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VOLUME 4

NATURAL LANGUAGE AUTOMATED PROCESSING AND ARTIFICIAL INTELLIGENCE: OPPORTUNITIES FOR CANADA

COGNOS

1984 FEBRUARY 29

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 HER MAJESTY THE QUEEN IN RIGHT OF CANADA (1983) as represented by the Ministers of Secretary of State and Department of Communications.

NOTE

This report, Opportunities for Canada, is the fourth 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

ACKNOWLEDGEMENT

The material in this report has been assembled on behalf of the contractor by Nordicity Group Ltd. It is based on input from various members of the study team and includes information supplied by numerous outside sources contacted through interviews. We are particularly grateful to Professor Mackworth of the University of British Columbia for his contribution on computer networking in Canada (Appendix 1).

Executive Summary

The Opportunities for Canada Report defines criteria for assessing Canadian opportunity and analyzes the players and interests in the artificial intelligence field in Canada. The key conclusions of this analysis are the following:

- government is active through several departments in machine translation, communications, defense, remote sensing and robotics;
- Canadian universities have a comparatively strong scientific base, although it is somewhat fragmented and dispersed geographically;
- the computing industry through which technology transfer would be carried out consists largely of foreign branch plant players in hardware and in software has some embryonic supply capabilities;
- Canadian industry as yet has a low level of demand interest.

Examining key applications areas, there are particularly interesting prospects for Canada in the areas of Machine Translation, Computational Vision and Natural Language Processing, while work in expert systems, and specialized robotics is required for particular domestic applications needs.

Current R&D funding is likely on the order of $5 million annually and an estimated 160 people, including 40-45 professors, are working in MT, NLP and AI in Canadian universities. Relative to the activities of other nations such as Japan, the United States and the United Kingdom, it was concluded that a larger effort is required if Canada is to compete successfully in information technology.

The Report recommends government leadership in support for research and academia, and through procurement for development. It is proposed that specific programs be instituted to support AI research by:

1. Provision of partial release time for computer science teachers and administrators to pursue AI/NLP/MT research, and provision of post doctoral fellowships for AI.

2. Creation of a new NSERC Strategic Grants Panel for AI.

3. The provision of state-of-the-art computing facilities for AI researchers. These are now cheaper and more powerful than previously but a capital investment of \$50k-\$150k per researcher is necessary (the level depends on the area of research). This should be recognized in the Strategic Grants program for AI. One or two of the existing AI centres should be funded for AI software development: to maintain, develop and import/export useful software tools. They should be supplied with the necessary infrastructure support to operate on a long-term basis. The need for high level equipment for AI research is also one of the recommendations made by the Waltz report for the US where, as we have seen in the state-of-the-art report, the level of support by industry (in the form of equipment donations) is extremely high compared with Canada.

4. Development of a computer network modeled along the lines of the ARPA network in the US (see appendix on networking).

5. Support for Computer Science through the Computing and Information Science NSERC Grant Selection Committee should be increased by at least 50% per year for the next 3 years.

Proposals for procurement activities are as follows:

1. A major effort in second generation machine translation with the lead Mission Department being the Secretary of State, and with funding support from the DND, where requirements are high. This effort could be cast in time frames and phases to permit not only specific hardware objectives, but also to provide for some element of broader, longer-term break-through research and development. In this regard, note emphasis the Secretary of State placed on viewing MT as part of AI in general.

2. A significant effort in NLP and intelligent databases, geared to office automation, databases for medicine, law and other professions, and to provide access to government data for both bureaucrats and consumers, and to command and control requirements in the military. This could include for example DOC and DND.

3. A major effort, partly centered in CCRS, to develop both image analysis and expert systems for applications in the resource sector, as well as in priority areas of medicine and education.

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Opportunities for Canada

1. Introduction

In this report, opportunities for Canada will be assessed by attempting to carry forward from the portions of the 'state-of-the-art' and the 'technological thrusts' to a position where some vision of domestic and global future needs, and competition, as well as realistic assessment of Canadian capabililty can be visualized.

In order to do this, 'opportunity' will be defined and then criteria will be set down for the assessment and measurement of an opportunity. In this connection and given the intensely competitive and urgent nature and character of activities in Machine Translation (MT), Natural Language Processing (NLP) and Artificial Intelligence (AI) technology, it is clear that a realistic assessment of an opportunity for Canada must include not only the occasion of technological advantage or market demand, but must also include factors such as existence of competition, the presence of industrial and commercial capability, the availability of manpower and other resources, and the presence of institutional mechanisms capable of facilitating exploitation.

A framework for visualizing future development will be discussed at a very general level to set a few bounds in which to work. The existing Canadian players and interests which could play a role will be laid out in an overview of the Canadian AI community.

1.1 Overview State of the Art

The State-of-the-Art report described an intensely competitive international scene in AI, NLP and MT, in which the Japanese announcement of the Fifth Generation computer is provoking strategic response in many other countries.

The British initiative is being focussed through the Alvey Report, and is likely to provide for concentration on software engineering, on the man-machine interface, on intelligent knowledge based systems (IKBS), and on very large scale integration (VLSI) technology.

West Germany, Italy, France, the Netherlands, Norway and Sweden are all formulating strategies and accelerating efforts in recognition of the crucial importance of the technology.

In the United States although no national program as such has been defined, AI, and NLP are receiving massive amounts of funding through the Department of National Defense (DOD), the National Institute of Health (NIH) and the National Science Foundation (NSF). While these programs are relevant to MT, it is not being directly supported.

What we are also witnessing in the United States is the development of strong collaborative initiatives in research between the larger computer companies (in the form of the Microelectronics and Computer Corporation (MCC)), and in the formation of many new small companies anxious to capitalize on research capabilities of the Universities, and to obtain leadership position in the new AI technology market place.

Against this international context, the Canadian situation reflects relatively strong specialised research capabilities in machine translation, in medical and resource related expert systems, and in the vision aspects of robotics. There is also substantial expertise in cognitive processes related to man-machine interaction and in the area of computational linguistics. Corporate user interest is beginning to emerge in a number of sectors, and various Departments of the Federal Government, (eg. Secretary of State, Department of Communications, Department of National Defence) are beginning to formulate strategic approaches to the technology.

1.2 Technology Thrusts

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 which have arisen in the past few years. In particular, the efforts in Japan, the United Kingdom, the United States, the Netherlands and the EEC are examined. Particular attention is paid to 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 assault of 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.

1.3 Definition of Opportunity

What needs to be considered next is the definition of opportunity. Opportunity cannot be regarded only as comprising a technological edge, and indeed the success of technological innovations has often been frustrated by the negative impact of other factors.

Thus, the definition of opportunity in a Canadian context encompasses many of the following criteria.

1. Where there is a base of, or potential for, competitive Canadian expertise, in an international context. In this connection, the expertise would embrace:

    - authoritative back-up research;
    - technical capabilities in industry as a basis for commercialization efforts;
    - marketing, managing and financing.

2. Where there is domestic market which might absorb front-end research, development & commercialization costs.

3. Where there is evidence of a niche market in the international arena.

4. Where there is a strong national need which could serve as a stimulant to the technology e.g., resource management, health care, education, agriculture, bi-lingualism, transportation, communications, manpower retraining.

5. Where there is strong or potentially strong industrial capability to organise and deploy resources for the innovation and commercialization process.

6. Where there is the appropriate institutional framework to facilitate the appropriate research and development activity.

7. Where sufficiently specific research/technical/marketing goals can be developed, in order to provide for adequately focused efforts.

8. Where, as necessary, foreign sources of technology can be readily accessed.

9. Where, for some reason, the international community has neglected R&D for reasons other than lack of technical potential.

10. Where the thrust involved is complementary to, or can be linked to, other major policy and/or technology thrusts, e.g.,
    - office and industrial automation;
    - major productivity improvements;
    - CAD/CAM;
    - Text translation programs;
    - Defence programs;
    - Computer Aided Learning;
    - Microelectronics;
    - provincial programs for modernizing education (e.g., Ontario, Quebec);
    - resource monitoring.

These criteria will be used to assess and measure opportunity in each sector of Artificial Intelligence technology.

1.4 Framework for Future Development

A general framework of future developments in key areas will be established as a basis for the detailed analysis and discussion which follows. The areas include economic conditions, movement of industrial structure to the information age, basic technological thrusts and development of AI industry structure.

The base assumptions are as follows:

1. general economic conditions: slow global growth through to 1990; sustained recovery 1990 to 2000.

2. information age: industry experiences accelerated change through to 2000.

3. international trade and information exchange:

   - trade continues along GATT basis, with some non-tariff barriers;

   - information exchange continues at scientific, technical levels.

4. scientific and technological developments:

   - fundamental research provides for signficiant advances in cognitive science during the 1980s;

   - supporting technological developments will occur on many fronts (ie. computer languages & hardware in areas such as natural language processing, computer architecture).

1.5 Players and Interests

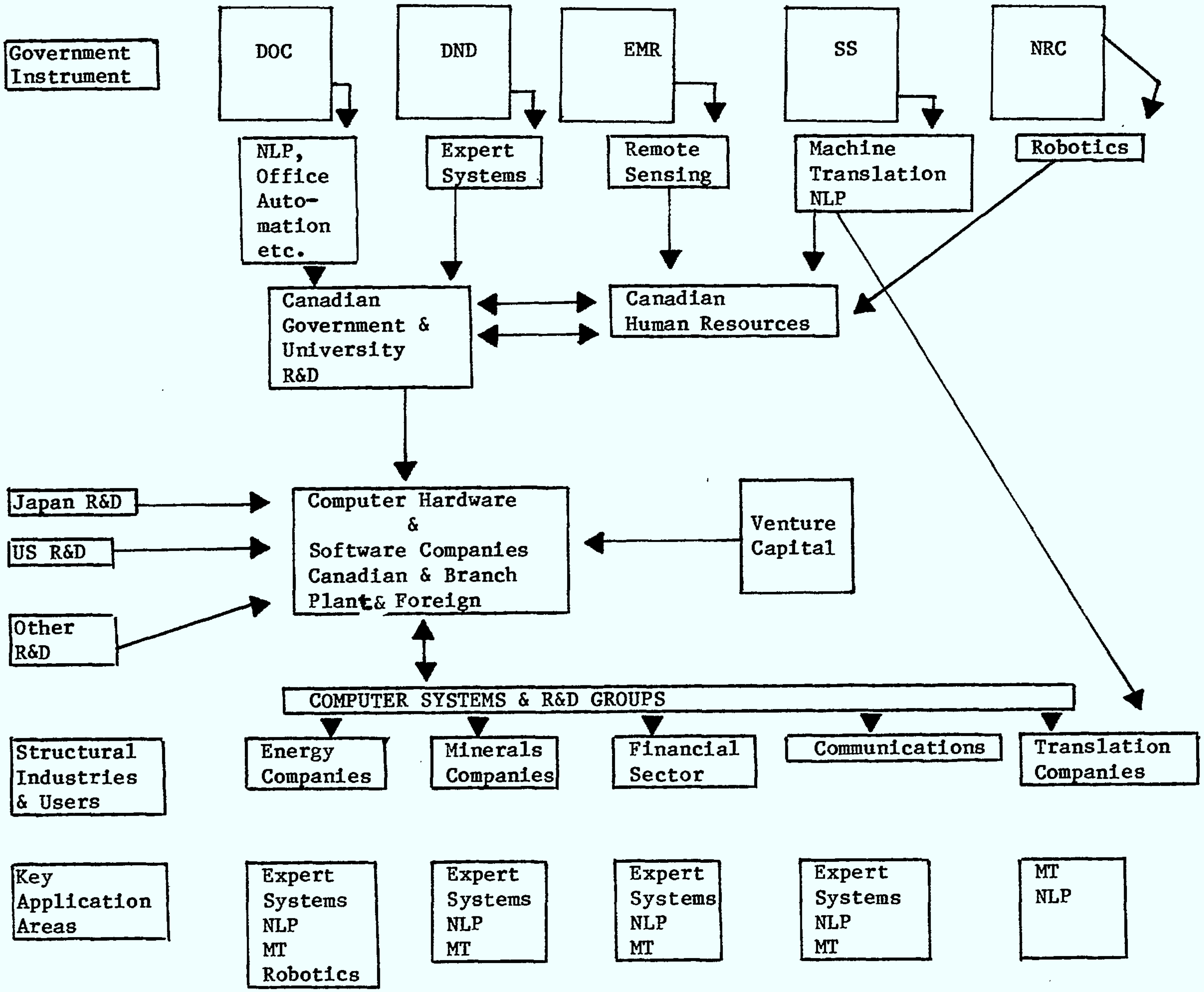
A high level view of key Canadian players and their interests in MT, NLP and AI is illustrated in Exhibit 1-1. In considering the opportunity for Canada, this is the framework in which they currently exist and from which plans must be developed and implemented. There are a variety of pathways in which developments will occur and the directions and timeframe varies for each application. But in order to conceptualize and fully assess the opportunities for Canada, this group of players and interests and the dynamics and relationships between them must be understood. This understanding, in conjunction with the state of the art review, the directions of technological thrust and the assessment of future markets will be the basis for assessing opportunity against the criteria developed. The players, interests and opportunities will be discussed as follows:

1. Government Departments - roles as instruments
2. Canadian Universities & Government R&D institutions
3. Computer Hardware & Software Companies
4. Industries & Users
5. Key Applications Areas
6. Foreign R&D
7. Summary Assessment of Opportunities

Exhibit 1-1

AI System Diagram

PLAYERS AND INTERESTS



2. Government Departments/Instruments

There are several government departments and agencies with current interests and/or activities in AI. They include the Secretary of State (SS), the Department of Communications (DOC), the Department of National Defence (DND), Energy, Mines and Resources (EMR), and the National Research Council (NRC). Each of these organizations will be reviewed in order to isolate their interests in AI, to assess how AI fits into their mandates, and to discuss their potential role in orchestrating a strategy for Canada.

2.1 Federal Government Departments

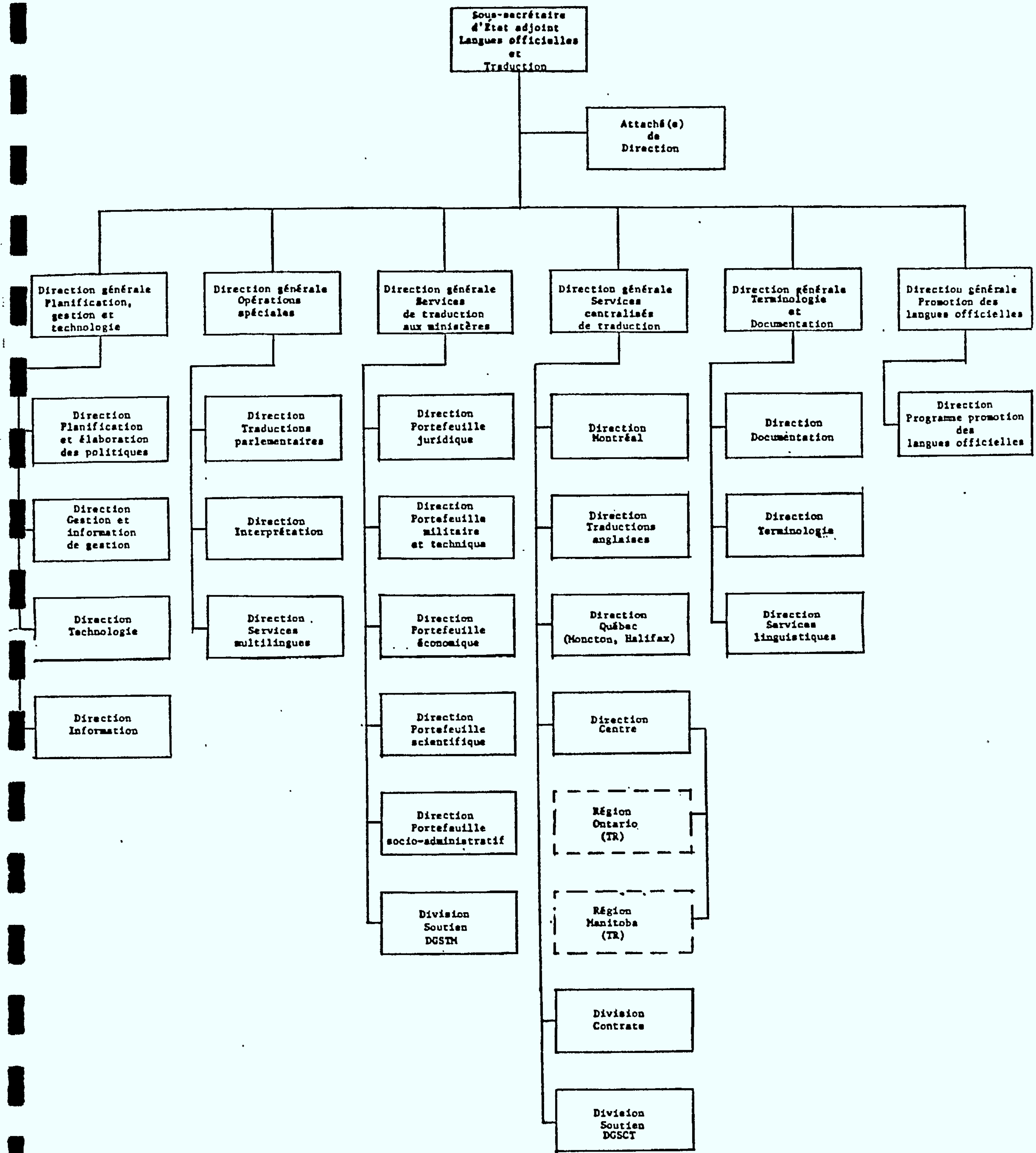
2.1.1 Secretary of State (SS)

Among the responsibilities of the Secretary of State is translation within the Federal Government. It is carried out through the Translation Bureau, whose organization is shown in Exhibit 2-1. It is estimated that the translation budget of approximately $75 million annually represents approximately 50% of the Canadian market for translation. This work consists of official languages services to parliament and a variety of departments and agencies. There is also a small volume of multi-lingual services provided upon request.

