture and image understanding system

- This system should actually store about 100,000 pieces of information in picture and image forms so as to be usable for knowledge information processing

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EXHIBIT 2-3

Items for Research and Development of the Japanese Fifth Generation Computer Project

Basic Application Systems	• Machine translation system • Question answering system • Applied speech understanding system • Applied picture and image understanding system • Applied problem solving system
Basic Software Systems	• Knowledge base management system • Problem solving and inference system • Intelligent interface system
New Advanced Architecture	• Logic programming machine • Functional machine • Relational algebra machine • Abstract data type support machine • Data flow machine • Innovative von Neumann machine

EXHIBIT 2-3 (cont'd)

Items for Research and Development of the Japanese Fifth Generation Computer Project

Distributed Function Architecture	• Distributed function architecture • Network architecture • Data base machine • High-speed numerical computation machine • High-level man-machine communication system
VLSI Technology	• VLSI architecture • Intelligent VLSI CAD system
Systematization Technology	• Intelligent programming system • Knowledge base design system • Systematization technology for computer architecture • Data base and distributed data base system
Development Supporting Technology	• Development support system

The first major development in the Japanese plan calls for a personal inference-computer for developing knowledge-processing software. This device will have a processor architecture similar to conventional computers rather than the advanced parallel processor arrays planned for the next step in fifth generation computer architecture.

2.3.1.1 Selected Research and Development Themes for the Japanese Plan

Among the many research and development themes in the Japanese plan the basic application systems, basic software systems and systematization technology may be of particular interest from a Canadian perspective. The specific components of each of these themes are summarized below: (after Moto-oka et al., 1981).

a) Basic Application Systems

Basic application systems represent functions characterized in human terms such as hearing, speaking, seeing, drawing, thinking and problem solving.

Consideration will be given to:

- machine translation
- question answering system

- applied speech understanding system
- applied picture and image understanding systems, and
- applied problem solving system.

i) Machine Translation

Results of research in documentation techniques and artificial intelligence for knowledge utilization will be combined in order to develop an integrated multi-lingual translation system. The specific R&D objectives include:

- designing a machine translation system and its core;
- development of the grammars for the languages;
- development of sentence generating grammars;
- development of a specialized terminology data base;
- development of a machine for the specialized terminology data base; and

- development of high-level word processing techniques.

The targets and specifications set for these tasks include:

- handling 100,000 words;

- machine translation accuracy of 90%, the difference to be handled by translators;

- the system must handle general purpose computer functions such as text compilation to printing of translated documents; and

- produce translation at a cost of 30% or less than that by translators.

ii) Question Answering System

The objective is to develop a question answering system for application in specialized fields such as intelligent computer-aided engineering/computer-aided design sytems, decision support sytems and intelligent robots. The R&D details are as follows:

- develop conversation analysis techniques;

- develop graphic data input/output capabilities;

- develop specialized data generating systems;

- create input error detecting processing techniques; and

- design and develop grammars and dictionaries for natural sublanguages.

Targets and specifications for the question answering system include:

- an interim target to be achieved in 5 years is to develop a trial question answering system for limited use in particular specialized fields. Specific characteristics for the interim system include:

    - 2000 Japanese words;

    - the user provides supplementary information to eliminate ambiguity;

    - the number of inference rules set at about 1000.

Following the development of the interim system it will be evaluated and prototype question answering systems will be developed for various specialized fields where the number of words will be expanded to 5000 and the number of inference rules increased to 10,000 or more.

iii) <u>Applied Speech Understanding System</u>

This facet of the project is aimed at research and development of a speaker identification system as part of a general-purpose speech responding system for input and output in machine translation, a phonetic typewriter and a telephonic inquiry system. The R&D details include:

- development of a phonetic typewriter;
- development of a speech responding system; and
- development of a speaker identification system.

The program targets include the following for each of:

- Phonetic Typewriter

- as an interim target a system of simple sentence construction data to handle several hundreds to several thousand words;

- as a final target a system capable of handling about 10,000 words with meaning analysis, automatic error correction during speech recognition, and generating comprehensible sentences.

- Speech Responding System

  - as an interim target ability to handle several thousand words;

  - as a final target a system capable of handling about 10,000 words, comprehending the meaning of questions to be answered, and developing a sophisticated structure to enable natural conversation.

- Speaker Identification System

  - as an interim target the system should be able to identify fifty to sixty speakers;

  - as a final target the system should be able to identify several hundred speakers within a practicable interval.

vi) Applied Picture and Image Understanding System

The research and development theme is to create a system for storage of picture and image data and provide effective retrieval of such information. The R&D details include:

- research on picture and image data storage and retrieval;

- development of a language system to retrieve picture and image data;

- development of a picture and image data base machine;

- development of a system to store and retrieve picture and image data.

The targets and specifications include:

- creating a picture and image data base of up to 100,000 retrievable picture and image data items;
- the system must store picture and image data within a few seconds;
- picture and image data must be retrievable within 100 m sec. on the average;
- as an interim target up to 100,000 pictures and image data items are to be handled and processed at about half the final target speed.

v) <u>Applied Problem Solving System</u>

The intent here is to develop a sophisticated formula understanding system. The game known as Go will be used as a model. Specific research and development tasks include:

- creating a formula understanding system for mathematical expressions;

- creating a system capable of playing Go.

The targets and specifications include the following for each of:

- formula understanding system

  - interim target to achieve performance characteristics similar to MACSYMA with inequalities and simple equation processing functions;

  - the final objective is to develop a knowledge representation and problem solving system related to formula combining sophisticated formula manipulating algorithms.

- Go game playing system

    - the interim target is to have an intermediate game playing system;

    - the final target is an advanced game playing capability.

b) <u>Basic Software System</u>

The 'basic software' system will constitute the core of the fifth generation computer. It will be comprised of a group of modules corresponding to basic information processing functions. There are three principle components each of which are as follows:

- Knowledge-based management system

- problem solving and inference systems, and

- intelligent interface system

i) <u>Knowledge Based Management System</u>

This task requires extensive research and development in intelligent system management techniques capable of formatting and storing human knowledge in a computer while at the same time supporting the user in solving problems. The five key research and development areas are as follows:

- research on knowledge representation and utilization techniques;

- knowledge acquisition and learning;

- research on a large-scale knowledge base system;

- development of a knowledge base management system; and

- development of a knowledge base management machine.

Targets and specifications include the following groupings:

- knowledge base management system

    - the interim targets consists of developing simultaneous management of rules and data, a data base access optimization mechanism, a mechanism for eliminating inconsistencies, and an interface with an inference machine;

- the final target is to have a multiple-world knowledge base, a distributed-knowledge base, learning based on inductive inference, and linkage to an inference machine.

- knowledge base machine

  - making inferences from 2,000 rules and one million data items is set as an iterim target;

  - for the final target these will be increased to inferences from 20,000 rules and 100 million data items.

ii) Problem Solving and Inference System

This will consititute the core of the processing functions in the fifth generation computers. The basic approach will be research to develop a problem solving system by establishing a processing model of the problem solving and inference system and explain its processing ability theoretically. The R&D objectives address:

- research on problem-solving and inference algorithms;
- development of a coding language to solve problems.
- development of an inference machine.

The targets and specifications include;

- the coding language for problem solving must also support functional and logic programming as well as object-oriented modular programming. The programming modules generated will form a knowledge based software component for effective use in intelligent programming.

- the inference machine should be capable of performing between 100 million to 1000 million logical inferences per second or 1000 million to 10,000 million instructions per second.

iii) Intelligent Interface System

This subsystem comprises the R&D necessary to create techniques for flexible conversational functions and elimination of the language gap between the user and the computer. The primary focus is on natural language and speech systems. The R&D details include focusing on:

- syntactic analysis
- semantic analysis
- discourse analysis
- sentence construction
- construction of a language data base
- multi-language basic grammar generation
- a phoneme identification system
- a speech synthesis system
- a system to recognize the differences between individual speakers, and

- development of a speech understanding system.

The targets and specificaions associated with this array of required R&D efforts include:

- creating man-machine communication techniques based on natural language or speech data as a means to create an intelligent man-machine interface;

- the natural language and speech system is intended to fulfill the following target:

    - vocabulary to be handled will include specialized as well as frequently used terms;

    - the system must adapt itself to speakers and communicate with unspecified speakers;

    - the system must be capable of speech output in both Japanese and English; and

- the system must identify speech signals on an almost real-time basis.

Similar details have been developed for all aspects of the research and development plans as outlined in Exhibit 2-3. In summary they are comprised of software and hardware components.