The mandate of the SS does not include subsidizing technical and scientific research or private sector development in automated translation. However, over the period 1973 to 1981 development of the second generation TAUM/METEO system (1976) and the TAUM/AVIATION system (1981) was funded by SS. Both of these constitute basic R&D.

Exhibit 2-1

Secretary of State Translation Bureau



By 1981, SS was at a crossroad in its Machine Translation activity. There was a requirement to reassess direction and support. Two options emerged. They were the development of a marketable second generation MT system and/or the continuation of university research oriented toward solving additional problems associated with second generation systems.

The activity required for the production of a marketable system was estimated to require 4 years of work and a team of professionals growing from 10 to 25. In addition, a 5 year research program requiring about 12 researchers would provide enough solutions for production of an initial prototype of a third generation machine translation system.

By 1981 the Translation Bureau felt that it could not justify further funding of the projects of the TAUM group, based on internal requirements. Simultaneously other factors such as increasing office automation and the arrival of US technologies in the form of the ALPS, WEIDNER & SYSTRAN II systems were occurring.

Since funding of the TAUM project ceased in 1981, the Bureau has made significant strides in introducing new technologies in the form of word processing and terminology banks. Today, the Department is reassessing the need for a program to stimulate R&D in the automation of translation.

2.1.2 Department of Communications (DOC)

Exhibit 2-2 shows an organization chart of the Department of Communications highlighting the organizational structure under the ADM Research. Current key research areas of interest include information technology, advanced information systems, computer networks and standards, behavioural research and artificial intelligence. In particular, DOC along with NRC is mandated to perform AI R&D.

DOC carries an ongoing interest in basic research, particularly in office automation. Work in this area will include fundamentals of natural language processing and artificial intelligence developments. In particular, DOC has expressed interest in using AI techniques as applied to behavioural, institutional and organizational research, software development and examination of systems aspects of integrated office networks. Other DOC interests include using AI to facilitate access to very large data bases, and as a vehicle to disseminate information in such areas as Telidon (of which this is only the beginning).

Exhibit 2-3 shows the organizations of the ADM Technology and Industry, which is a new sector at DOC. This area will provide support to promising new technological innovations in the information technology area. The emphasis will be on applications programs. The purpose is to expedite the transfer of basic technology to the private sector.

Exhibit 2-2

ORGANIZATION OF THE DEPARTMENT OF COMMUNICATIONS TELECOMMUNICATIONS, INFORMATICS, & SPACE R&D

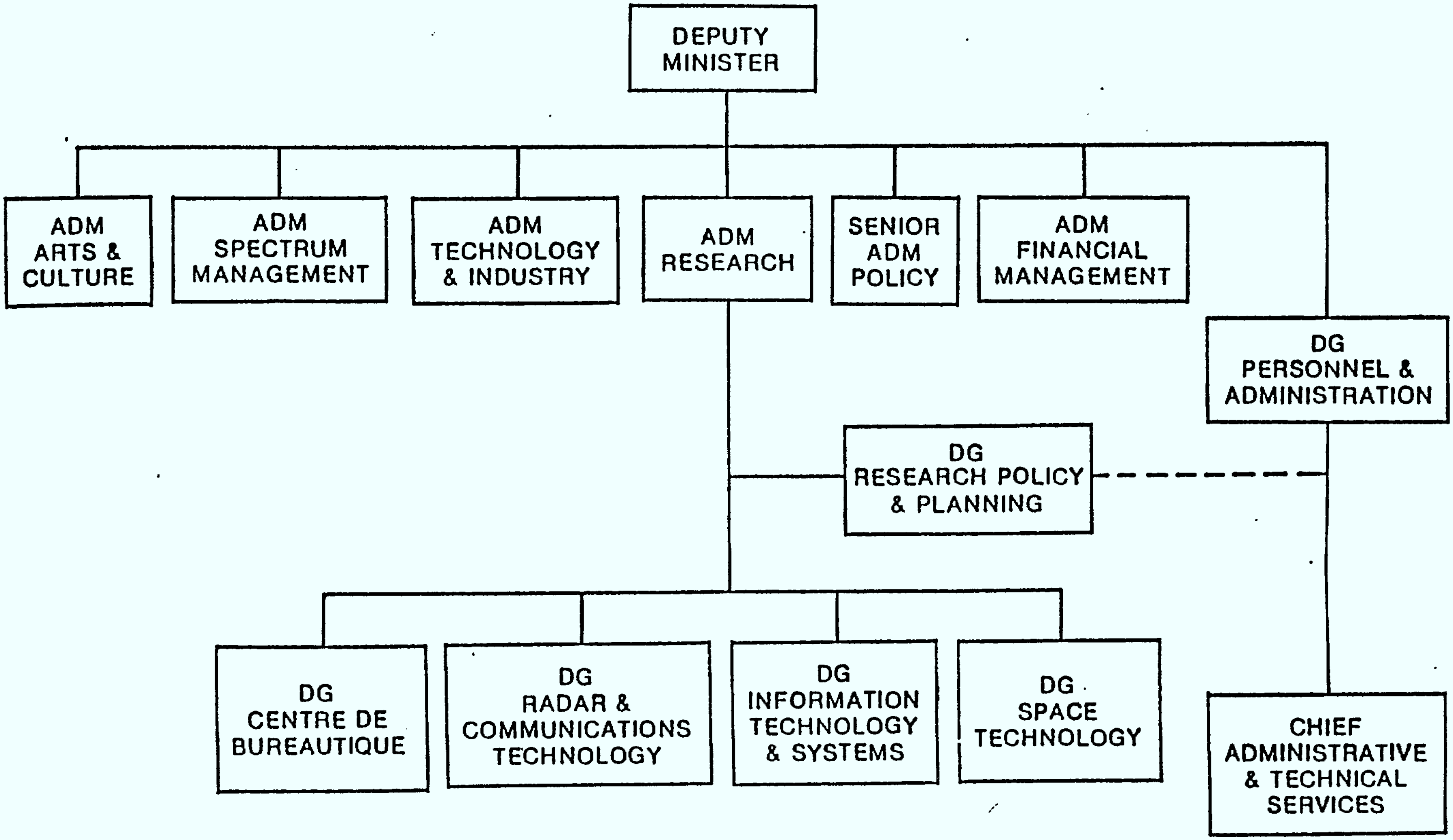


Exhibit 2-3

Organization of ADM Technology & Industry Sector

ADM TECHNOLOGY & INDUSTRY SECTOR

DG TECHNOLOGY & POLICY ASSESSMENT

- ASSESS NEW TECHNOLOGIES
- POLICY AND STANDARDS ANALYSIS

DG INDUSTRY & ECONOMIC DEVELOPMENT

- INDUSTRIAL DEVELOPMENT
- MARKETING SUPPORT
- ECONOMIC AND MARKETING ANALYSIS
- DAVID FLORIDA LABORATORY

DG APPLICATIONS PROGRAMMES

- PROGRAMMES:
  - MSAT
  - OCS
  - TELIDON
- MANAGEMENT SYSTEMS AND SERVICES
- PLANNING AND ADMINISTRATION

DG GOVERNMENT TELECOMMUNICATIONS

- DEVELOPMENT AND ENGINEERING
- TELECOMMUNICATIONS SYSTEMS DESIGN AND MANAGEMENT
- GOVERNMENT TELE-COMMUNICATIONS PLANNING AND COORDINATION
- FINANCE AND ADMINISTRATION

2.1.3 Department of National Defence

The Department of National Defence has long been aware of the importance of developments in artificial intelligence to military applications. In 1974/75 a small program was established at Defence Research Establishment Atlantic in applied AI aimed at acoustic signal analysis. Today complimentary research on knowledge representation and acquisition software is underway.

Recently, DND identified interests in natural language interfaces to data bases and expert systems in applications such as:

1. decision-aiding mechanisms for command and control including intelligent data bases
2. training tools
3. smart weapons that can remove humans from areas of danger or physiological stress

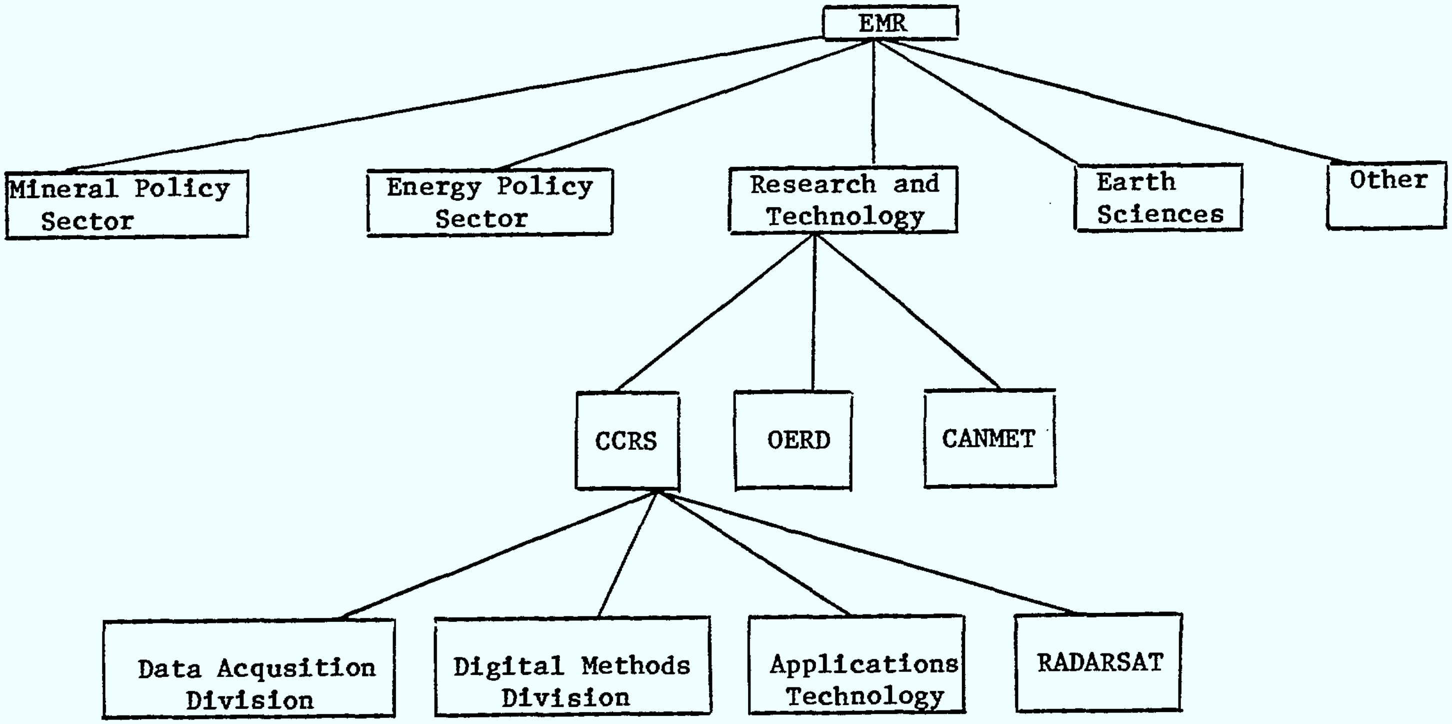
DND has experienced hiring problems in the artificial intelligence area and is now considering several options including undertaking work with external contractors - both university and industry.

2.1.4 Energy, Mines and Resources (EMR)

The main interest of Energy, Mines and Resources in AI is focussed in the Digital Methods Division of the Canada Centre for Remote Sensing (CCRS) and forms part of the Research and Technology Sector. A summary organization is outlined in Exhibit 2-4.

<u>Exhibit 2-4</u>

<u>Organization of Energy, Mines & Resources</u>



The Methods Division is looking to AI technologies in the expert systems area for the future generations of image analysis systems. New sensors (ie. the thematic mapper and radar) produce orders of magnitude more data. In addition, the increasing desire to overlay sensor output, map historic developments and readily produce intelligent analysis demands advances in image analysis technology.

CCRS is moving quickly to acquire AI skills and tools. Having completed a preliminary study in 1983, the group has ordered a LISP interpreter/compiler and plans to do some AI based work in 1984/85. By 1986/87 the activity could involve a team of more than 4 scientists and the farming out of software contracts, if funding is available. To date CCRS has given contracts for image processing to UBC, McGill and the University of Alberta.

2.1.5 The National Research Council (NRC)

NRC's principle interest in AI will be focussed in its new research laboratory, The Institute of Manufacturing, to be located in Winnipeg. The facility is planned to be in operation by the Spring of 1986. The research activities of this new laboratory will include computer aided design, robots and mechanisms, sensors, integrated manufacturing, and artificial intelligence, with AI proposed as the largest core group in the laboratory.

Staffing is expected to commence within the next couple of months, the plan being to assist the start-up by locating and integrating these new researchers into related research activities of existing laboratories in NRC in Ottawa and possibly elsewhere. The current plan includes the accommodation of up to 6 AI researchers in NRC Division of Electrical Engineering in the field of AI, with emphasis in knowledge representation, expert systems, knowledge based sensory interpretation (primarily vision), and planning and decision making. Computer facility support consists of several VAX computers, (or equivalent) and a LISP machine (on order). The related activities include graphics, image processing, vision sensor development, intelligent robotics and computer assisted training. Similar opportunities in other areas such as CAD/CAM, Flexible Manufacturing systems and micro processor control will also be available.

Of course, work related to the above activity is already happening in other sections of NRC. In the areas of computer interface technology and mechanical engineering in Ottawa activities overlap into robotics and flexible manufacturing systems.

2.2 Provincial Interests

There are a variety of provincial groups that may have interests in machine translation, natural language processing and artificial intelligence. For example, there are substantial translation activities in Ontario, Manitoba, and New Brunswick. Currently, these groups are interested in terminology data banks; in future their thoughts may move to MT.

The provincial education and health care activities may lead to work in computer aided instruction and expert medical systems in future.

2.3 Conclusions

There are several centres of strong interest in AI in the federal government each with different applications areas of interest. In considering the AI system diagram of Exhibit 1-1, one realizes that each department apparently faces the same challenge of encouraging research, development and finally technology transfer - although key factors, such as the state of the market and appropriate institutional arrangements, for each application area is very different and will ultimately dictate success or failure of efforts undertaken by these groups.

3. Canadian Institutional Capabilities

3.1 Canadian Universities

Activity in MT, NLP and AI exists in many universities across the country. For the purposes of this study, the work of the major centres including the Universite de Montreal, the University of Toronto, the University of British Columbia (UBC) and McGill University will be discussed in some depth, while work at many other institutions will be provided in tabular form.

3.1.1 Universite de Montreal

The TAUM Group

The Universite de Montreal housed the TAUM machine translation research group from 1965 to 1981. Initially, the group was funded by research grants from the National Research Council; but after 1972, funding came from Secretary of State under the form of research and development contracts. At the end of the first development contract in 1976, the group delivered the TAUM-METEO system. This system currently translates weather bulletins on a daily basis at the Canadian Meteorological Centre in Dorval, and remains to date one of the most advanced operational MT systems.

Following TAUM-METEO, the group undertook the development of the more ambitious TAUM-AVIATION, for the translation of aircraft maintenance manuals. In 1980, a prototype was evaluated and it was concluded that, while it produced relatively good translations, its scope was still too narrow for actual production. The Secretary of State judged that its needs alone for translation of maintenance manuals did not warrant the investments required to extend the prototype, and the project came to a halt.

The TAUM group has made internationally acknowledged contributions to the development of second-generation MT technology, an approach in which: software design features a modular separation between algorithms and linguistic descriptions, as exemplified in TAUM's (now classical) Q-SYSTEMS; and the linguistic model was "indirect", separating the translation process in successive stages of analysis, transfer and generation. These principles, together with an approach whereby systems are tailored for particular sublanguages led to the landmark success of TAUM-METEO.

Before TAUM was disbanded, Pierre Isabelle, then scientific director of the group made detailed proposals for further development work to yield a marketable second generation system; and further research work which could enable Canada to retain its lead in MT, by pioneering the development of a third generation of systems. These newer systems would integrate more knowledge of semantics, pragmatics and the external world.

Linguistics Department

Professor Richard Kittredge was director of the TAUM group between 1973 and 1976. He is widely known for his contributions to the development of a theory of natural sublanguages. His studies have shown that, in spite of all the gaps in our current understanding of language as a whole, NLP/MT problems become much more tractable when viewed in the context of specific sublanguages. The tight syntactic, semantic and pragmatic restrictions observed in sublanguages make it much easier to develop practical systems in the near term.

Within that framework, Professor Kittredge has recently designed, together with Professor Igor Melcuk, a prototype system for automatic synthesis of English language stock market reports on the basis of stock quotations.

The Computer Science Department

An interest group in AI called INCOGNITO (INformatique COGNITive) has recently been created within the Computer Science Department, by Professors Guy Lapalme, Paul Bratley and Jean Vaucher. The group is planning research activities in the areas of knowledge representation, intelligent programming environments and NLP.

3.1.2 The University of Toronto

The Computer Science Department

At the University of Toronto, AI research is centred at the Computer Science Department, with five faculty members and twenty-three graduate students involved.