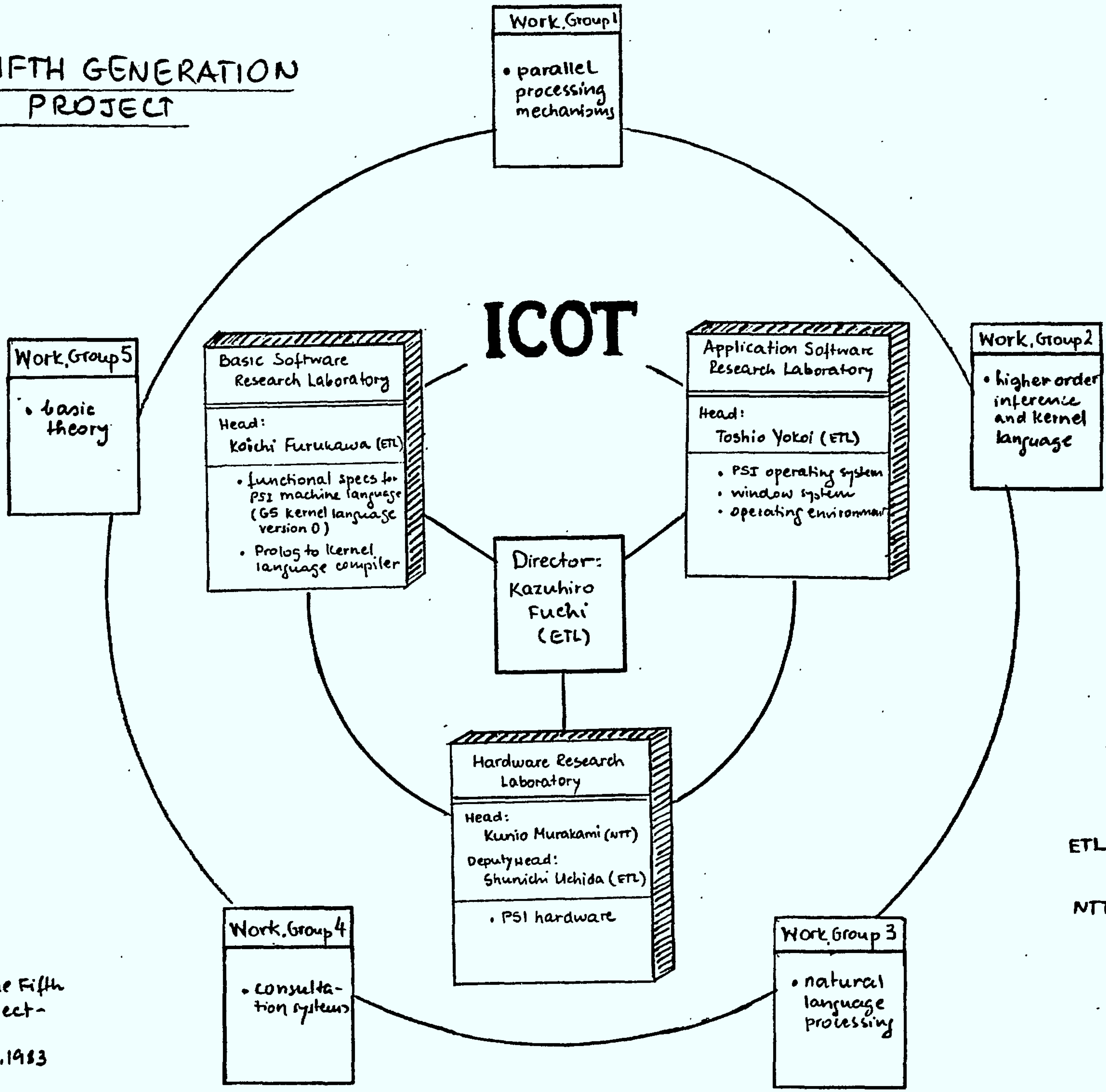
In order to execute this overall plan within the 10-year time frame set out for the project, it would appear that a massive amount of research and development is required.

The Japanese launched the program with an open invitation for other nations and organizations to cooperate. However, to date most response has been nationalistic in that various countries and non-Japanese institutions are seeking ways to organize and plan a counter the Japanese Fifth Generation Project. The stakes are high.

2.3.1.2 The Organization of the Japanese Effort

The Ministry of International Trade and Industry (MITI) has played the key role in establishing the Fifth Generation Project. The Ministry attends to the long term interests of the Japanese economy through a concerted effort of anticipating the future while watching the past. As noted in Feigenbaum and McCorduck (1983), MITI has policies

THE FIFTH GENERATION PROJECT



Source of info:
E.Y. Shapiro, The Fifth Generation Project - A Trip Report, Comm. ACM, Sept. 1983

ETL - Electrotechnical Laboratory

NTT - Nippon Telephone and Telegraph

EXHIBIT 2-4

for both declining and emerging industries. Through an elaborate and successful information and analysis section MITI tracks worldwide industry trends. Furthermore, MITI nurtures long term relationships with the various sections of Japanese industry. In so doing, its policies and plans generally reflect the consensus of members of a given industrial sector. MITI's aim is to create the strongest possible corporations with the greatest competitive potential (Vogel, 1980).

As prelude to the current project MITI felt it was time that Japan become a major innovator in advance technologies. Creating a new generation of computers ideally suited this requirement.

The Institute for New Generation Computer Technology (ICOT) coordinates the entire project. It is responsible for the design of all hardware and software for the fifth generation subsystems and for the development of all software. The computer hardware manufacturing will be contracted out to Japanese computer companies. ICOT is staffed by both government and private sector personnel. The organization of ICOT is portrayed in Exhibit 2-4. The member organizations in the Project are identified in Exhibit 2-5.

ICOT's work is not considered to be proprietary with respect to member organizations. However, industrial researchers will be rotated on a three to four year basis back through their parent organization. The purpose of the rotation program is to encourage indepth transfer of know-how back into the participating enterprises.

EXHIBIT 2-5

PARTICIPANTS IN THE JAPANESE FIFTH-GENERARTION COMPUTER PROJECT

Industrial Participants

- Electrotechnical Laboratory
- Fujitsu Laboratory
- Hitachi Ltd.
- Japan Electronic Computer Co., Ltd.
- Matsushita Commication Industry Co., Ltd.
- Mitsubishi Electric Co., Ltd.
- Nippon Electric Co., Ltd.
- Nippon Telegraph and Telephone Public Corp.
- Oki Electric Industry Co., Ltd.
- Toshiba Corp.

University Participants

- Keio University
- Kyoto University
- Seikei University
- Tohoku University
- Tokyo Institute of Technology
- University of Tokyo
- Waseda University

In addition to these industrial groups within ICOT, there are also closely allied research and development groups in each parent corporation. The purpose of these groups is to track the project and foster proprietary R&D inhouse.

As a further organizational consideration, each firm has identified a particular area or areas of interest for their productization plans. ICOT supports this view and works to accomodate corporate needs.

This well thought out plan for developing fifth generation computers places a clear emphasis in moving Japan out of its traditional technology life cycle options of adopting and adopting and adapting. Emerging from this project is a strong Japanese will to generate creative innovations and succeed in the ultimate aims of the project. The excellent innovation vehicles and the cooperative venture between government, industry and universities appears well suited to a long-term R&D effort, even if some of the research appears to require major breakthroughs.

Many Western technologists have been very skeptical about the prospects for success in the Japanese effort. Their mistake is in applying the wrong definition of "success". The Japanese 5G project <u>will</u> succeed--indeed, it has <u>already</u> succeeded--not just in a technological sense, but in a much broader, more lasting, and (hence) more significant way. It has focused Japanese attention and energies in new directions, engendering new organizational as well as technological innovations. (from G.E. Lindamood, 1983)

2.3.2 The British Response

In the winter of 1982 the Government of the United Kingdom (UK) established the Alvey Committee in direct response to the Japanese Fifth Generation challenge launched in the autumn of 1981. The committee was set up under the auspicies of the Minister for Information Technology with the purpose to advise the ministry on the scope for a collaborative research program in information technology and to make recommendations appropriate to a British response.

The British took the Japanese plan very seriously. They further considered that an American plan would be forthcoming. The Alvey Committee put forward a national action plan focusing on four so called enabling technologies as follows:

- software engineering (10 years)

- interface between man and machine (5 years)

- intelligent knowledge based systems (e.g. expert systems) (10 years), and

- VLSI production methods and new hardware architectures in support of new intelligent systems (10 years)

Highlights of the Alvey Report include the following (Alvey Committee Report 1982)

- there should be a national 5 year program for advanced information technology (IT)
- the aim of the program is to mobilize UK strengths in IT
- the program should be a collaborative effort between industry, academia and other research organizations within the UK
- a research support and training program should be established in universities
- a high level of Government support is essential
- a broadly based program is needed with specific technical targets and coverage of important interactions and overlaps between the enabling technologies
- the program roughly doubles existing UK efforts in the enabling technologies
- the program covers pre-competitive activities such as basic research, communications infrastructure to link researchers

- foreign multinationals should participate only where they can contribute a particular asset vital to the program and where it is guaranteed that valuable technical information will not leak from the UK;

- the EEC ESPRIT program is complementary to the UK effort but Japan, US and others are serious challenges, and

- it is vital to generate more skilled human resources to develop advanced IT products

- unless there is action to implement this IT program the prospect of the UK competing successfully in the world IT market will be sharply reduced. The speed of advanced IT applications in the UK will also be sharply constrained. Both of these would be extremely damaging to employment prospects to UK industrialized efficiency and to the general UK economic position.

2.3.2.1 Enabling Technologies

The enabling technologies identified in the Alvey Committee Report form the foci of the UK plan for advanced IT. The R&D efforts associated with each will now be considered. The plan calls for the UK to become as world leader in software engineering by the end of the current decade. The means by which this may be achieved are centered around the development of 'information systems factories' (ISF), which in principle will be hardware/software systems used to develop IT systems using software engineering techniques. The major subsystems of an ISF will include:

- specification and prototyping capabilities;
- programming support aids for complete systems;
- life cycle development;
- CAD tools for VLSI design;
- knowledge base of re-usable hardware and software components (appropriate to this type of IT application being built); and
- local and wide area network interconnections

The man/machine interface component of the study will address:

- human factors such as communications, cognitive compability with systems and expertise transfer between humans and computers

- input/output devices with particular reference to building high resolution scanners and copiers.