Professor John Mylopoulos has been working in the areas of knowledge representation and applications to data bases. In particular, he has been developing a knowledge based representation language, called PSN, and a data model and language called TAXIS.

Professor J.K. Tsotsos has been working on the application of vision techniques and medical expert systems to the field of cardiovascular medicine.

Among former University of Toronto students, H. Levesque and M.D. Raussopoules have made interesting contributions to the theory of semantic networks. Levesque has also produced an excellent widely circulated tutorial paper on LISP. A thesis on Speech Acts by R. Cohen is often cited in the literature. All three are currently employed in the US.

3.1.3 McGill University

The Department of Electrical Engineering

Professors M.D. Levine and S.W. Zucker have established a computer vision and graphics laboratory with wide ranging research activities. The laboratory has a staff of four professors and a group of sixteen students and research assistants.

Levine and Zucker have published widely in the area of knowledge based computer vision systems. In particular, work is being undertaken in computational vision, rule based image segmentation and uses of texture in computer vision.

The group is also involved in robotics and integrated circuit manufacture, medical applications of pattern recognition, and human perception and psychophysics. Sponsors of the group include NSERC, MRC, FCAC and other research contracts.

3.1.4 University of British Columbia

The Department of Computer Science

The Laboratory for Computational Vision was founded by Alan Mackworth in 1974. He was joined in 1978 by Robert Woodham, a Canadian who did his doctoral research at the Massacheusetts Institute of Technology. The group currently consists of six professors and sixteen students and research assistants.

The laboratory maintains a working relationship with a number of Vancouver area firms including MacDonald Dettweiler & Associates, and others.

Mackworth and Woodham with William Havens are investigating fundamental vision problems and applying their findings to automatic scene interpretation. In particular, research work focuses on two application domains - interpretation of Landsat satellite imagery and interpretation of hand drawn sketch maps. Mackworth pioneered application of the computational vision paradigm to remote sensing. Woodham's early work in the application of digital terrain models in Landsat image analysis has furthered the computational vision approach to remote sensing.

The facilities of the laboratory have been funded by the UBC Programmes of Excellence (original funds) and by National Science and Engineering Research Council (NSERC) (1981).

Raymond Reiter, working in the area of reasoning and knowledge representation has contributed major results in the logic of default reasoning.

3.1.5 Other Universities

There are individuals or small groups working and/or teaching in the areas of machine translation, natural language processing and artificial intelligence at many other universities including the University of Western Ontario, University of Alberta, University of Ottawa, University of Guelph, Simon Fraser University, University of New Brunswick, Universite du Quebec, Carleton University, Acadia University, University of Waterloo, Queen's University and Concordia University. The details of these activities are laid out in Exhibit 3-1 to indicate the broad and fragmented efforts underway across the country that are associated with AI. Exhibit 3-2 shows an overall estimate of university personnel in Canada who are working in AI related areas.

3.2 Other Research Institutes

3.2.1 Canadian Institute for Advanced Research (CIAR)

The Canadian Institute for Advanced Research is a private non-profit corporation, aiming to promote excellence and achievement in Canadian research.

The group's objective has led it to define the field of Artificial Intelligence, Robotics and Society as its initial research program. Specifically, the program will promote research on sensate and smart robots and the implications of these machines for society. The

Exhibit 3-1

MT, NLP and AI Capability in Canadian Universities

University	Research Staff	Field of Study
Universite du Quebec a Montreal	P. Plant	• development of a software environment for text analysis (DEREDEC)
	S. Curry N. Rochon L. Bouchard C. Pichet	• expert systems
University of Alberta	W. Davis	• pattern recognition
	J. Pelletier	• formal semantics, NLP
	L. Schubert	• representation of knowledge
University of Western Ontario	Z. Pylyshyn	• representation of knowledge information processing model of the mind; application of cognitive science to human factors
	E.W. Elcock	• logic programming techniques for data base use and for natural language parsers
	D. Kuchner	• low level vision
Simon Fraser University	N. Cercone (also President of (CSCSI)	• NL Query Systems
	Dr. B. Funt	• vision
	Dr. V. Dahl	• logic programming, natural language processing
University of New Brunswick	Dr. B.J. Kurz	• pattern recognition • image processing
	Dr. W. Dana Wasson	• logic design and pattern recognition

Exhibit 3-1 (cont'd)

MT, NLP and AI Capability in Canadian Universities

University	Research Staff	Field of Study
Carleton University	Dr. Fray Appacher	• NLP
	Dr. Wilf Lalonde	• general AI
Queen's University	Dr. Roger Browse	• vision, cognitive science
University of Ottawa	Dr. D. Skuce	• LESK Language for exactly stating knowledge
	Dr. Stan Matwin	• applications of logic programming to software engineering
	Dr. Brian Harris	• MT
University of Guelph	Dr. T. Carey	• human machine interface • office automation
University of Waterloo	Dr. J.A. Brzozowski	• knowledge representation
	M.H. Van Emden	• logic programming
	R. Goebell	• expert system
	Dr. E. Manning	
	Dr. Marlene Colbourn	
Concordia University	Dr. Renato De Mori	• speech understanding
	C.Y. Suen	• computer perception and recognition of visual signals and auditory signals

Exhibit 3-1 (cont'd)

MT, NLP and AI Capability in Canadian Universities

University	Research Staff	Field of Study
University of Calgary	I.H. Witten	• data base enquiry (NLP)
	J. Cleary	• adaptive systems and foundations of learning
University of Manitoba	Dr. R. Gordon	• pattern recognition
University of Saskatchewan	Dr. G. McCalla	• planning, computer aided instruction
Acadia University	Dr. J. Bradford	• computational linguistics • NLP • Learning Systems • Robotics
	Dr. M. Brehant	• CAI
	Dr. R. Giles	• CAI
	Dr. T. Pietrzykowski	• user friendly software • special computer architecture

Exhibit 3-2

Summary

Estimate of University Personnel In Canada Working in AI

University	Professors	Total # of People*
University of Toronto	5	28
UBC	6	22
Concordia	2	15
Calgary	2	2
Saskatchewan	1	3
Montreal	2	6
McGill	4	20
Ottawa	1	10
Manitoba	1	2
Waterloo	3	8
IQAM	3	5
Alberta	3	5
Western	4	10
Simon Fraser	3	8
UNB	-	2
Carleton	-	2
Guelph	1	1
Acadia	1	4
Queens	1	5
Total	43	158

* includes professors, graduate students and research staff

program's work will focus on sensory processing in the area of visual processing by computers. In this connection CIAR will bring together expertise from the University of British Columbia, McGill University and the University of Toronto. In addition, cross-disciplinary interaction of the fields of computer science, engineering, psychology and neuroscience will be encouraged. Finally, the program will be a vehicle for research interaction and exchange with the private sector. Two researchers from Spar Aerospace will be involved in the current program. W.G. Tatton is Senior Fellow of the Institute with responsibility for the program in Artificial Intelligence, Robotics and Society.

3.2.2 The Natural Sciences and Engineering Research Council (NSERC)

The Natural Sciences and Engineering Research Council of Canada is a federal granting agency whose mandate is to support research in Natural Sciences and Engineering fields. Researchers from the university community can apply for funds for work in these fields. NSERC screens these applications for approval through a committee and peer review process for operational and strategic grants. Operational grants are those made from NSERC's general pool of funds while strategic grants are additional funds, available for areas which have been deemed of national concern. Applications in computer science and communications are eligible for strategic grants.

For the next year, total funds for all operational grants are in the range of $140 million while strategic grants are approximately $28 million. NSERC is currently reviewing its position regarding the funding of AI.

3.2.3 CCIS-CRC

The proposed Canadian Communications, Informatics and Space Research and Development Institute (CCIS) is to be built around the existing Communications Research Centre (CRC) of the Department of Communications. The concept, currently being studied by a task force, is to have a non-profit corporation owned by the Federal Government and other sponsors (eg. provincial governments and private sector). Within the study bounds, CCIS could involve research and development in a variety of fields including telecommunications, space technology, informatics and computer sciences. The final mandate could certainly include work in artificial intelligence - acting as a focal point for potential customers such as federal and provincial government departments and agencies, communications facilities, equipment manufacturers and foreign customers. Exhibit 3-3 shows the organization for informatics R&D at CRC.

3.2.4 National MicroElectronics Design Network

The impending incorporation of the Canada Microelectronics Co-operative (CMC) is a new approach in Canada for joint industry-university effort in developing and commercializing specific technology projects. The organization will be based at Queen's University in Kingston, Ontario and will be funded by NSERC at the level of $17 million during the next 5 years. The objective will be to establish a computer networking system to allow broad participation by Canadian universities in performing research related to design of advanced microchips. Canadian manufacturers such as Northern Telecom, for example, could bring some of these designs into production.

Exhibit 3-3

Informatics R&D at CRC

INFORMATION TECHNOLOGY & SYSTEMS R&D

- **INFORMATION TECHNOLOGY**
  - STRUCTURE AND CODING
  - ADVANCED SIGNAL PROCESSING
  - ENHANCED VIDEOTEX
  - SPEECH SYNTHESIS
  - SPEECH RECOGNITION
- **RADIO SYSTEMS**
  - H.F. SYSTEMS
  - VIDEOTEX/ TELETEXT DELIVERY
  - MOBILE SYSTEMS
- **BEHAVIOURAL RESEARCH**
  - INFORMATION REPRESENTATION & COGNITIVE PROCESSES
  - TECHNOLOGY INTERACTION
  - GENERAL PROBLEMS OF EXPERT SYSTEMS
- **COMMUNICATIONS NETWORKS**
  - TELEMATIC STANDARDS
  - NETWORKS AND SERVICES
  - COMPUTER COMMUNICATIONS
  - BROADBAND SYSTEMS

This approach is one that could be considered when developing models for AI research & development in Canada.

3.3 Conclusions

Although capability and interest in several MT, NLP and AI fields exists in Canada, it is generally fragmented and separated geographically at various universities and institutions across the country. There are some potential vehicles for increased activities in MT, NLP and AI including the strong bases in the leading university groups (University of British Columbia, University of Toronto, McGill and Universite de Montreal); and in existing institutions such as CRC and CIAR. The NSERC role could be strengthened and a major program along the lines of the CMC could be designed and launched.

4. The Computer Industry in Canada

An assessment of the computer industry in Canada must be undertaken in the evaluation of opportunities for Canada because this is the industry which ultimately will carry AI technology to the marketplace. The structure, some key characteristics and future trends of the industry will be examined to set a framework of understanding regarding the capability of the computer industry in Canada today to take a leading role in technology development and transfer role.

Exhibit 4-1 shows worldwide data processing revenues and market share of the leading fifteen vendors forecast to 1985. Revenues are forecast to rise to $130 billion by 1985 with IBM holding a market share of approximately 35%, while the next largest competitors with shares ranging from 4 to 6% will include NCR, Control Data, Digital Equipment Corporation, Sperry Univac, and Hewlett-Packard, all of these firms being United States based multinationals.

In Canada, the computer industry had sales of $5.5 billion in 1982, showing growth of 25 percent and accounting for 1.6 percent of the GNP.* Exhibit 4-2 shows the top 100 companies in the Canadian computer industry with IBM Canada leading in EDP revenues at $1.9 billion followed by Digital Equipment Corporation of Canada Ltd. at $295 million and Control Data ranking third at $231 million. The largest Canadian owned companies include AES Data Inc. at $188 million, whose main activity is hardware and Canada Systems Group Ltd. at $141 million, Datacrown Inc. at $88 million and B.C. Systems Corp at $63 million, all of which are mainly service bureau operations.

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* Evans Research

Exhibit 4-1

Worldwide Data Processing Revenues and Market Share of the Leading Fifteen Vendors 1978-1985

	1978	1979	1980	1981	1982	1983	1984	1985
IBM	38%	35%	34%	35%	35%	35%	34%	34%
Honeywell	3	3	3	3	3	3	3	2
CII-Honeywell Bull	2	2	2	2	2	2	2	2
NCR	5	5	5	5	4	4	4	4
Control Data	4	4	4	4	4	4	4	4
Digital Equipment Corp.	4	4	4	5	5	6	6	6
Sperry Univac	4	4	4	4	4	4	4	4
Burroughs	5	5	4	4	3	3	3	3
ICL	2	3	3	2	2	2	2	2
Hewlett-Packard	2	2	2	3	3	4	4	4
Fujitsu	3	3	2	2	2	2	2	3
Olivetti	2	2	2	2	2	2	2	2
Hitachi	2	2	2	2	2	2	2	2
NEC	2	2	2	2	2	2	2	2
Nixdorf	1	1	1	1	1	2	2	2
Other	21	23	26	24	26	23	24	24
	100%	100%	100%	100%	100%	100%	100%	100%
Total	$45,510	53,039	62,765	72,550	84,000	97,000	110,000	130,000

Source: Estimate of MSRA, Inc.

Exhibit 4-2

The Top 100 Companies in the Canadian Computer Industry

	Company Name	Fiscal Year End	Ownership	Total Revenues 1982	EDP Revenues *1 1982	1981	1980	Source Code
1.	IBM Canada Ltd.	Dec. 31	U.S.	2,204.0	1,890.0	1,517.7	1,216.5	C
2.	Digital Equipment of Canada Ltd.	July 1	U.S.	294.9	294.9	252.6	163.7	B
3.	Control Data Canada Ltd.	Nov. 30	U.S.	231.0	231.0	181.3	162.6	B
4.	Philips Information Systems Ltd.	Dec. 31	NL	199.6	199.6	140.0	100.3	B
5.	AES Data Inc.	Dec. 31	Can.	188.1	188.1	172.8	155.4	B
6.	NCR Canada Ltd.	Nov. 30	U.S.	180.0	162.0	152.4	150.1	C
7.	Canada Systems Group Ltd. *2	Dec. 31	Can.	140.6	140.6	136.7	116.3	C
8.	Sperry Inc.	Mar. 31/83	U.S.	354.0	140.4	141.0	132.0	C
9.	Honeywell Ltd. (Information Systems)	Dec. 31	U.S.	340.0	110.0	94.4	85.0	B
10.	Burroughs Canada *3	Nov. 30	U.S.	121.0	108.5	114.0	94.0	B
11.	Hewlett-Packard (Canada) Ltd.	Oct. 31	U.S.	182.0	101.9	81.0	63.5	B
12.	Datacrown Inc.	Dec. 31	Can.	88.0	88.0	86.2	68.6	A
13.	STC Canada Inc.	Dec. 31	U.S.	84.7	84.7	56.4	28.8	B
14.	Amdahl Ltd.	Dec. 31	U.S.	77.0	77.0	72.6	43.0	B
15.	Wang Canada Ltd.	June 30	U.S.	64.7	64.7	44.5	21.0	B
16.	B.C. Systems Corp.	Mar. 31/83	Can.	63.0	63.0	57.9	49.1	B
17.	Radio Shack (Tandy Electronics Ltd.)	June 30	U.S.	197.7	61.3	39.7	22.3	C
18.	Memorex Canada *3	Nov. 30	U.S.	57.4	57.4	40.5	30.8	B
19.	Gandalf Technologies Inc.	July 31	Can.	53.3	53.3	40.2	26.1	A
20.	MAI Canada Ltd.	Sep. 30	U.S.	52.0	52.0	47.1	39.4	B
21.	I.P. Sharp Associates Ltd.	Dec. 31	Can.	51.6	51.6	42.0	35.3	B
22.	Xerox Canada Inc.	Dec. 31	U.S.	596.0	47.7	40.2	30.9	C
23.	Geac Computer Corporation Ltd.	Apr. 30/83	Can.	47.0	47.0	35.6	23.6	B
24.	Systemhouse Ltd.	Aug. 31	Can.	39.8	39.8	30.5	19.3	A
25.	CGE Co. Ltd. (Information Services)	Dec. 31	U.S.	1,633.8	37.0	31.0	26.0	C
26.	Nabu Manufacturing Corporation *4	July 3	Can.	35.0	35.0	29.9	18.2	A
27.	DMR & Associates	May 31/83	Can.	33.1	33.1	27.2	18.7	B
28.	Data General (Canada) Inc.	Sep. 25	U.S.	32.4	32.4	29.0	23.0	B
29.	ESE Limited	Dec. 31	U.S.	30.4	30.4	10.0	5.4	B
30.	Commodore Business Machines Ltd.	June 30	Bah.	n/a	30.0	18.0	7.4	C
31.	Northern Telecom Ltd.	Dec. 31	Can.	3,035.5	29.0	26.2	21.0	C
32.	L'Industrielle-Services Techniques Inc.	Nov. 30	Can.	28.4	28.4	23.8	20.4	A
33.	Mohawk Data Sciences Canada Ltd.	Apr. 30/83	U.S.	26.8	26.8	22.3	16.5	B
34.	Electrohome Ltd.	Dec. 31	Can.	196.3	25.0	20.0	10.0	B
35.	Apple Canada Inc.	Sep. 24	U.S.	24.2	24.2	20.1	0.0	B
36.	Datapoint Canada Inc.	June 30	U.S.	23.5	23.5	n/a	n/a	B
37.	ADP Automatic Data Processing Inc.	June 25	U.S.	23.0	23.0	20.0	16.7	C
38.	Cherney Mills Inc. (CMI Company)	Dec. 31	U.S.	22.4	22.4	15.9	20.7	B
39.	SaskCOMP	Dec. 31	Can.	21.7	21.7	16.7	12.8	A
40.	Lanpar Technologies Inc.	Jan. 31/83	Can.	21.4	21.4	16.4	15.0	A
41.	Altel Data	Dec. 31	Can.	n/a	21.0	15.0	12.0	C
42.	Tandem Computers Canada Ltd.	Sep. 30	U.S.	20.5	20.5	15.7	5.2	B
43.	Quasar Systems Ltd.	Aug. 31	Can.	18.6	18.6	11.1	5.7	A
44.	National Advanced Systems *5	Mar. 31/83	U.S.	18.0	18.0	15.0	12.0	B
45.	General DataComm Ltd.	Sep. 30	U.S.	17.2	17.2	13.9	12.5	B
46.	Olivetti Canada Ltd.	Dec. 31	I	64.0	17.0	15.5	11.0	B
47.	Intergraph Systems Ltd.	Dec. 31	Can.	16.6	16.6	16.1	12.4	C
48.	Ahearn & Soper Inc.	Dec. 31	Can.	16.0	16.0	14.0	12.8	B
49.	Prime Computer of Canada Ltd.	Dec. 31	U.S.	16.0	16.0	13.0	10.0	C
50.	Manitoba Data Services	Mar. 31/83	Can.	15.7	15.7	15.5	13.0	B
51.	Comterm Inc.	Jan. 31/83	Can.	15.3	15.3	9.5	6.0	A
52.	ICL Computers Canada Ltd.	Sep. 30	U.K.	14.0	14.0	15.0	15.3	B
53.	Tulsa Computer Products Ltd. (Telex)	Mar. 31/83	U.S.	13.9	13.9	9.0	6.0	B
54.	Four Phase Systems Ltd.	Dec. 31	U.S.	13.1	13.1	13.4	12.4	B
55.	ITT Courier (ITT Canada Ltd.)	Dec. 31	U.S.	12.7	12.7	9.5	7.2	B
56.	Greyhound Computer of Canada Ltd.	Dec. 31	U.S.	12.3	12.3	5.9	5.1	A
57.	Computer Sciences Canada Ltd.	Mar. 31/83	U.S.	12.0	12.0	12.2	11.2	C
58.	Matrox Electronic Systems Ltd.	Mar. 31/83	Can.	11.0	11.0	8.7	4.7	B
59.	STS Systems Ltd.	Apr. 30/83	Can.	11.0	11.0	9.0	6.8	B
60.	NCR Comten Inc.	Dec. 31	U.S.	10.4	10.4	5.2	2.5	B