- speech and image processing which will include speech recognition, speech synthesis, feature extraction and pattern recognition

The Intelligent Knowledge Based Systems (IKBS) or expert systems phase of the study is a major component of the overall program. The IKBS effort will address:

- research in all aspects of IKBS

- development of IKBS based on program research, and

- production of development prototypes.

As part of this activity demonstration projects will be established as the level of knowledge and technical know-how increases.

The final enabling technology, VLSI, incorporates a number of steps associated with the engineering and materials science technologies involved in silicon chip manufacturing. Also included in this part of the program is a major investment in computer aided design in support of developing VLSI chips.

2.3.3 The American Response

The American response to the Japanese plan has primarily come from the grass roots level, where universities and a number of corporations have voiced concern about the potential impact of a successful Japanese effort in fifth generation computer technology. More recently, a Congressional Committee has been appointed to examine the Japanese plan in the context of whether it constitutes a threat to American supremacy in the computer industry. Similarly a number of organizations such as the National Science Foundation and the National Aeronautics and Space Administration have been actively involved in assessing various aspects of the technologies outlined in the Japanese plan.

The United States does not have a national plan which is dedicated to the development of fifth generation computers. There are, however, a number of major projects underway or in advanced planning stages. Funding for these efforts is coming from both the private sector and the public purse. Notable among private sector efforts is the Microelectronics and Computer Technology Corporation (MCC). Established in January 1983 as a consortium of American corporations with a vested interest in advanced computer technology it now comprises 13 corporate members. They are identified in Exhibit 2-5.

Exhibit 2-6

<u>Consortium Members of the Microelectronics and Computer Technology Corporation</u>

Advance Micro Devices Inc.
Control Data Corp.
Digital Equipment Corp.
Harris Corp.
Honeywell Inc.
Martin Marietta
Mostek
Motorala Corp.
National Semiconductor Corp.
National Cash Register
RCA Corp.
Sperry Corp.
United Technologies

The consortium has come together as a direct commercial challenge to the Japanese and in advance of proposed relaxations in US antitrust law regarding joint venture R&D.

MCC has established four R&D projects. The projects, each of a different duration, are as follows:

- advanced computer design project (10 years).
- software technology project (7 years);
- computer-aided design and computer-aided manufacturing project (CAD/CAM) (8 years); and,
- advanced research into packaging and interconnecting integrated circuits (6 years);

The advanced computer design project has as its objectives four concurrent activities:

- an artificial intelligence effort to establish the theoretical basis for AI architectures and to develop a prototype system capable of 100,000 inferences per second;

- a prototype database machine architecture with a 10 fold performance improvement over present processing architectures;

- a human interface system incorporating prototype speech and image recognitive capabilities; and

- the development of one or more parallel architectures.

The first three years of this 10 year project are devoted to assembling and assimilating all available knowlege in each theme area. Within 3 years it is anticipated that VLSI technology will be sufficiently well understood to permit its effective integration across all four areas. The development of actual prototype systems would not likely start until about the seventh year of the project.

The software technology project will emphasis the use of intelligent systems by developing new means by which users and programmers interact. These systems will be based on principles of artificial intelligence.

The CAD/CAM project has similar objectives to the Japanese Fifth Generation Project. Specifically it aims to:

- reduce design costs for chip making by advancing the state-of-the-art, and

- improve the quality of production by permitting the mixing of chip technologies in layout while allowing from 1 million to 10 million devices.

The objectives of the packaging project are to:

- create packaging and interconnection technology that is compatible with automatic assembly at the integrated circuits and system level;

- maintain flexibility for different applications; and

- support a high per count device (eg. greater than 400)

The overall intention of MCC is to create a Centre of Excellence which chooses its own research and development programs in support of its shareholder partners and provides its participants with a three year lead in exploiting any technology or process developed within MCC. MCC will release its discoveries and inventions to the open market through licensing agreements after a three year proprietary period. Once licensing fees start to flow MCC expects to turn a profit.

On a slightly different front another consortium, made up of a number of large American semiconductor manufactures, established the Semiconductor Research Cooperative (SRC). SRC operates by channelling funds through universities as a means to develop highly innovative new VLSI designs which could be licensed back from the universities. This permits the member companies to participate in a technology transfer process while receiving certain tax concessions for their investments. The motivation for establishing SRC comes directly from the recent and rapid erosion of American dominance in certain fields of the semiconductor industry as a direct result of Japanese government and industry programs.

The biggest backer of AI in the United States is the military. Over the years the Department of Defense has provided the bulk of funds for U.S. AI researchers. The primary recipients have been universities and nonprofit research corporations. The Defense Advanced Research Projects Agency (DARPA), the Office of Naval Research (ONR) and the Air Force Office of Scientific Research (AFOSR) have, among others, been the key suppliers of funds and users of AI applications.

In 1982 the U.S. Defense Science Board completed a study of the key technologies considered critical to military interests. These are illustrated in Exhibit 2-7. Of a total of 17, AI and associated areas figured high in four categories. The number three priority is advanced software with a predominant component of artificial intelligence.