Exhibit 4-2 (cont'd)

61.	Comshare Limited	Dec. 31	Can.	10.3	10.3	10.2	7.6	B
62.	Dataline Inc.	Dec. 31	Can.	10.3	10.3	9.9	8.2	B
63.	Nelma Data Corporation	June 30	Can.	10.1	10.1	7.6	4.2	B
64.	Data Terminal Mart	June 30	Can.	10.0	10.0	8.5	7.5	B
65.	Norpak Corporation	June 30	Can.	10.0	10.0	7.2	5.0	A
66.	Texas Instruments Canada Ltd.	Dec. 31	U.S.	n/a	10.0	10.0	10.8	C
67.	Digitech Ltd.	June 30	Can.	51.0	9.7	9.0	7.9	C
68.	Develcon Electronics Ltd,	Aug. 31	Can.	9.7	9.6	6.7	3.1	B
69.	Reynolds & Reynolds	Sep. 30	U.S.	15.4	9.5	11.7	12.6	B
70.	Hamilton Rentals (Hamilton Group Ltd.)	Apr. 30/83	Can.	9.4	9.4	7.0	3.8	B
71.	Centronics Canada Inc. *6	Dec. 31	U.S.	9.2	9.2	9.1	6.8	B
72.	Newfoundland & Labrador Comp. Serv. Ltd.	Mar. 31/83	Can.	9.2	9.2	8.4	7.3	B
73.	Real Time Datapro Ltd.	Feb. 28/83	Can.	9.5	9.0	6.4	5.1	B
74.	Datamex Ltd.	June 30	Can.	8.3	8.3	5.7	4.8	B
75.	Thorne Riddell	Dec. 31	Can.	145.0	8.1	6.1	4.0	C
76.	Datatech Systems Ltd.	Aug. 31	Can.	9.1	8.0	6.5	4.8	B
77.	Perkin-Elmer Canada Ltd. (Data Systems)	June 30	U.S.	n/a	8.0	6.8	6.1	C
78.	Recognition Equipment (Canada) Ltd.	Oct. 31	U.S.	8.0	8.0	8.1	6.3	C
79.	Sydney Development Corporation	Mar. 31/83	Can.	8.0	8.0	4.9	0.6	C
80.	Zentronics (Westburne Industries)	Mar. 31/83	Can.	32.0	8.0	8.0	4.0	C
81.	ACT Computer Services Ltd.	Dec. 31	Can.	7.8	7.8	7.5	6.8	B
82.	Alphatext (Ronalds-Federated Ltd.)	Dec. 31	Can.	7.8	7.6	4.9	4.7	B
83.	CTS Computer Systems Inc. *7	Dec. 31	Can.	7.4	7.4	7.0	4.7	B
84.	Bailey & Rose	June 30	Can.	7.3	7.3	5.4	2.9	B
85.	Cableshare Inc.	Aug. 31	Can.	7.2	7.2	6.6	4.2	B
86.	Cybernex Ltd.	Jan. 31/83	Can.	7.1	7.1	5.2	3.1	B
87.	Riley's Datashare International Ltd.	May 31	Can.	7.0	7.0	5.8	5.1	A
88.	Tektronix Canada Inc.	May 28	U.S.	32.0	7.0	9.0	6.0	B
89.	TRW Canada Ltd. (TRW Data Systems) *8	Dec. 31	U.S.	n/a	7.0	28.0	22.0	C
90.	Computervision Canada Inc.	Dec. 31	U.S.	6.9	6.9	5.0	2.8	C
91.	Dasco Data Products	Sep. 30	Can.	6.9	6.9	6.2	5.1	B
92.	Hospital Computing Services of Ontario	Mar. 31/83	Can.	6.9	6.9	6.0	4.9	B
93.	National Datacentres Corp.	Mar. 31/83	Can.	6.0	6.0	6.3	5.2	C
94.	Comtech Group International Ltd.	June 30	Can.	5.9	5.9	5.8	5.7	A
95.	Nixdorf Canada Ltd.	Dec. 31	FRG	5.5	5.5	3.5	4.0	C
96.	Comcheq Services Ltd. *9	May 31	Can.	5.4	5.4	4.8	3.6	B
97.	M.I.C.R. Systems Ltd. *10	Nov. 30	Can.	5.1	5.1	6.1	5.1	A
98.	MSA Canada Inc.	Dec. 31	U.S.	5.1	5.1	3.1	3.2	A
99.	Perle Systems Ltd.	May 31/83	Can.	5.1	5.1	3.9	1.7	B
100.	Cincom Systems of Canada Ltd.	Sep. 30	U.S.	5.0	5.0	3.4	2.2	B
	Total				5,412.0	4,477.3	3,516.7	
	% Growth				21	27		

Notes:

*1 Figures in $ Canadian millions, for the fiscal year ending in year indicated. Domestic and export EDP-related are included.
*2 CSG's reported revenues are: 1982 - $127.6 million (includes 8 mths. of Computel Systems Ltd.); 1981 - $95.4 million (restated); 1980 - $77.9 million. CSG survey revenues include: estimated revenues of Computel Systems Ltd. of $13.0 million for the 4 mths. ending April 1982; 1981 fiscal year revenues of $41.3 million and 1980 fiscal year revenues of $38.3 million.
*3 Division of Burroughs Memorex Inc. of Canada. Memorex Canada changed its FYE from Dec.31 to Nov. 30
*4 Includes revenues for Consolidated Computer Inc. and Volker-Craig division
*5 Division of National Semiconductor
*6 Changed FYE from June 30 to Dec. 31
*7 Acquired by Mohawk Data Sciences Canada Ltd. in March 1983
*8 1980 and 1981 revenues include sales and service of Datapoint Corp. products, now distributed by Datapoint Canada Ltd.
*9 Calendar year revenues
*10 Changed FYE form Dec. 31 to Nov. 30

Source Codes:

A = Published by Company
B = Confirmed by Company Officer
C = Estimated by Evans Research Corporation

4.1 Hardware Industry

Exhibit 4-3 splits out Canada's leading hardware companies. Canada's hardware industry is dominated by US multinationals particularly IBM, DEC and CDC.

The industry leader, IBM, has so far not moved vigorously into artificial intelligence, although for example, the firm has been developing the EPISTLE text critiquing system at one of its US research centres. This 'product' is still under development and IBM has not yet announced plans to introduce it to the market. In the area of natural language query systems, IBM has decided to market INTELLECT, an artificial intelligence product developed by AI Corp. INTELLECT is compatible with a wide variety of data base systems, particularly those that run in an IBM environment.

Digital Equipment Corporation has built a strong AI position, with 70 to 100 AI researchers in their Hudson, Massachusets operation. They have developed with university based consultants such expert systems as XCON and XCEL for the configuring of computer systems. Others are under development.

DEC has an external research program that allows for third party relationships and sponsorship of university work in many areas. The program can involve exchanges of equipment and people or seminar series in which DEC plays a brokerage role. The results of these activities have short and long term benefits in the areas of sales, recruitment of talent and technology transfer. DEC is interested in work in NLP,

Exhibit 4-3

The Top EDP Hardware Suppliers in Canada

Company Name	% of Total 1982	% of Total 1981	EDP Hardware Revenues *2 1982	EDP Hardware Revenues *2 1981	% Change '81 to '81	Source Code	Ownership
1. IBM Canada Ltd	41.4	40.8	1,846.0	1,480.0	25	C	US
2. Digital Equipment of Canada Ltd.	6.7	7.0	294.9	252.6	17	B	US
3. Control Data Canada Ltd.	4.6	4.4	206.0	161.0	28	C	US
4. Philips Information Systems Ltd.	4.5	3.9	199.6	140.0	43	B	NL
5. AES Data Inc.	4.2	4.8	188.1	172.8	9	B	
6. NCR Canada Ltd.	3.5	4.0	154.0	145.4	6	C	
7. Sperry Inc.	3.2	3.9	140.4	141.0	0	C	
8. Honeywell Ltd. (Information Systems)	2.5	2.6	110.0	94.4	17	B	
9. Burroughs Canada	2.4	3.1	108.5	114.0	(5)	B	
10. Hewlett-Packard (Canada) Ltd.	2.3	2.2	101.9	81.0	26	B	
11. STC Canada Inc.	1.9	1.6	84.7	56.4	50	B	
12. Amdahl Ltd.	1.7	2.0	77.0	72.6	6	B	
13. Wang Canada Ltd.	1.5	1.2	64.7	44.5	45	B	
14. Radio Shack (Tandy Electronics Ltd.)	1.4	1.1	61.3	39.7	54	C	
15. Memorex Canada	1.3	1.1	57.4	40.5	42	B	
16. Gandalf Technologies Inc.	1.2	1.1	53.3	40.2	33	A	
17. MAI Canada Ltd.	1.2	1.3	52.0	47.1	10	B	
18. Xerox Canada Ltd.	1.1	1.1	47.7	40.2	19	C	
19. Geac Computer Corporation Ltd.	1.1	1.0	47.0	35.6	32	B	
20. Nabu Manufacturing Corporation	0.8	0.8	35.0	29.0	17	A	
21. Data General (Canada) Inc.	0.7	0.8	32.4	29.0	12	B	
22. ESE Limited	0.7	0.3	30.4	10.0	204	B	
23. Commodore Business Machines Ltd.	0.7	0.5	30.0	18.0	67	C	
24. Northern Telecom Ltd.	0.7	0.7	29.0	26.2	11	C	
25. Mohawk Data Sciences Canada Ltd.	0.6	0.6	26.8	22.3	20	B	
26. Electrohome Ltd.	0.6	0.6	25.0	20.0	25	B	
27. Apple Canada Inc.	0.5	0.6	24.2	20.1	20	B	
28. Datapoint Canada Inc.	0.5	n/a	23.5	n/a	n/a	B	
29. CGE Co. Ltd. (Information Services	0.5	0.4	21.0	16.0	31	C	
30. Tandem Computers Canada Ltd.	0.5	0.4	20.5	15.7	31	B	
31. National Advanced Systems	0.4	0.4	18.0	15.0	20	B	
32. General DataComm Ltd.	0.4	0.4	17.2	13.9	24	B	
33. Olivetti Canada Ltd.	0.4	0.4	17.0	15.5	10	B	
34. Prime Computer of Canada Ltd.	0.4	0.4	16.0	13.0	23	C	
35. ICL Computers Canada Ltd.	0.3	0.4	14.0	15.0	(7)	B	
36. Comterm Inc.	0.3	0.3	15.3	9.5	61	A	
37. Tulsa Computer Products Ltd.	0.3	0.3	13.9	9.0	54	B	
38. Four-Phase Systems Ltd.	0.3	0.4	13.1	13.4	(2)	B	
39. ITT Courier (ITT Canada Ltd.)	0.3	0.3	12.7	9.5	34	B	
40. Matrox Electronic Systems Ltd.	0.3	0.2	11.0	8.7	26	B	
41. NCR Comten Inc.	0.2	0.1	10.4	5.2	100	B	
42. Nelma Data Corporation	0.2	0.2	10.1	7.6	33	B	
43. Norpak Corporation	0.2	0.2	10.0	7.0	43	A	
44. Texas Instruments Canada Ltd.	0.2	0.3	10.0	10.0	0	C	
45. Develcon Electronics Ltd.	0.2	0.2	9.6	6.7	43	B	
46. Centronics Canada Inc.	0.2	0.3	9.2	9.1	1	B	
47. Perkin-Elmer Canada Ltd. (Data Systems)	0.2	0.2	8.0	6.8	18	C	
48. Recognition Equipment (Canada) Ltd.	0.2	0.2	8.0	8.1	(1)	C	
49. Cybernex Ltd.	0.2	0.1	7.1	5.2	37	B	
50. Tektronix Canada Inc.	0.2	0.3	7.0	9.0	(22)	B	
51. Computervision Canada Inc.	0.2	0.1	6.9	5.0	38	C	
52. Nixdorf Canada Ltd.	0.1	0.1	5.5	3.5	57	C	
53. G.A. Computer Ltd.	0.1	0.1	4.4	3.7	19	B	
54. Floating Point Systems Canada Ltd.	0.1	0.1	3.7	3.4	9	C	
55. Anderson Jacobson Canada Ltd.	0.1	0.1	3.5	2.5	40	B	
56. Plessey Peripheral Systems	0.1	0.1	2.2	2.2	0	B	
57. dy-4 Systems Inc.	0.1	0.0	2.1	0.8	163	B	
58. Orchatech Inc.	0.0	0.0	1.4	n/a	n/a	B	
59. Victor Technologies (Canada) Inc.	0.0	0.0	1.2	n/a	n/a	B	
60. ABC Systems International Inc.	0.0	0.0	1.1	0.4	175	B	
Total			4,461.9	3,624.9	23		

Notes

*1 Includes those firms which derive a major portion of their revenues from the sale or lease of hardware of their own manufacture.

*2 Figures are in $ Canadian milions, and include domestic and export revenues

Source Code

A = Published by Company
B = Confirmed by Company Officer
C = Estimated by Evans Research Corporation

CAD/CAM, robotics and computer aided instruction. It is also interesting to note that DEC equipment has been the traditional choice of AI workers.

Control Data Corp. Canada has shown interest in AI related activity in Canada. Several years ago CDC showed early interest in bringing the TAUM machine translation system into a commercial product. However, the corporation decided not to proceed with commercialization.

4.2 Assessment of the Canadian Hardware Situation

The major hardware companies in Canada are US firms with significant US based R&D resources. While they will be a source of significant R&D stimulation, will likely be leaders in US AI technology and may take individual initiatives in Canada, a technology transfer process with these companies in leading roles would be difficult to structure in a national plan.

4.3 Software Industry

The packaged software industry was launched in 1969 with the unbundling* of software by IBM. The advent of an independent software industry had a slow start and was dominated by consulting firms with services for building custom solutions. The relatively recent micro and minicomputer revolution has spawned many software houses, particularly in North America, aimed at developing packaged software. Currently the largest firms are in the US and have sales of approximately $100

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* software was no longer free with purchases of hardware

million per year (for example, MSA, Cullinet), but in general 95% of firms in the software package business have sales of less than $5 million per year.

Strategically, it has been suggested that the role for Canada in AI should be in software. Exhibit 4-4 shows Canada's leading software and EDP consulting companies (excluding major hardware vendors such as IBM, DEC). The industry is still in a relatively immature state with 3 firms in the $20-40 million sales range and the remainder of the industry consisting of many small companies below $10 million in sales.

In general, activities of these companies consist largely of consulting activities and traditional systems development, with only a few companies like Quasar (recently renamed Cognos Inc.) leading in the development of general purpose software packages for a particular installed hardware base that can meet market needs at a fraction of the customer's inhouse development costs.

Currently, the software market is suffering all of the strains of fast growth business including shortage of professional management, ill-defined market and product strategies, and highly fragmented industry structure. For the Canadian companies to be successful they must take an export market orientation, an approach that is costly for small companies.