EXHIBIT 2-7

U.S. Defense Science Board list of Future Technology Priorities.

1. VHSIC (Very High-Speed Integrated Circuits)
2. Stealth bomber
*3. ADVANCED SOFTWARE (Artificial Intelligence)
*4. COMPUTER-AIDED INSTRUCTION (CAI)
5. Fault-tolerant electronics
6. Rapid solidification technology
*7. MACHINE INTELLIGENCE (ROBOTICS/AI)
*8. SUPERCOMPUTERS (VLSI)
9. Advanced composite materials
10. Monolithic focal-plane arrays
11. Radiation-hardened electronics
12. Space nuclear power
13. High-power microwave generators
14. Space structures
15. OPTOELECTRONICS
16. Space radar
17. Short-wavelength lasers

* These items represent areas with major AI components.

In November 1983 DARPA announced funding a so-called Strategic Computing Plan. The plan specifically focuses on the development and application of machine intelligence to defense related problems. In particular the research areas include applying AI to:

- autonomous vehicles
- expert associates; and
- large-scale battle management systems

The project is both hardware and software oriented. New computers will be developed which will be equipped with sensory and communications modules enabling them to hear, talk, see and act on information and data they develop or receive. In addition, it is intended to develop special computers that will exploit opportunities for concurrent processing of expert systems. Software will be dominated by expert systems.

DARPA will use an extensive infrastructure of computers, computer networks, rapid system prototyping services, and silicon foundries to support the development of these new intelligence based computers. The ARPANET will be heavily used in liking participants and establishing a productive research environment.

The project is scheduled for launching in early 1984 and is expected to run for at least 5 years.

EXHIBIT 2-8

U.S. AI COMPANIES

Company	Market Area
Applied Intelligent Systems	Visual
Artificial Intelligence Corp	Language
Automatix	Visual
Bolt Beranek & Neuman Inc	Instruction
Centigram	Voice
Cognex	Visual
Cognitive Systems Inc	Language
Computer* Thought Corp	Instruction
Control Automation	Visual
Decision Products Inc	Language
Everett/Charles	Visual
Excalibur Technologies Corp	Language
General Electric	Visual
Int Robomation/Intelligence	Visual
Intelligenetics	Expert Systems
Interstate Electronics Corp	Voice
Machine Intelligence	Visual
Nippon Electronic Co America	Voice
Object Recognition Systems	Visual
Octek	Visual
Perception Inc	Visual
Robotic Vision Systems	Visual
Scott Instruments Inc	Voice
Smart Systems Technology	Expert Systems
Symantec	Language
Systems Control Technology Inc	Expert Systems
Tecknowledge Inc	Expert Systems
Threshold Technology Inc	Voice
Verbex Corp	Voice
Votan	Voice

source DM Data Systems 1983

Traditionally the forte of AI research in America has been carried out at universities. Consequently most AI researchers are still attached to academic institutions. Recently universities, particularly those with AI programs such as MIT, CMU, Stanford and Yale, have been attracting considerable attention from the US computer industry. Contributions have included foundation funding for such activities as the Center for Study of Languages at Stanford and equipment grants for computer learning projects such as Athena at MIT.

In addition to the outstanding contributions to AI from many American universities an entirely new source of AI enterprise has developed. The heightened interest in recent years over the commercialization of AI products has created a plethora of entrepreneurial AI corporations. Although some have been around for several years, the majority have only recently opened for business. Exhibit 2-8 illustrates a recent selection of such corporations and also identifies the key market area for their products.

In addition to ongoing AI research in large corporate laboratory and government facilities a select group of nonprofit corporations continue to make significant contributions to the field of AI. Most notable among these are SRI and MITRE Corp.

In summary, although there is not a national plan nor even a clear national position in the U.S. regarding the emerging field of fifth generation computers and the myrid of subsystems associated with their introduction, a consensus is emerging and various forces are positioning to reap what they believe will be the benefits. This includes a plethora of new or recently formed companies working on AI, MT and NLP problems and products.

2.3.4 The Dutch Response

In August 1982 the Dutch Ministry of Education and Science established an Advisory Committee on Artificial Intelligence to provide recommendations to the government on the implications for Dutch industry of the emerging field of artificial intelligence. The committee, comprised of academic and government personnel, undertook to assess the field of artificial intelligence from both an international and a Dutch perspective. Of particular concern to the study team was the need to define and develop an appropriate strategy that would provide a balanced research and development effort in the Netherlands on an appropriate scale to efforts underway elsewhere.

The current state of AI in the Netherlands was found to be weak. Industry, at least up to the present, has not invested significantly in AI R&D. Similarly AI research in universities and government laboratories has been limited. In universities where expertise does exist the strength lies in problem solving, natural language processing and cognitive science.

Four objectives have been identified as a means to enhance the activity in the Netherlands. They are as follows:

- stimulate R&D in AI in order for Dutch industry to remain competitive

- initiate both fundamental and applications oriented AI research programs in universities and government laboratories
- create closer links between academic research and industry in order to foster R&D transfer to industry, and
- stimulate a cooperative environment between Dutch and foreign researchers with particular reference to efforts in the European Economic Community.

In order to meet these objectives, a set of research and development areas have been defined in context of:

- current strengths
- areas of particular national interest, and
- generally accepted areas key to AI applications development

A program for specific research and development had been identified to include:

- natural language and speech processing;
- knowledge-based expert systems with particular application to solving technical problems;
- cognitive modelling and human-computer interaction, and
- tools to support AI research

In order to formalize these research thrusts each area has been cast into an initial five year program as follows:

i) Natural Language and Speech Processing

The aim of this program being to create:

- text processing tools equipped with linguistic knowledge of Dutch;
- a transportable natural language interface system to specific types of databases, and
- a speech synthesis system for Dutch

ii) Knowledge-Based Expert Systems

This program is intended to address both fundamental and applications oriented research in knowledge-based systems. In the case of the former, the focus is on:

- knowledge representation formalisms;
- knowledge acquisition techniques, and
- problem solving methods

The applications research areas aim at developing:

- an inference system handling queries and updates to a database, and

- expert systems appropriate to the design of elementary VLSI circuits and for planning and budget control of engineering projects

iii) Cognitive Modelling and Human-Computer Interaction

The aim of this program is to increase the effectiveness and acceptance of human-computer interactions. Suggested components for fundamental research include:

- examination of conceptual models and misconceptions of computer users
- analysis of prototypical errors
- determining ways for cooperative problem solving
- developing acceptability criteria for computer systems, and
- studying the principles of information exchange between humans and computers.

Anticipated applications areas resulting from this research would be the creation of:

- tools and design principles for developing human computer interfaces.
- a methodology for building expert systems with tools for extracting the knowledge from human experts and for building adequate interfaces, and

- development of computer based instruction and teaching techniques suitable for, among other things, undergraduate subjects such as physics.

iv) Tools to Support AI Research

It's the intent of this the fourth and last program to develop tools to support AI research in general and industrial and educational applications in particular. The fundamental research component of the program should include:

- research into the primary language used in AI
- the implementation of AI language and systems on new computer architectures

Practical results of this program include:

- development of a personal computer for AI research
- creation of an inexpensive personal computer for practical applications in industry, the office and education, and
- create an interface between the personal AI computer and classical software.

2.3.5 European Economic Community Response

Under the auspices of the EEC, member states have chosen two major initiatives aimed at maintaining world class expertise and technology opportunities within Europe. Through the largest project, ESPRIT, it is hoped to revitalize the European information technology industry with the ultimate goal of creating a major world class centre for advanced information technology within 5 years. Unfortunately some member states are blocking funding or seeking restructuring of unrelated areas in the EEC. Concurrently, several countries notably the UK and France have their own national IT programs which may in practice dilute the overall EEC effort.

The EUROTRA MT project aims at creating machine translation across all pairs of EEC member languages. It is a complex undertaking which is somewhat complicated by the sheer number of participating nations. Initial funding is for 5 years.

2.3.6 Program Approaches

2.3.6.1 Japan

The Japanese have opted for a centrally planned approach to launch and run their Fifth Generation Computer Project. Under government auspices a group of public servants and academics invested considerable effort in developing a national plan. They then set about to institutionalize the process whereby the basic R & D could be undertaken. This has been achieved by assigning coordinating authority for the project to a central government laboratory, the Electrotechnical Laboratory, which in turn has created a new institution, the Institute for New Generation Computers (ICOT), to execute the plan. At the same time, a number of major Japanese electronics and Computer Corporations were asked to express their specific interest and enter into the project by supply staff to ICOT. ICOT's research is equally shared by all participants and much of it is in the public domain. The ICOT research teams are intended to be catalysts to independent and parallel R & D groups within each of the participating company. Once ICOT work is transferred into corporate laboratories it becomes proprietary whereupon the individual corporations exploit their areas of specific interest.

2.3.6.2 United Kingdom

The UK government launched into a 10 year national plan with a request for 5 years of funding for advanced information technology in direct response to the challenge issued by Japan on establishing a new generation of smart computers. The Plan, commissioned by the government, was primarily prepared by a group of industrialists and academics. What the UK plan advocates, which is not unlike other countries, is to take a very nationalist view and proclaim the need to maintain national technological leadership by exploiting existing resources in ways that parallel the key elements of the Japanese plan. In effect they have opted to take a broad approach at addressing emerging areas of artificial intelligence and microelectronics. Consequently the British thrust is to put more resources into what they are currently doing. A major part of which is catching up to North American know-how in software engineering.