In considering opportunities for Canada in Artificial Intelligence it is possible that the greatest industry launched successes will be with small firms working on a well planned product line in particular

Exhibit 4-4

Canada's Leading Software and EDP Consulting Companies*2

	Company Name	% of Total 1982	% of Total 1981	EDP Revenues*1 1982	EDP Revenues*1 1981	% Growth 82/81	Source Code
1.	Systemhouse Ltd.	28.2	28.9	39.8	30.5	30	A
2.	DMR & Associates	23.4	25.8	33.1	27.2	22	B
3.	Quasar Systems Ltd.	13.2	10.5	18.6	11.1	68	A
4.	Sydney Development Corporation	5.7	4.6	8.0	4.9	63	C
5.	Bailey & Rose	5.2	5.1	7.3	5.4	35	B
6.	MSA Canada Inc.	3.6	2.9	5.1	3.1	65	A
7.	Cincom Systems of Canada Ltd.	3.5	3.2	5.0	3.4	47	B
8.	Computech Consulting Canada Ltd.	3.4	3.7	4.8	3.9	23	B
9.	Le Groupe BST Ltd.	2.3	3.3	3.2	3.5	(9)	B
10.	LGS Data Processing Consulting Inc.	2.0	1.7	2.8	1.8	56	B
11.	ISS Information System Services Ltd.	2.0	3.5	2.8	3.7	(24)	B
12.	Pansophic Systems of Canada	1.7	1.9	2.4	2.0	20	B
13.	University Computing Co. Can. Ltd.	1.6	1.8	2.2	1.9	16	C
14.	Applied Data Research Canada Ltd.	1.5	1.0	2.1	1.1	91	B
15.	Dyad Computer Systems Inc.	1.5	2.0	2.1	2.1	0	B
16.	Polaris Technology Corp.	1.5	n/a	2.1	n/a	n/a	B
	Total			141.4	105.6	34	

Notes

*1 Figures are in $ Canadian millions

*2 Includes those firms who derive the bulk of their revenues from EDP-related consulting and/or sale/licensing of custom and/or "packaged" software

Source: EDP In-depth Reports, June, 1983 applications areas. Critical corporate capabilities needed to back a successful R&D team will include packaging skills, marketing and sales capabilities, software product management and capital.

In a field that will continue to be dominated by IBM for the forseeable future, some suggested strategies are:

- encourage BNR/NT as the largest Canadian company with computer activity as a centre for research in the areas of their interest (currently communications activity);
- encourage joint ventures of key firms ie. AES-Cognos;
- support 'winning' Canadian based software houses;
- encourage the assignment of world product mandate for software to Canadian based multinationals; and
- encourage continued formation of new companies.

4.4 Spawning of New Companies for AI

The emergence of AI as an increasingly viable technology has caused the formation of many new companies, particularly in the United States. In Canada, there are several of these new groups also, for example:

- Nexa of Ottawa
- Canadian Artificial Intelligence Products Corporation of Nepean
- Micronet Limited of Halifax
- Northwest Research Associates of Vancouver
- Cognicom Corp of Toronto

These groups must develop specific and immediate strategies for carrying their AI skills to market effectively. In Canada, this activity seems to be well behind the US where there is a lead of at least 2-3 years, with the result that more than 30 AI software companies are currently underway. Some indications of the type of activities that are underway in Canada are described below, with a larger sample indicated in Exhibit 4-5. In all cases these firms are still relatively small, ranging in size from 2 people to approximately 15.

4.4.1 Nexa Corporation

Nexa Corporation of Ottawa is a privately held investment and management company that operates in computer related areas. Nexa has various interests in artificial intelligence areas through involvement with MPG Canada, a Martin Marietta Data Systems Company, KWIP, and CTI.

4.4.2 Micronet Limited

Micronet Limited of Halifax is led by Peter B. Macauley and includes seven other people. The company is working on the development of a self-learning controller to reduce the cost of heating domestic hot water. The controller uses a Z80 microcomputer and is based on the Cerebellar Model Arithmetic Computer (CMAC) work by James S. Albus.

4.4.3 Northwest Research Associates

Alan Campbell of Northwest Research Associates in B.C. was one of the principals in the original Prospector project at SRI. As an economic geologist he helped to formulate the models of ore bodies. He has now implemented a new system called Prospector II that provides the functionality of Prospector with the addition of several new features. It provides a good 'naive user' interface and allows full interaction with a map data base. The system runs on a so-called knowledge Engineering Workstation which is a fully configured IBM PC with a graphics tablet. The system allows the user to specify his knowledge in

Exhibit 4-5

Canadian AI Companies

Company Name	Key Personnel	Area of Work
Nexa Corporation. Ottawa, Ontario	Mr. John Branch	investment, natural language
Micronet Limited, Halifax, Nova Scotia	Mr. Peter Macauley	self-learning controller
Northwest Research Associates, British Columbia	Dr. Alan Campbell	expert systems (geological)
Cognicom Corp., Toronto, Ontario	Dr. Zenon Pylyshyn	consulting in MT, NLP and AI
Canadian Artificial Intelligence Products Corporation; Nepean, Ontario	Mr. Peter MacKinnon	natural language processing, machine translation, expert systems; AI consulting
Robotic Systems International Ltd., Sidney, B.C.	Mr. Jack Wilson	robotics
Expert Systems Corp., Vancouver, B.C.	Mr. John Davies	expert systems, signal processing
N.W. Artificial Intelligence, Vancouver, B.C.	Dr. Peter Rowat	expert systems, (avalanche forecasting)
Gomi AI Systems, Kanata, Ontario	Mr. Gomi	expert systems, medical

an English-like language which is then compiled into a new rule-based knowledge representation language. This system and others like it represent an important new area of activity for Canada.

4.4.4 Cognicom Corp.

Cognicom Corp. of Toronto is a group of leading Canadian academics who have recently organized and are prepared to address a wide range of consulting studies in the areas of MT, NLP and AI.

4.4.5 Canadian Artificial Intelligence Products Corporation (CAIP)

CAIP Corp. of Nepean, Ontario is a recently organized privately held firm specializing in development, acquisition, marketing and sales of natural language processing, machine translation and expert systems products. The firm also provides senior consulting services through ties to Cognicom Corp. There are currently five senior staff members. The president is Peter MacKinnon.

4.5 Conclusions

The computer industry in Canada consists mainly of branch plants of multinational firms which are primarily sales organizations with some manufacturing. There have also been some initiatives on the part of several of these firms toward encouragement of research and development; but the fact that in 1981, an Evans Research Corporation study estimated that Canada's 13 largest foreign owned computer firms spent less than $25 million on research and development in Canada in 1978 indicates the level of activity.

In packaged software alone only Cognos has sales on the $15 million sales range with the remainder of the industry very fragmented. At the same time there is evidence of early development of a group of Canadian AI companies.

The purpose of this assessment was to gain an overview of the industry and to evaluate opportunities for Canada from the point of view of this industry. While there are currently limited Canadian strengths in this important sector, key strategies that emerge are:

- encourage world product mandates;
- assess technology development and transfer opportunities through arrangements with companies like DEC, CDC;
- approach companies that could be leaders to determine interest (e.g., BNR/NT, AES, Cognos);
- encourage continued formation of new companies through contracts;
- support current 'winning' Canadian based software houses through procurement programs (eg. efforts in AI/NLP/MT joint ventures).

5. Canadian Industry Sectors and Special Interest Users

"Innovation is the entire process leading to the commercial success of new and improved products and production methods. This leads to two critically important points. First, innovation is market-driven; that is, innovation responds to the realities of the market place and does not simply represent a technical advance without commercial application. Second, innovation is an on-going process undertaken by firms in the course of doing business. The innovation process begins with the identification of a market opportunity and is generally comprised of four elements: acquisition of the necessary technical knowledge (technology), whatever the source; research, development, design and engineering; manufacturing start-up; and marketing."*

The above quotation is an extreme view of the market pull technology push equation; it has been included to emphasize the value of attempting to assess the Canadian market interest in AI even at this early stage.

The Canadian industry sectors and special interest users are the fundamental domestic demand base for machine translation, natural language processing and artificial intelligence applications. Companies in these sectors could lead or at least shape the technology development, and marketing of competitive new products

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* Background Paper for the Workshop Discussions, Canada Tomorrow Conference, D.H. Fullerton, Nov. 1983.

and processes through organization into appropriate institutional mechanisms; however, where sectors are dominated by branch plant organizations or highly fragmented industry structure, the likelihood of joint industry-government research and development efforts is low.

In strategic areas such as mining, aerospace, energy, banking and manufacturing, companies were selected to determine the status and sophistication of their current computer systems, the awareness of artificial intelligence techniques, the application areas of interest, and the expected timeframe for market readiness of AI products and implementation. The existence of in-house R&D activity in the field and the potential for the companies in question to play a role in leading development were also considered. While detailed market forecasts cannot be made based on these data, the information provides a basis for assessing domestic needs and institutional opportunities.

Exhibit 5-1 shows a distribution of real domestic product by sector to demonstrate the relative sizes of the major areas. Exhibit 5-2 gives an overview sense of foreign ownership in selected industry groups in Canada. This aspect is significant in assessing the areas where there may be an interest in a leading role in R&D and applications development in Canada. Among the areas we are considering, there is high Canadian ownership in forestry, metal mining, finance and services.

5.1 Translation

The Canadian translation industry consists of 4000-5000 translators, which work for both public and private sector groups. In the public sector, about 2000 translators are employed at all levels.

Exhibit 5-1

Distribution of Real Domestic Production by Sector 1950-1979 (%)

	1950	1960	1970	1979
GOODS	38.4	37.8	37.3	35.0
Agriculture	5.9	4.6	3.2	2.6
Industry	32.5	33.2	34.1	32.4
SERVICES				
TRSCU	9.4	10.2	11.8	13.5
TRADE	12.1	12.0	11.8	12.1
FIRE	12.4	12.4	11.7	13.1
CBPS	19.2	18.1	19.9	19.4
PADM	8.5	9.5	7.5	6.9
TOTAL SERVICES	61.6	62.2	62.7	65.0

TRSCU: Transportation, Storage, Communication and Utilities
TRADE: Wholesale and Retail Trade
FIRE: Finance, Insurance and Real Estate
CBPS: Community, Business and Personal Services
PADM: Public Administration

Source: Based on data available from Statistics Canada, Real Domestic Product by Industry, cat. 61-213, various years.

Exhibit 5-2

Degree of Foreign Ownership of Corporations in Selected Industry Groups in Canada

	Per cent Assets		Per cent Sales	
	1973	1974	1973	1974
Major Industry Group				
1. Agriculture, Forestry and Fishing	10	10	8	7
2. Metal Mining	45	45	43	44
3. Mineral Fuels	75	75	87	88
4. Other Mining	55	57	60	59
5. Total Mining	58	59	61	64
Manufacturing				
6. Food	48	49	38	39
9. Rubber Products	93	94	91	91
11. Textile Mills	60	60	57	56
14. Wood Industries	29	28	23	24
16. Paper and Allied Industries	45	44	45	45
18. Primary Metals	16	15	20	19
19. Metal Fabricating	44	52	45	41
20. Machinery	70	68	71	70
21. Transport Equipment	81	80	90	89
22. Electrical Products	65	65	68	65
23. Nonmetallic Mineral Products	66	66	54	56
24. Petroleum and Coal Products	99	100	99	99
25. Chemical and Chemical Products	79	78	84	83
26. Miscellaneous Manufacturing	50	48	52	49
27. Total Manufacturing	56	57	57	57
28. Construction	15	14	12	12
Utilities				
33. Total Utilities	10	9	11	11
34. Wholesale Trade	32	30	29	29
35. Retail Trade	19	18	17	16
36. Finance	12	11	11	11
37. Services	26	25	24	23
39. Total nonfinancial industries	34	34	37	36

Source: *CALURA, Report for 1974*, pp. 106, 111, 130, 136.

The federal government translation bureau dominates the market, although there is considerable activity in provincial governments, municipal governments and crown corporations.

The private sector consists of three groups:

- translation services of large private corporations
- translation agencies
- freelance translators

Most large private corporations in the country have in-house translation activities, in order to operate in Quebec, or for the purpose of supporting activities in world markets. Some sample companies who expressed strong interest in machine translation activities include, for example, Gulf Canada and Imperial Oil.

Translation agencies are firms that accept material for translation from outside parties and undertake the translation in-house or contract it out. These organizations can range from a company such as Devienne, Forgues and Associates of Montreal, which has approximately 50 translators in-house in addition to some freelancers, to companies incorporated with 1 employee. Looking ahead a few years it is roughly estimated that assuming a WEIDNER or ALPS system is operating on a minicomputer and is priced around $20,000 there could be 20-40 Canadian translation agencies interested in acquiring such a system.

Finally, there a large number of freelance translators who work under contract to all of the above groups, who will eventually be impacted by the entrance of machine translation into this market.

5.2 Communications/Space

The communications sector will be critical to Canada's future role in the information-driven world. As the importance of information management rises in economic terms, the quick and efficient handling of information provided by the various areas of the communications sector will be significant.

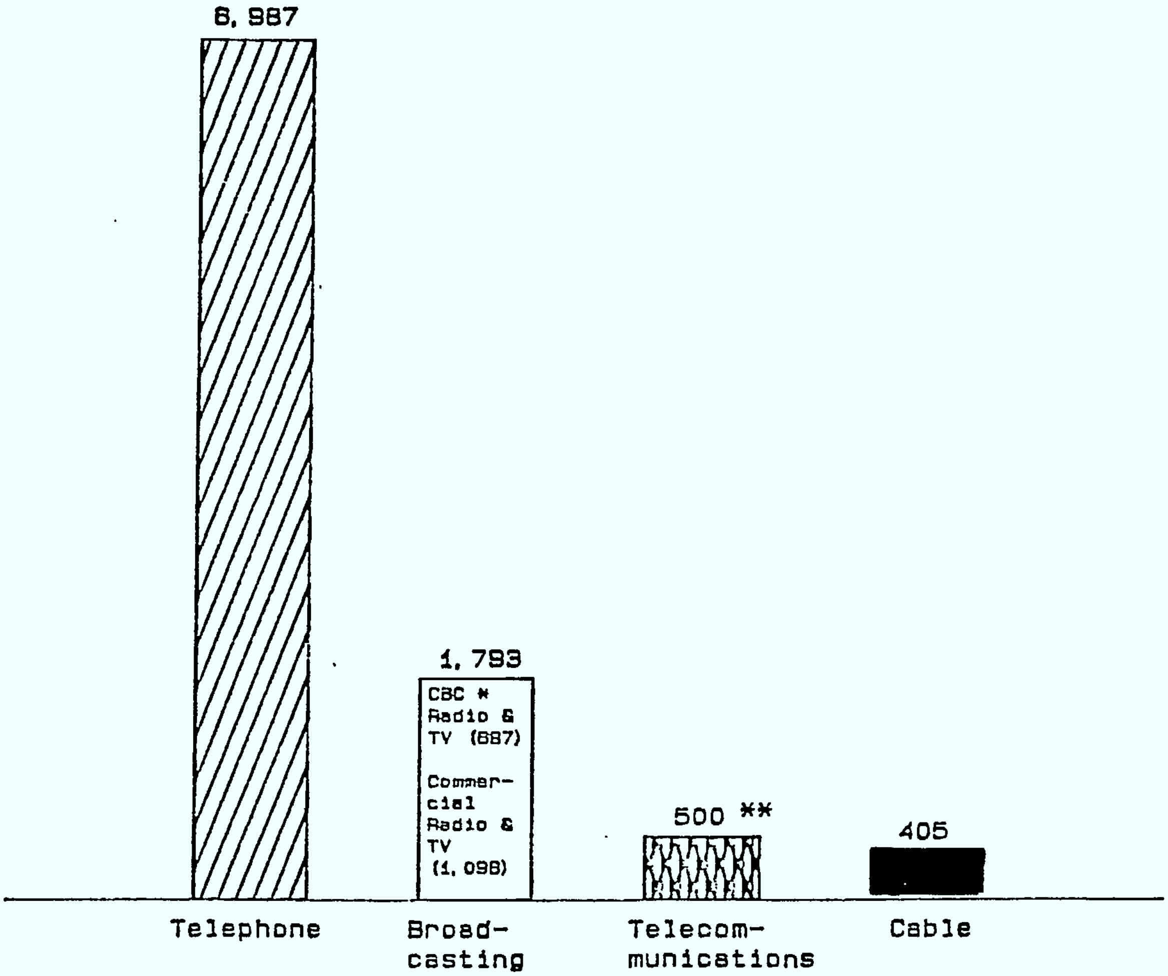
The communications sector is an umbrella which can include the telecommunications, broadcast, telephone, and cable industries as well as their suppliers which are in fields ranging from microelectronics to space.

In total, the 1981 revenues of the communications industry were $11.7 billion, as indicated in Exhibit 5-3. Exhibit 5-4 shows a breakdown of employment in R&D for suppliers to the industry which range from Northern Telecom and AEL Microtel to many smaller companies indicating roughly the profile of the industry and the domestic R&D activity. It is interesting to note in Exhibit 5-5, that in a global context that even Northern Telecom can be considered quite small.

Exhibit 5-3

Communications Industry Operating Revenue, 1981

($ millions)



Notes:

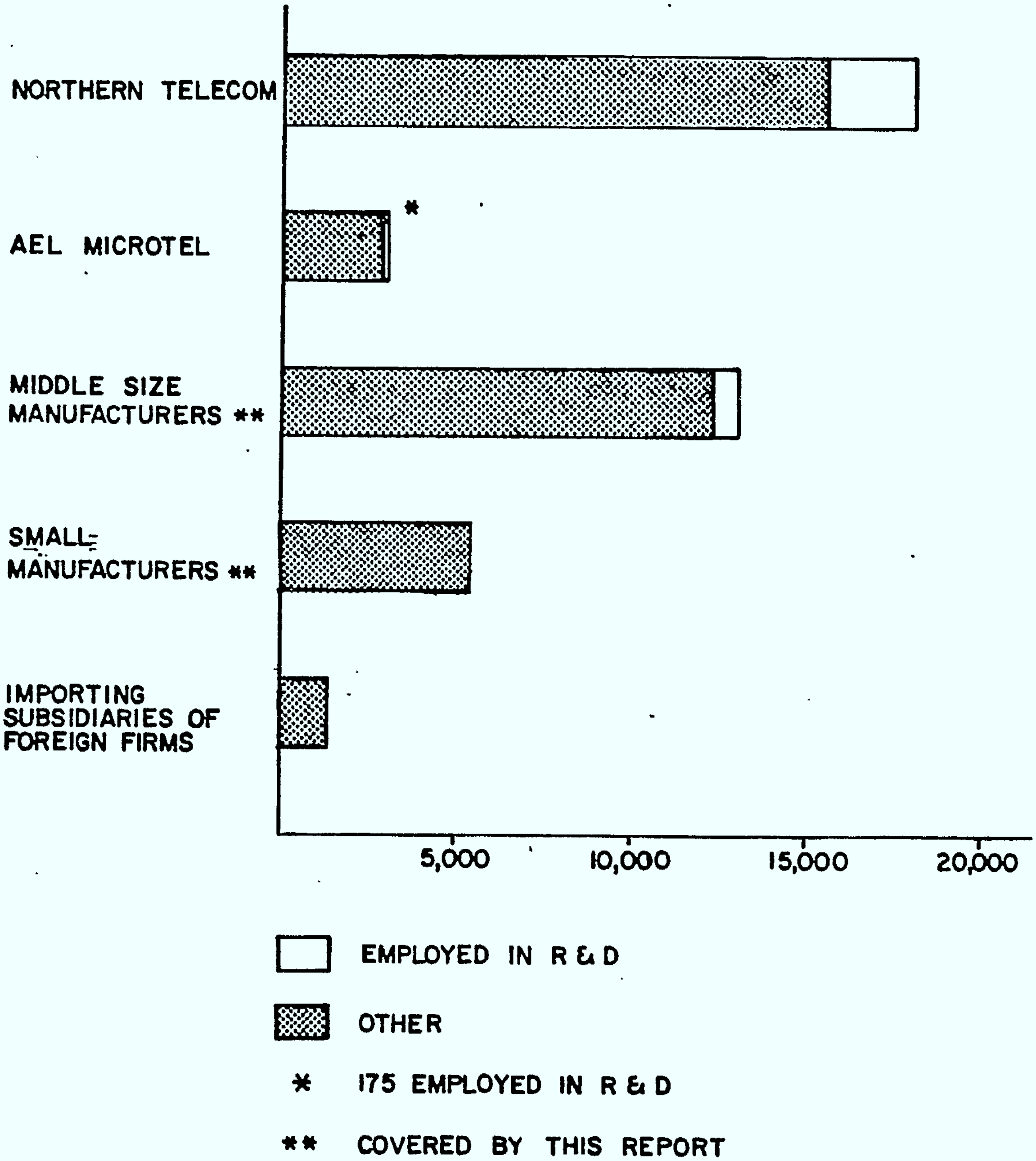
* Includes CBC expenses and depreciation; excludes CBC revenues
** Estimated for 1981

Sources: Statistics Canada, Cable Television, 1981; Telephone Statistics, 1981; and Radio and Television Broadcasting, 1981.

Source: Profile of Cable TV Supplier Industry in Canada; Department of Communications, 1983

Exhibit 5-4

Canadian Residents Employed by Manufacturers/Suppliers of Communications Equipment in 1978



Source: The Supply of Communications Equipment in Canada, Department of Communications, 1981

Exhibit 5-5

World Communications Equipment Manufacturers with 1978 sales* of Communications Equipment

Exceeding $1 Billion

Manufacturer (in order of total sales)	Total sales ($ billion)		Communications equipment sales ($billion)		Total number of employees	Base Country
International Telephone & Telegraph	US	19.4	US	4.7	379,000	US
Philips Lamp Holding Company	C	17.3	C	4.4	387,900	Holland
Siemens AG	C	16.5	C	3.1	322,000	FRG
Hitachi*	US	10.8	US	1.8	138,700	Japan
Western Electric	US	9.5	US	9.5	161,000	US
General Telephone & Electronics	US	8.7	US	1.8	214,000	US
Rockwell International	US	5.7	US	1.3	114,200	US
General Electrical Company (UK)	C	5.5	C	2.1(E)	178,600	UK
Cie Générale d'Electricité	C	5.2	C	1.4	104,900	France

Exhibit 5-5 (cont'd)

Manufacturer (in order of total sales)	Total sales ($ billion)	Communications equipment sales ($billion)	Total number of employees	Base Country
Thomson-Brandt*	C 4.3	C 2.2	109,200	France
Nippon Electric Company	US 3.7	US 1.4	60,500	Japan
L.M. Ericson	US 2.1	US 2.1	61,400	Sweden
Northern Telecom	C 1.5	C 1.5	31,000	Canada

* 1977 data for Hitachi and Thomson-Brandt; 1978 data for all other companies

(E) Estimates. General Electric (UK) does not report net product group sales or intra-company sales

+ The Canadian and US company sales are quoted in the dollar currency reported. The sales of overseas companies are converted to Canadian dollars at the average exchange rate for 1977 or 1978, except for Nippon, Hitachi and Ericsson which report in US dollars.

Source: Company Annual Reports

Source: The Supply of Communications Equipment in Canada, Department of Communications, 1981

Opportunities for AI applications in this sector range from the Office of the Future developments to Spar Aerospace activities - as leading communications satellite contractor and their related work in remote manipulator systems. In addition, under this umbrella are manufacturers of specialized electronic products. In these companies the technologies of the computer and telecommunications equipment are increasingly converging. Canadian companies such as Gandalf and Mitel are well established with products on the leading edge of communications technology.

It is suggested that Northern Telecom and AEL Microtel could be key companies to consider for leading roles if a national plan were to be considered, although a procurement strategy could identify other interested and capable parties.

5.3 Other Industries

In this section we will discuss at a very high level the activities and interests indicated by representative companies in the resource, transportation, manufacturing and financial sectors.

Discussions were held with major companies in each of these sectors, all of whom have large systems organizations and sophisticated activities in a variety of financial, technical, and other applications areas. Generally, the interviewees had a high level of awareness of artificial intelligence techniques and were starting to assess the areas of application where AI products might be of interest.

In most cases, the areas of artificial intelligence that were cited were machine translation, natural language access to data bases, and expert systems. A detailed list of interests mentioned by company is shown in Exhibit 5-6. Longer term in our key resource industries such as forestry, mining, fishing and agriculture, the particular application of remote sensing/computational vision will play a role in resource monitoring, expert systems can help to find and manage resources and robotics will be used increasingly in extreme environments.

Through the range of discussion, there was little indication among these companies of a strong interest in taking a leading role in research and development in these areas. In most cases, the position is to monitor developments and await offerings and/or propositions of the major hardware and software producers. Generally, the likely timeframe for implementation of products was expected to be 5 to 10 years away, although early innovators may be involved sooner.

Exhibit 5-6

Sample Interests of Canadian Companies

Company	Areas	Specific Applications
Bank of Montreal	Expert Systems	Financial Advisor
Imperial Oil	MT	
	NLP	timely, access to data
	Expert Systems	refinery scheduling optimizing distribution system analyzing siesmic reservoir analysis
Hydro	NLP	access to 115 corporate data bases
	Robotics	work in dangerous environments
	Expert Systems	system control
Noranda	Expert Systems	open pit mining land use planning for forest products process control advances
Canadian General Electric	Expert Systems	in area of machinery
Nova	NLP	office automation
	Voice Recognition	Novatel activities
	Robotics	systems engineering Novacor
	Expert Systems	well-log analysis
Bombardier	Robotics	flexible manufacturing systems
	NLP	data base query

6. Key Applications Areas

In assessing the opportunities in the various application areas, we will review the highlights of the state of the art review, consider the key technology developments and discuss markets, and competitive interests.

The applications areas to be discussed will include:

- Machine Translation
- Natural Language Processing
- Expert Systems
- Speech Recognition, Optical Character Recognition, and other AI applications

6.1 Machine Translation

6.1.1 State-of-the-Art

The State-of-the-Art Report defined stages of development for MT. First generation machine translation systems produced in the early 1960s consisted of huge non-modular programs which produced a poor quality product of limited application. Some improved first generation systems, SYSTRAN & LOGOS, were developed in the period 1966 to 1975 and used where high quality translation was not required. Advances in the area of linguistics, formal grammar, parsing and compilation led to a new modular approach: 1) separation between analysis of source language text, transfer, and synthesis of target language text and 2) separation between linguistic data and algorithmic components. Systems with these modular characteristics are considered second generation.

The next major stage underway since 1975 is the exploration of suboptimization techniques including machine aided human translation (MAHT), restricted input systems, human aided machine translation (HAMT). Currently, there are several operational products for example, ALPS, WEIDNER and TAUM-METEO. While limited in scope, TAUM-METEO is the only fully automated high quality translation system.

There are several development projects underway including various public and private projects in Japan; METAL at University of Texas, sponsored by Siemans Corp; ESOPE, a French national project; and EUROTRA, an EEC undertaking. However, as to longer term research directly focussed on MT, very little is going on currently except in Japan.

6.1.2 Key Technological Thrusts

The advancement of machine translation activities will require both long term basic research and short term developments both in specific MT problem areas and interdisciplinary approaches.

Some active areas of basic research where developments could be expected are as follows:*

- viewing the human speech activity as a special case of planned, goal-directed behavior;
- developing a unified view of discourse phenomena such as anaphora, ellipsis and focus;

* State-of-the-Art Report

- understanding how the structure and semantics of specialized sublanguages relate to those features of the language as a whole;
- developing more refined techniques for knowledge representation such as the KL-ONE language and other formalisms for networks, frames and logic;
- developing richer logics, including models of common-sense reasoning;

In addition, MT and NLP need to be able to take into account a much broader context both linguistic context (eg. text grammar and non-linguistic context (eg. encyclopedia knowledge).

On the more practical side, these advancements and others in supporting technologies could lead to a commercialization scenario involving MT & NLP and eventually all forms of AI as speculated below:

1. during 1984:

- commercialization by AI Corp. and by Symantec of English query systems for data bases on micro-computers (IBM PC and others) at a price of $300-$500;
- commercialization by Siemens Corp. of Munich of the METAL system of U. Texas, at least on a trial basis (difficulties likely during attempts to extend system to new domains);

- enhanced workstation capabilities added to existing MT systems of ALPS and WEIDNER; English-German pair added to LOGOS system.

2. 1985-86:

- commercialization of first English-Japanese MT system in a restricted domain (Hitachi??);
- commercialization of a text-critiquing system such as EPISTLE;
- commercialization of French language versions of data base query systems such as INTELLECT and the more powerful micro-computer query systems commercialized by Symantec;
- synthesis of bilingual texts in very restricted domains on an operational scale (assuming sufficient investment) to replace MT in those domains (eg. market reports, statistical reports);
- multi-lingual data base query systems for specific large applications in government and industry;
- public contact with first expert systems or "advisory systems" which explain their reasoning in a rudimentary way in specific applications (eg. banking services, insurance planning, health care, legal advice, travel planning).

3. 1987-1990:

- commercialization by one or more Japanese firms of English-French and English-Spanish MT systems with good quality (efficient revising) and large coverage of grammar and vocabulary; challenge met by North-American and French companies with somewhat less usable results;

- relatively intelligent dialogue available for novice interaction with large computer systems (system seems to guess the user's wishes and knowledge level), particularly in context of programming;

- movement towards automobile instrumentation which is voice-activated, first as gimmicks; widespread use of synthesized speech for danger and fault warning in automobiles and other complex devices;

- advances in document storage and retrieval; usable abstracts generated automatically;

- documentation for complex devices begin to be replaced by integrated "knowledge base", allowing for easier instruction and debugging of the device through built-in terminal;

- widespread use of text synthesis and other AI accomplishments for computer-aided instruction.

6.1.3 Markets

6.1.3.1 Canadian Markets

The Canadian market for translation is on the order of 500-750 million words* per year of which more than half is federal government work. At an estimated rate of 20-25** cents per word, the market is approximately $100-190 million per year of which $75 million is centered in the Federal Government Bureau of Translation.

6.1.3.2 International Markets

The total international market has been estimated at 20 to 60 billion words annually or $5 to 15 billion at 25 cents per word;* this estimate may be conservative given the work by Jeida 1982 showing the annual translation volume in Japan alone at 40 billion words.* In the area of technical documention alone, we have been told that Transtec, a US company, estimates the world market at $4 billion US, and North America at $400 million US.

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* State-of-the-Art Report, p.85-86

6.1.3.3 Assessment of the Market for MT

Thus, the above scoping estimates indicate that there is a significant marketplace for the translation function. Of critical interest to this study is a sense of how much of that market could be accessible to machine translation.

Translation activities can be broken down into the four major segments.

- Fully automated high quality translation
- Human aided machine translation
- Machine aided human translation
- Human translation.

The top end of the scale is fully automated machine translation. A system such as METEO is approaching this in practical terms. It is estimated that the portion of the market that could be addressed by this type of system in the timeframe is at most 10 percent. This limited share is because of the requirement for restrictions on domain in order to achieve a highly automated system.

For the machine aided human translation and the human aided machine translation techniques a significantly larger portion of the market could potentially be addressed likely in the range of 20 to 30 percent.

Market Characteristics

There are several key considerations in assessing the penetration of machines into the translation arena. These include the following:

- Communications infrastructure/production environment
- The nature of the text
- Human psychological factors
- Acceptance of the sub-optimal solution

The state of the communications infrastructure and production environment are critical for the successful introduction of machine translation . In fact, translation involves a production process of sorts. In small volumes and certain domains an old-style job shop or custom product type of process with minimal automation is firmly entrenched in many areas. In environments handling large volumes of materials of specific domains and with the appropriate state of the art office automation and production line environment, the introduction of some form of machine translation would be compatible with the existing system and would in fact allow for significant productivity gains over the whole process. For example, while the Federal government Translation Bureau has the high volume work, and has tried MT, and built terminology banks, it also has to take into account the type of text and degree of post editing of its many client departments. Mitel, on the other hand has an infrastructure which is completely controlled and in which the author is essentially part of the translation loop.

The nature of the text is an important consideration in two aspects. First, one has to be able to foresee what is going to be processed. Then one must determine whether the sub-languages are sufficiently stereotyped and restricted such that suitable dictionaries can be built.

Finally, there is the aspect of resistance by translators. Mitel's success to date is related as much to a translator on staff who was commited to the dictionary building and implementation of the system as to the infrastructure and the restricted domains for their technical work.

The Machine Translation market is prime for assessment of acceptance of suboptimal solutions. The ultimate goal for the scientist is fully automated high quality machine translation, which is defined as translation completely by machine with the output acceptable without alteration. The goal for a large scale translation manager should be productivity improvements such that the costs of translation per word are minimal.

In recent years, because of a general realization that fully automatic high quality translation of unrestricted text was excessively difficult, there have been attempts to develop suboptimal solutions. One approach is to build systems which will deal only with restricted input; in systems like SMART, the input is artificially restricted. This approach can be very successful, but is applicable only in certain cases.

A second suboptimization approach, called human-aided machine translation, is to compromise somewhat on the degree of automation, and resort to human intervention. This intervention can take place: 1) before the automated process (pre-editing), as with CULT; or 2) during it (interactivity), as with ALPS; or 3) after it (post-editing), as is done to some extent with all current commercial systems.

The third and last suboptimization technique is machine-aided human translation. In this approach, the human translator retains the basic initiative in the translation process, but uses a workstation in which various tools such as word-processing and on-line dictionaries are integrated.

Extensive use of these methods, sometimes in various combinations, has been made in the last few years. Thus, the recent successes in MT are not due to major theoretical breakthroughs in the field (although there has been some amount of progress); they were rather made possible by advances in system development or productization for the marketplace.

6.1.4 Canadian Market Drives

The major users for machine translation are Federal Government Bureau of Translation and provincial government bureaus, with supplementary drives in the translation activities within other large organizations (ie. major corporations) and within those companies that are exclusively occupied with machine translation. The key drives for all of these groups should be economic, although economics is intrinsically tied to the human element. While the economics of existing machine translation systems have not been documented or demonstrated to date, it is interesting also to note that the Translation School at the University of Ottawa does not at this time have a course for undergraduates in the use of machine translation or in computational linguistics. Thus, the mechanisms of education that could lead change of methods in the marketplace are not in fact in place yet.

While the potential demand exists for MT in some form, its diffusion in the marketplace particularly in the suboptimal state requires improved products, demonstrated economics, committed management and appropriately trained translators.

6.1.5 Competitive Analysis

The competitive analysis will consist of comparative evaluation of the State of the Art material regarding development projects that were identified. Exhibit 6-1 summarizes the key factors for the project activities in Germany, US, France, and the European Economic Community. The funding levels for the work in Europe is considerable ranging from less than $1 million/yr for SUZY to several million dollars annually for EUROTRA. When examining the goals for the systems it is interesting to note that the lessons learned by the TAUM group - specifically "the necessity to take into account better criteria for the selection of application domains, the necessity of a better separation between research and development goals and the necessity of an adequate institutional environment for each type of goal"* have not generally been addressed with the exception perhaps of the US METAL project.