The organization structure around which this plan is to operate is framed by a proposed new Directorate within the Department of Information with liaison and support coming from the Science and Engineering Research Council and the Ministry of Defence.

The UK plan advocates the role for local and wide area networks to serve the needs of researchers.

2.3.6.3 <u>United States</u>

To date the United States has chosen not to create a coordinated national plan but rather let the market determine preferred interests. In support of the overall AI effort in America the Government is using the Department of Defense, notably DARPA, and granting agencies such as the National Science Foundation and the National Institute of Health to create market demands by sponsoring extensive research and development in universities and non-profit corporations. Major Defence procurements in AI promise to stimulate innovation in the private sector AI corporations as well as loosen the flow on private venture capital.

Proposed changes in antitrust law with respect to cooperative R&D and tax incentives for research contributions to universities are adding to the flow of capital. The net result is the development of a number of new Centres of Excellence. Through these centres and associated AI companies the chances of significant breakthrough and technological innovation appear to be high.

Existing national computer networks are being used to facilitate exchanges among researchers.

2.3.6.4 The Netherlands

The Dutch government has approached the issue of emerging information technologies in a similar way to the Japanese albeit on a smaller scale. A national plan has been created by a government/academic group which addresses the key areas of concern to the government in terms of keeping Dutch industry competitive. The organizational framework calls for united efforts among the relatively small AI community with coordination through a national steering committee. The committee has responsibility for stimulating, coordinating and evaluating AI R & D. Once a national purpose is established, traditional funding agencies will be used to support scholarly research. A stimulation program to transfer technology and know-how from the universities to industry is also advocated. It should be noted that a national computer network is envisaged as a key to linking the Dutch AI community.

2.3.6.5 The European Economic Community

The major EEC effect in AI and related areas are operating on a grand scale. In part this is a result of the complex of nations and organizations operating within the EEC. Although the intent of these project are excellent the complexity in concept as well as management make them difficult to assess in terms of intended success.

2.3.7 Summary of National Efforts

The announcement by Japan of the Fifth Generation Computer Project in the Autumn of 1981 has brought a flurry of responses from a number of industrial countries. The nature of the responses has varied from scattered industrial and government agency plans, as in the case of of the United States to a massive cooperative venture on the part of the European Economic Community. The intent is clear--compete for a piece of the emerging information industry or be left in the electronic third world. Canada too must seek a position. It is hoped that this series of reports will provide a framework from which to guide the nation in its effort to effect some degree of world class role in this emerging information industry.

The net effect of the Japanese effort, independent of technical success at home, may be to have triggered a 'sputnik effect'. Major national and international efforts are being mounted to create the concept of the fifth generation as so openly laid out by the Japanese. The tasks at hand are extremely complex. There are many unknowns. The ability to bring to bear the necessary resources in the form of scientist, engineers and management is critical. Significant commitment is emerging and a world wide momentun is building. Whether the Japanese are successful in meeting all their objectives no longer seems critical. A series of world class centres of excellence are emerging. Motivated for various reasons the opportunity for innovative developments seem likely. The nature of many of these ventures seems to provide an open opportunity for access to basic research and development. Technology transfer will likely disseminate very rapidly through licensing and leap frogging.

3. PROGRAM FUNDING

3.1 Introduction

Up to this point program funding has not been identified in order that comparison of dollar efforts could be assembled in one place.

The complexity of funding sources varies considerably from country to country, in part due to the breadth and depth of efforts underway; consequently the funding levels identified below should be considered minimal values. Exhibit 3-1 presents a breakdown by country and project. The current level of funding is staggering - over 4 billion dollars from just the projects identified in the Exhibit. This does not account for the myriad of NLP, MT and related AI projects in scores of countries and numerous institutions.

EXHIBIT 3-1

Earmarked and Estimated Allocations for Ongoing AI Related Research

Japan			
Supercomputer Project	1981-83		$ 125,545,000
	1984-89		N/A
Optoelectronics Project	1979-83		$ 98,181,600
	1984-86		N/A
Fifth Generation Computer Project	1981-83		$ 54,546,000
	1984-91	est	500,000,000
United Kingdom			
Alvey Committee plus others	1983-88		$ 340,000,000
	1988-92	est	300,000,000
United States			
DARPA	1984-88		$ 600,000,000
MCC	1983-86		150,000,000
Center for Integrated Systems	1983- ?		19,000,000
Center for Study of Language	1983-87		15,000,000
Project Athena	1983- ?		70,000,000
AI Corporations (DM Data)	1983-84		210,000,000
NSF	1983-84	est	25,000,000
NIH	1983-84	est	25,000,000
The Netherlands			
National AI Program	1983-87		$ 3,400,000
The European Economic Community			
ESPRIT	1983-88		$1,500,000,000
EUROTA	1983-88		28,000,000
	TOTAL		$4,063,672,600