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* State-of-the-Art Report

Exhibit 6-1

Competitive Analysis

Development Projects

Project	SUZY	TAUM-AVIATION	METAL	ESOPE	EUROTRA
Country	Germany	Canada	US	France	EEC
Organization	University of Saarbruken	University of Montreal	University of Texas	French National Project	complex
Sponsor	Deutsche Forschung Gesellschaft	Federal Secretary of State	Siemens Corp	French Government	EEC
Goals	general purpose MT German to Fr, Eng; Russian, French, English to German	operational system for aircraft maintenance	operational & marketable multilingual MT system for technical translation	technology transfer multilingual MT development	operational prototypes for language translation between 7 current languages
Status	moving to Suzy-2 3 yrs out	abandoned 1981	early development	early stages	early specifications
Approach	sophisticated first generation	typical second generation	second generation	second generation	little info available
Funding	$890,000/yr	$Ø now	?	$9 million	1982-1988 $27 million
Evaluation	Suzy not state of the art not likely moving to market	state of the art except for most recent developments in semantics	overly ambitious	ambitious	extremely ambitious technically; organizationally complex

6.1.6 Prospects for Canada

In the State of the Art Report, we made an inventory of current MT-related activity under the following headings: operational and/or commercial products, development projects and research projects. Examination of available commercial products shows that virtually all of them are clearly below what can be achieved with state of the art techniques. In many situations, these products cannot meet the quality requirements of potential customers. There is thus plenty of room on the market for better products.

A careful look at current development projects (eg. METAL, ESOPE, EUROTRA), reveals that there is currently a strong tendency to build ambitious wide-scope systems on the basis of a relatively conservative technology. The projects will turn out second-generation MT systems which do not seem to embody much in the way of dramatic technological improvements over the systems developed in the seventies. In fact, there is very reason to believe that if a system like TAUM-AVIATION was improved and generalized along the lines described in Isabelle (1981), it could compete with any of the systems that are now being developed. Instead of trying to build general purpose MT systems, we believe that the best approach would be to use what is now known about the relative complexity of sublanguages to select one or several sublanguages that would appear promising, even if more difficult, for example, than weather forecasts.

Finally, when we turn to research projects devoted specifically to MT problems, we see that nearly nothing is being done at the present time. A lot of excellent research is being pursued in NLP/AI, especially in the US. But very few of the recent results are being applied to the solution of MT problems. As far as we can see, this lack of interest toward MT problems in the American research community is much more accidental than due to the nature of the problem. There seems to be no reason why Canada could not take advantage of this situation, and become a leader in MT research by applying, adapting and improving the latest techniques in syntax, semantics, pragmatics and knowledge representation. In addition, some original research on translation theory and its relations to AI/NLP could be pursued; very little has been done in this direction recently. The aim would then be to acquire, after a few years of research, a capability to develop MT systems that can clearly overcome some of the limitations of current systems.

In short, there is room on the market for better MT products, the technology that Canada has developed in the past is still competitive when compared to current development projects, and there is an opportunity for Canada to take a new lead in MT research, given the resources we have and the lack of significant efforts abroad.

Finally, there are related applications such as the broader field of NLP (discussed in section 6.3) and computer aided language instruction.

6.1.7 Conclusions

R&D in machine translation and related fields presents interesting opportunities for Canada. First, it is an area where Canada can compete on the international scene with relative ease: although there are products on the markets and a few large scale efforts to develop systems in other countries, a long term commitment to R&D would be likely to give Canada an edge in MT and related technologies. Second, very large markets may open up progressively to repay the investment.

6.2 Natural Language Processing

6.2.1 State-of-the-Art

Natural language processing is notably the largest potential AI market. The State-of-the-Art Report indicated that several industrialized countries have recently launched important national programs based on a recognition of the market potential for NLP in the near future. Several products, mainly originating from the US have already made their way to the international market. This activity is likely to accelerate in the next few years because NLP/AI technology is just beginning to reach a level where it can help to solve important real-world problems.

The State of the Art Report discussed natural language processing building from applied systems for language analysis, to the more complex applied systems for language synthesis. With work proceeding on many fronts, the State-of-the-Art pointed to a strategy of focusing on an application such as MT and monitoring NLP developments for opportunity areas and synergies.

6.2.2 Key Technological Developments

The key technological developments and future scenarios laid out in the Section 6.1.2 regarding MT are applicable to NLP.

6.2.3 Market Outlook

In the area of Natural Language Processing, there have been several market estimates. SRI estimates $7-8 million in cumulative sales to 1982 and only moderate growth to $50-$60 million by 1987 with data base management and management information systems leading growth. In Exhibit 6-2 DM Data shows a detailed near term forecast of $18 million sales in NLP for 1983 for 5 major companies, while indicating the formation of 10-20 new start-up companies in 1983. Predicting that this activity will eventually have 20-25% of the total market for software sales DM Data predicts 1990 NLP revenues of $1.1 billion in Exhibit 6-3.

The project team estimates sales to mid 1983 of the INTELLECT system alone at $9.8 million so that the market activity is in the range estimated by SRI and DM Data.

6.2.4 Canadian Market Drives

The drives in the Canadian market for NLP are those that are common to the US and other industrialized nations moving into the information age. Fundamentally, industry is looking for aids for data and information management.

Exhibit 6-2

Calendar Year Sales*
($ Millions)

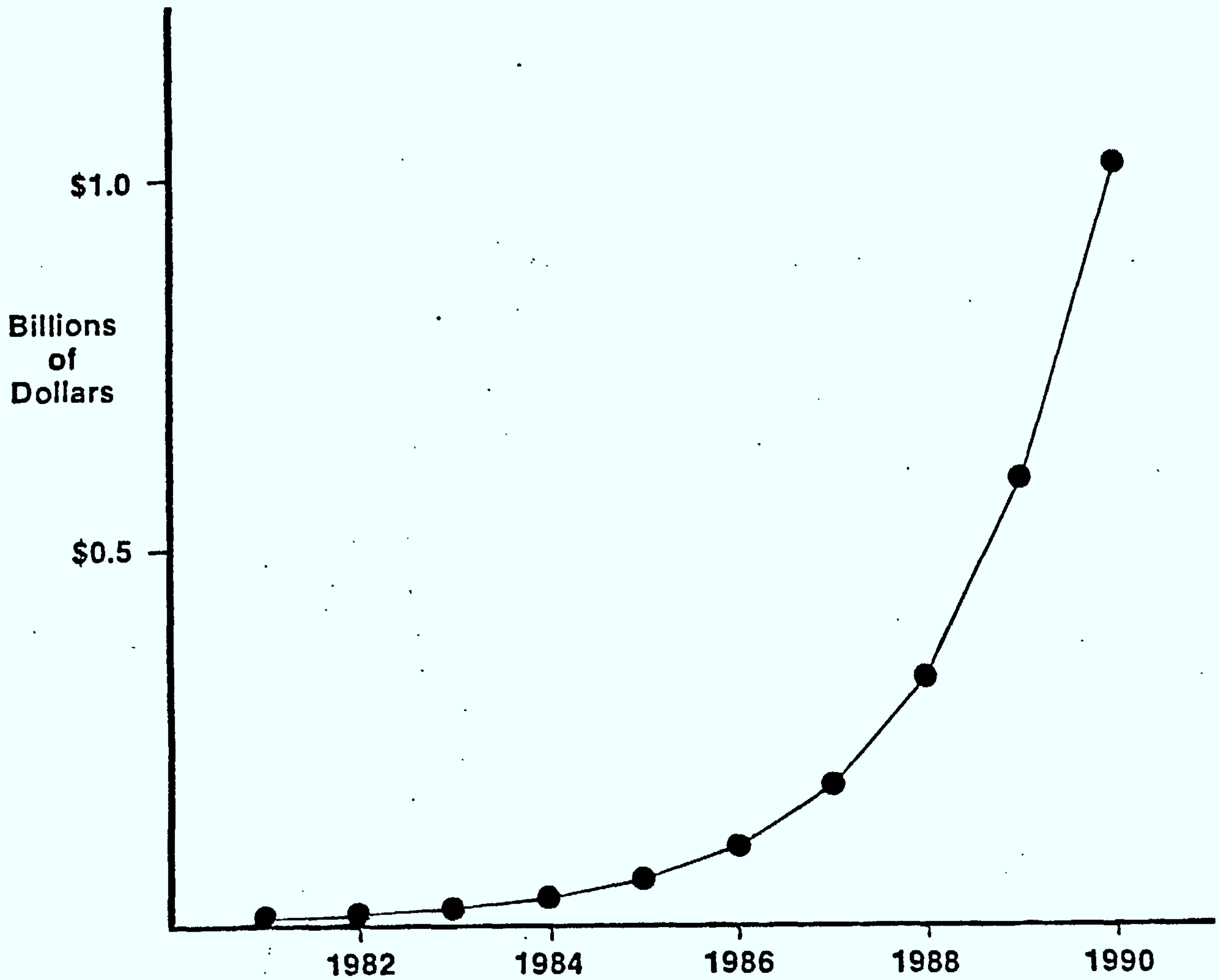
"Natural Language" Software Companies	1982	Est. 1983	Est. 1984
Artificial Intelligence Corp.	$3.0	$ 4.7	$ 7.0
Cognitive Systems Inc.	0.5	1.5	3.0
Decision Products Inc.	1.5	2.0	3.5
Excalibur Technologies Corp.		1.0	1.8
Symantec		.8	1.7
Others	3.0	8.0	15.0
TOTAL	$8.0	$18.0	$32.0

* Exact sales usually are not disclosed.

Source: The Emerging Artificial Intelligence Industry, D.M. Data Inc., August 1983

Exhibit 6-3

The US Market for Natural Language Software



Source: The Emerging Artificial Intelligence Industry, D.M. Data Inc., August 1983

Exhibit 6-4 lays out some industry interests noted in NLP applications. Generally, the computer software packagers and services industries will likely develop these products and bring them to market; rather than have large users develop programs in-house.

6.2.5 Competitive Interests and Resources

Natural language processing is a significant part of the plans announced to date by Japan, Britain and others. In general, there are long term research areas in addition to short term goals. These have been discussed in the Technology Thrusts Report.

6.2.6 Prospects for Canada in NLP

The State of the Art Report and the discussions in section 6.1 points to a strategy for MT which is inherently related to NLP. While a focus on MT seems advisable for Canada, we should keep in mind that NLP is a coherent domain, in the sense that the technology required for one application, eg. MT, is likely to overlap with the technology required for other natural language applications. It has been pointed out by R. Kittredge that multilingual synthesis can occasionally be a viable alternative to translation. R&D on MT and text synthesis would clearly be synergistic technologies: not only would they both contribute to the solution of some translation problems, but the technology developed for one would be likely to benefit the other.

Another interesting area would be computer-assisted language instruction (CALI). Very little attention has so far been paid to these systems in the US. There are also two ways in which CALI systems associate naturally with MT and text synthesis: first they bring a different but

Exhibit 6-4

Sample Canadian Market Interests in NLP

Company	Area
Nova	office automation "user friendliness"
Cognos	data base query systems "systems as easy to use as telephones"
Imperial Oil	top management information needs "timely do-it-yourself access to quality data"
Ontario Hydro	major need is data base query "many data bases and many people wanting access"
Nexa	natural language front ends to expert systems "NL and other intelligent access to computer systems is the hottest commercial item of AI"

potentially important contribution to bilingualism (or multilingualism) policies; second, the best existing CALI systems make extensive use of language synthesis techniques.

6.3 Expert Systems

The assessment of opportunity for Canada necessitates a review of the potential in the area of expert systems (ES) since it is a commercially active area in AI at this time.

6.3.1 State-of-the-Art

The State-of-the-Art review distinguished five types of expert systems, specifically: diagnosis systems, designer systems, advisor systems, tutor systems and inventive systems. The current applications areas included 1) scientific and engineering, 2) medical, 3) educational and 4) business.

The commercial development of expert systems in these applications areas was scoped and clearly current efforts are focussed mainly in the US with thirty to fifty organizations and approximately 500 people involved with ES development and 100 researchers with direct link to ES development. Canada, in 1983 has only modest ES commercial activity. In general, successes to date have been related to the discovery of particular applications that make use of a limited knowledge domain applied to problem solving by inferencing (both logical and probabilistic inferences).

6.3.2 Key Technology Developments

The key technology developments required for the advance of expert systems include:

1. better tools for building expert systems so that non-competitive experts can develop own systems (better methods for acquiring, managing and changing rules)
2. development of causal models
3. development of significant industrial applications
4. development of better human interfaces including inputs, generation for output for explaining the reasoning process
5. development of simple consumer oriented expert systems ie, finance, tax, medicine.

6.3.3 Market Outlooks

In order to assess the opportunity in the area of expert systems there must be a measure of the market opportunity in this area.

DM Data has attempted to develop market forecasts based on extrapolation of recent measureable activity. SRI has commented more generally on current markets and expected growth rates. Exhibit 6-5 shows a detailed estimate of the US expert system market for 1982, 1983, 1984, while Exhibit 6-6 extrapolates a longer term view showing an annual market of $220 million by 1990 based on a 55% annual growth rate. SRI, on the other hand estimates the expert system market in 1982 at 2-3 million dollars growing at 60-75% to $30-40 million by 1987 with even higher growth dependent on the coinciding development of positive economic conditions and technical advances.

Exhibit 6-5

Expert Systems Market
Est. Calendar Year Sales*
($ Millions)

Expert System Companies	1982	1983	1984
Intelligenetics	$0.8	$ 1.4	$ 2.0
Smart Systems Inc.	0.3	0.8	1.0
Systems Control Technology, Inc.**	3.0	5.0	8.0
Teknowledge, Inc.	2.0	3.0	5.0
TOTAL	6.1	10.2	16.0

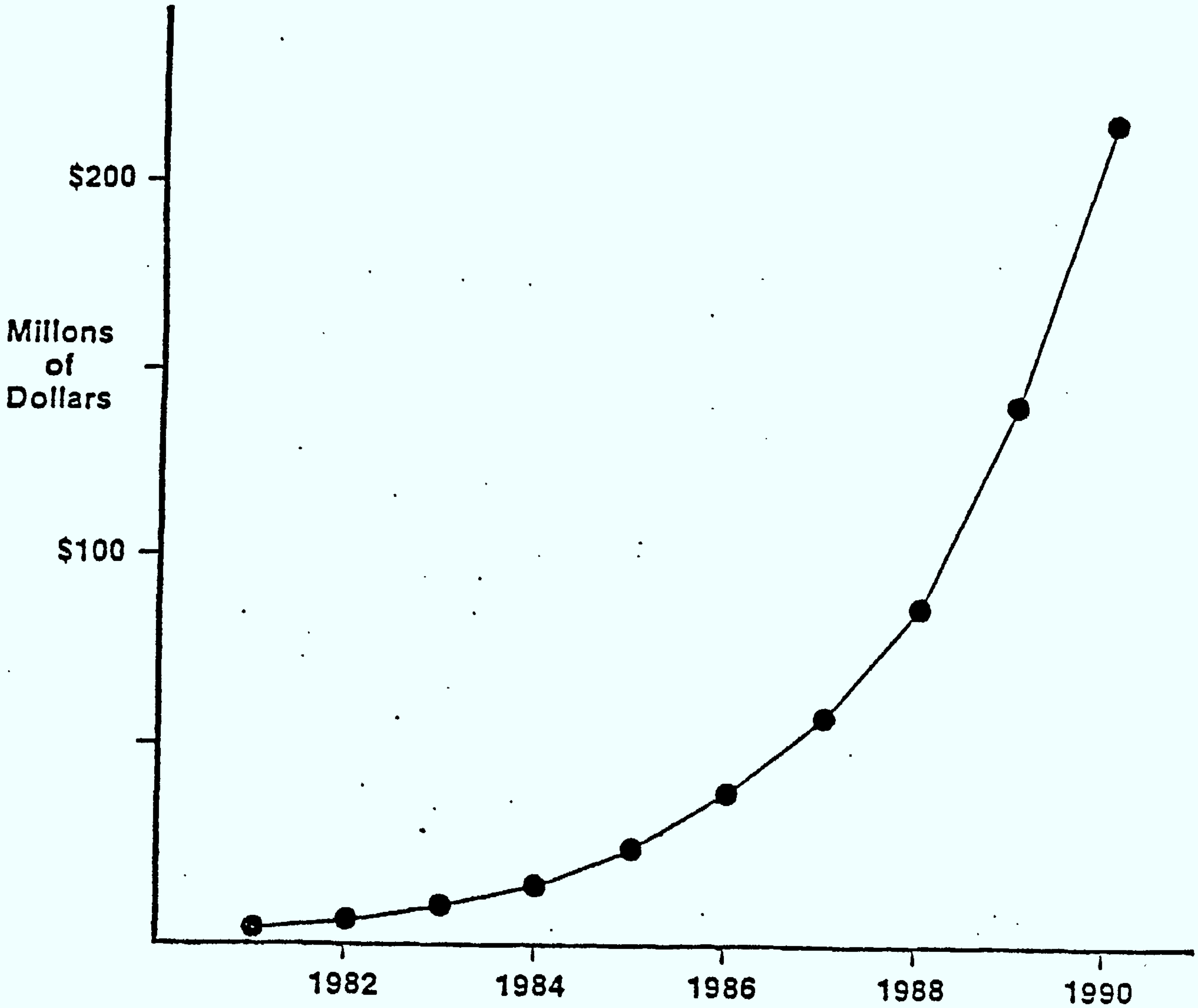
* Not disclosed--companies are privately held

** Estimated AI portion of company business

Source: The Emerging Artificial Intelligence Industry, D.M. Data Inc., 1983

Exhibit 6-6

The US Market for Expert Systems



Source: The Emerging Artificial Intelligence Industry, D.M. Data Inc., 1983

6.3.4 Canadian Market Drives

Exhibit 6-7 shows some future opportunities for expert systems. Our interview process and specific application areas requiring R&D effort to solve Canadian problems were identified. These are listed in Exhibit 6-8. Development of some of these systems to an optimal state could have economic value in the hundred of millions of dollars annually for the Canadian economy. In particular, several of the new AI companies such as GOMI AI systems and Northwest Research Associates are working in expert systems development.

6.3.5 Prospects for Canada

Canada has particular domestic applications needs for expert systems development, particularly in areas of traditional strength such as resource management and communications. Groups are forming up to address those needs so that government encouragement in this area through research and development grants and procurement activity could be fruitful.

6.4 Speech Recognition, Optical Character Recognition and Other Artificial Intelligence Applications

The State of the Art Report described the current status and prospects for these areas of work. In this section we will look mainly at available market forecasts for speech recognition, optical character recognition, and robotics. Then particular Canadian interests in the areas of computational vision, robotics and human machine interface will be discussed.

Exhibit 6-7

Future Opportunities for Expert Systems

Domain	Application
Equipment	Automated equipment control Fault diagnosis Maintenance and repair Intelligent machinist
Manufacturing	Intelligent computer-aided design systems Job scheduling Inventory and distribution control Detection, warning, and control of problems in critical processes
Business management/ office automation	Intelligent decision support systems Management information system control Consultation on management problems - "Everybody's Peter Drucker"
Professional services	Advice, instruction, and analysis in special areas of medicine, law, accounting, and finance
Education	Computer-aided instruction Testing and evaluation Diagnosis of learning problems
Home computing	Nutritional advice Cash management and budgeting Tax advice Emergency advice (first aid)
Entertainment	Intelligent games (interacting in nonpatterned, nonrandom ways)
Energy	Exploration Management and control
Military	Tactical mission planning Missle launch troubleshooting Finding water

Source: SRI International

Exhibit 6-8

Expert System
Examples of Canadian Applications Interests

Companies/Organization	Applications Interest
Northwest Research Associates	Prospector II
N.W. Artificial Intelligence	Avalanche forecasting
Bank of Montreal	Financial Advisor
Gomi AI Systems	Medical
Crack Resources	Analysis of Siesmic Data
Imperial Oil	Refinery Scheduling Distribution system optimization Analyzing seismic Reservoir Analysis
Ontario Hydro	Process Control Enhancements
Nexa	Consumer software products
DND	Sonar Analysis Operations Planning Advisor
CCRS	Advanced Image Analysis
Noranda	Open pit mining design process control
Alcan	Process control
DOC	Computer aided browsing & intelligent indexing of Telidon & very large data bases
MacDonald Dettwiler	Access and handling large data banks of maps Flight tracking & planning systems
B.C. Dept of Forestry	Forestry management
Alberta Research Council	Hail forecasting

6.4.1 Market Forecasts

Exhibits 6-9 and 6-10 show DM Data's forecast for visual and voice recognition systems. Longer term forecasts are shown in Exhibit 6-11 and 6-12. Clearly, visual recognition markets are expected to dominate.

In 1981, there were 250 robots in Canadian industry with forecasts for several thousand installed by 1990. The traditional robotics market is estimated to be small, on the order of $10 to 20 million per year and is not expected to grow substantially. In fact, fierce competition is expected in this area worldwide with control and vision systems the key area of development.

Exhibit 6-13 shows a market forecast for remote sensing analysis systems, equipment which will increasingly employ artificial intelligence capabilities from the field of computational vision. The forecast shows that over the period of 1983-2000, the cumulative market is expected to be on the range of $1.1 to $2.8 billion US (1983).

6.4.2 Canadian Interests

There are strong interests in these various application areas of AI in several Canadian groups, particularly centred in British Columbia with UBC, and various companies, and in Montreal with S. Zucker's work at McGill, and activities at Bell Northern Research. Particularly, in computational vision, Canada has a world lead in applications in remote sensing and is carrying on work in medical applications.

Exhibit 6-9

The Visual Recognition Market
($ Millions)

Companies	1981	1982	1983
Applied Intelligent Systems	-	0.2	1.0
Automatix	1.0	3.0	5.0
Cognex	-	0.2	2.0
Control Automation	-	0	0.7
Everett/Charles	1.5	2.0	4.0
General Electric	-	0.5	2.0
Int Robomation/Intelligence	-	-	0.1
Machine Intelligence	-	1.4	1.6
Object Recognition Systems	-	0.3	1.0
Octek (Oct. FY values)	-	0.8	1.4
Perception Inc	-	0.2	1.5
Robotic Vision Systems (Sept. FY values)	1.0	2.6	3.0
Other	3.0	4.0	7.0
TOTAL	6.5	15.2	30.3

Note: Values listed are estimated sales of the machine vision equipment only and are not necessarily the total sales of the company.

Source: The Emerging Artificial Intelligence Industry, D.M. Data, 1983

Exhibit 6-10

The Voice Recognition Market
($ Millions)

Companies	1981	1982	1983
Centigram*	0.1	*	*
Heuristics Inc.**	0.1	-	-
Interstate Electronics Corp.	1.0	1.5	2.0
Nippon Electric Co America	0.8	1.0	2.0
Scott Instruments Inc.	0.1	0.2	0.3
Threshold Technology Inc.***	1.0	1.5	1.0
Verbex Corporation	0.3	0.3	1.0
Votan	-	0.7	1.5
Others	0.5	0.5	2.5
TOTAL	3.9	5.7	10.3

* Centigram has dropped its voice recognition activities, but is active in other areas of the voice market.

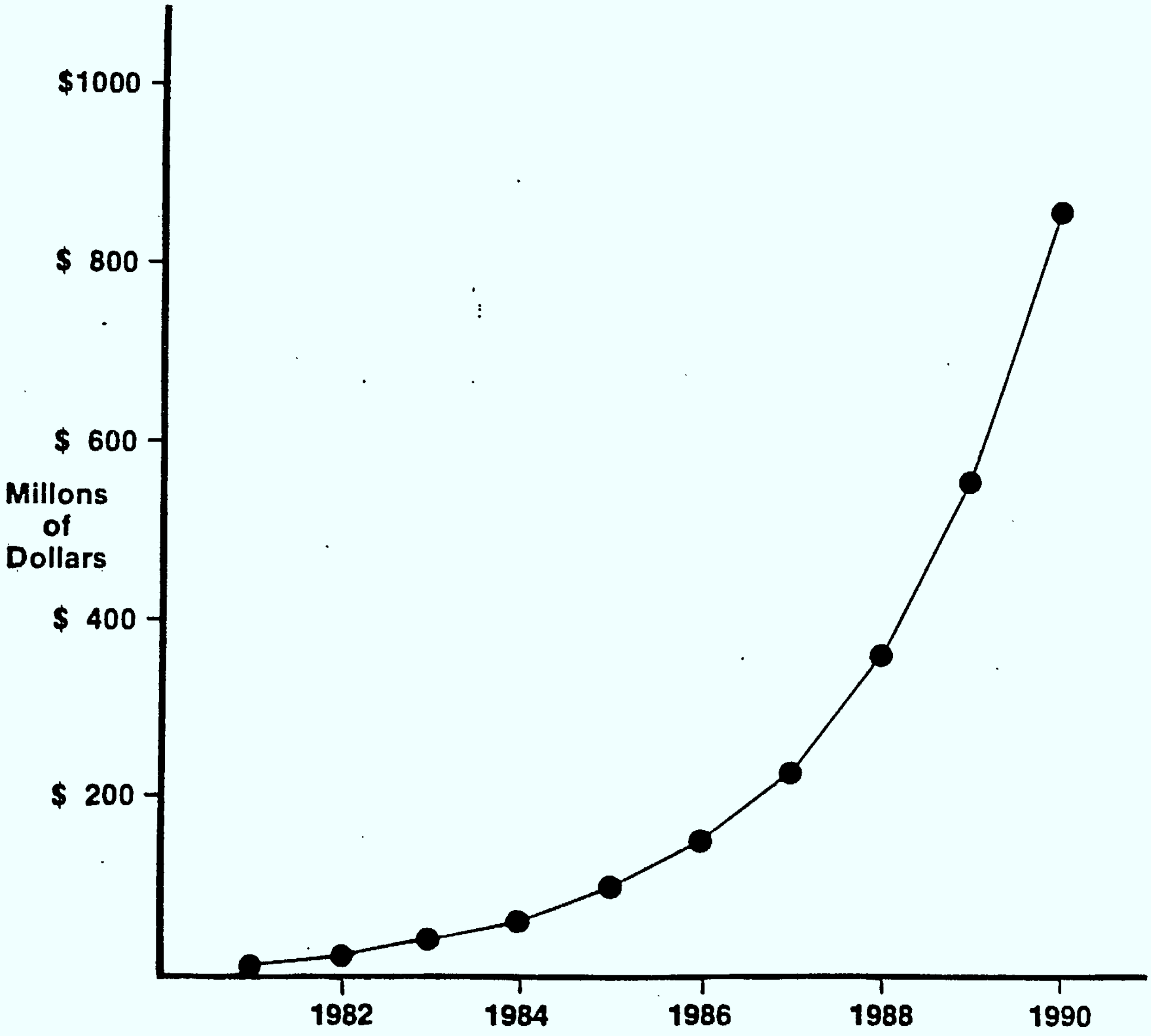
** Heuristics has dropped out of the business.

*** Threshold Technology Inc. is active in the market but is operating under Chapter 11 conditions.

Source: The Emerging Artificial Intelligence Industry, D.M. Data, 1983

Exhibit 6-11

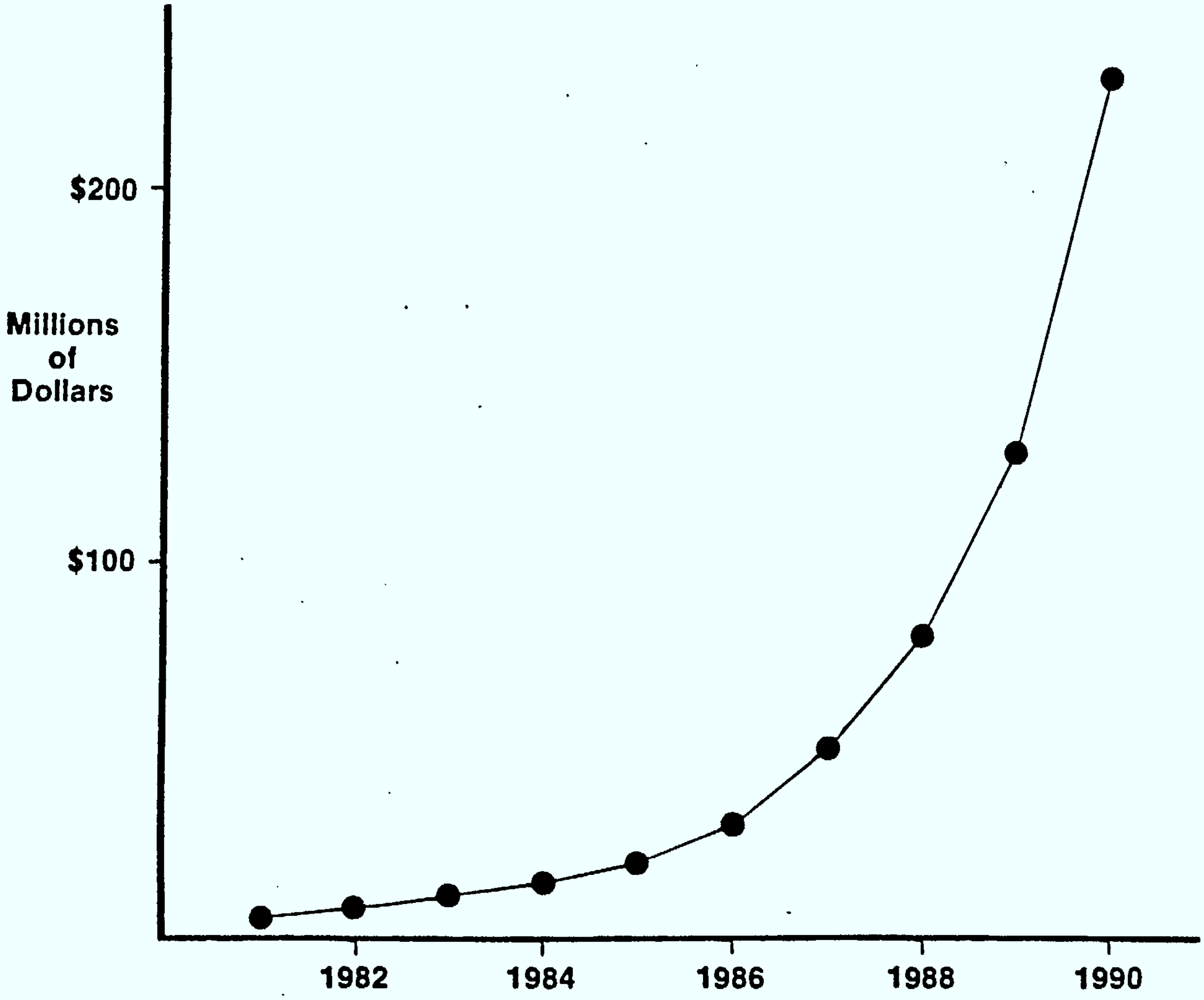
The US Market for Visual Recognition Equipment



Source: The Emerging Artificial Intelligence Industry, D.M. Data Inc., 1983

Exhibit 6-12

The US Market for Voice Recognition Equipment



Source: The Emerging Artificial Intelligence Industry, D.M. Data Inc., 1983

Exhibit 6-13

Remote Sensing

Analysis Systems Global Market Forecast
(millions of 1983 US dollars)

	Maximum Case		Minimum Case	
	Sales	Real Growth	Sales	Real Growth
1983	50	15	30	10%
1984	58	15	33	10%
1985	66	13	36	8
1986	76	13	39	8
1987	86	13	42	8
1988	97	13	45	8
1989	110	13	49	8
1990	124	10	53	6
1991	136	10	56	6
1992	150	10	60	6
1993	165	10	63	6
1994	182	10	63	6
1995	200	10	67	6
1996	220	10	75	6
1997	242	10	80	6
1998	266	10	85	6
1999	293	10	90	6
2000	321	10	95	6
cum. total	$2.8 billion		$1.1 billion	

Source: Nordicity Group Estimate, Radarsat Economic Review and Assessment, Energy, Mines and Resources, 1983

In robotics, there are interests in both manufacturing and resource industries. For example, developments in specialized robotics can be applied in future to develop heavy duty smart robots for tough environments (e.g., underwater robots for pipeline and oil platform inspection/repair, forest robots for tree planting and cutting, Spar smart arm for hydro applications). Also, companies such as Bombardier are now examining systems for flexible production capability allowing small orders and reduced production runs to be managed economically.

In the areas of human/machine interface applications, particular Canadian interests include speech and sketching/graphics interfaces, telidon and videotext developments, large image databases and videodisc applications.

6.4.3 Prospects for Canada

There is evidence of Canadian capability and interest in these areas. In the computational vision application of remote sensing, Canada has a world lead currently. With the Spar smart arm and leading edge British Columbia activities in submersible applications there are some opportunities in specialized robotics. The traditional robotics market in general, however, is expected to be in a consolidation phase and highly competitive.

7. Foreign R&D & Canada's Response

The foreign R&D programmes that have been launched have been discussed in great detail in the report on technological thrusts. The purpose of the discussion in this report is to highlight the programmes comparatively, discuss the various alternatives for response and identify the opportunities for cooperation or joint venture activity.

7.1 Comparative Analysis

Exhibit 7-1 compares the national plans for AI activities of other countries. The plans vary considerably in objectives, priorities, funding, institutional method and timeframe.

7.2 Canadian Response

There are several alternatives for Canadian response including:

1. non-response
2. support for modest increase in established activities
3. launching of a national plan

In order to adequately assess these alternatives an understanding of Canada's current status in the areas of funding and manpower is required. Then a discussion of potential objectives and potential institutional methods should be developed. Finally, the various responses need to be delineated in general terms.

Exhibit 7-1

National Plans

Objectives	Japan	Britain	Netherlands
	providing for the conditions and information demands of the society in the 1990s, basic research vs commercial product	mobilize technical strength in information technologies	R&D to maintain computer industry; fundamentals and applications in universities and government laboratories; transfer to industry cooperate abroad ie. EEC vision, robotics, office automation
Priorities	broadly based plan	Software Engineering Man Machine Inter-faces Intelligent Knowledge Based Systems (IKBS)	NL and Speech processing; Expert Systems - technical; cognitive modelling in human machine interface; support technology for AI
Funding	?	$700 M 500 M government 200 M industry	$3.5 million
Manpower	year 1; 40 researchers	year 1; 40 reseachers year 5 150 researchers will require 100 skilled personnel of which 500 must be trained	year 1; 19 year 5; 25
Key Institution Method	ICOT - with 10 Japanese 3 stages	collaborative effort, industry academics and other harness technical strengths to industry objectives	universities, government labs transfer to industry
Timeframe	10 years	5 years	5 years

7.3 Current Funding and Manpower in Canada

Data regarding funding and manpower while not readily available can be roughly estimated from the work undertaken on this report. Historically, NRC provided $750 thousand for MT work from 1965-73 and Secretary of State spent approximately $3 million from 1973 to 1981 for MT projects. Currently, the key sources* of funds for existing AI research and development are:

- NSERC grants
- DND activity
- EMR activity
- NRC
- CIAR
- Provincial funding, particularly Ontario, and British Columbia

Exhibit 7-2 shows that it is likely that the funding for AI excluding Canadian university infrastructure costs is on the order of $5 million for 1983. Compared to US and Japanese activities, the level of funding is extremely low. Based on our work in Section 3 and the survey responses and other data collected in the course of this study, it is apparent that there are up to 160 university personnel (including professors, graduate students and research staff) in Canada working in AI or closely related fields.

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* AI expenditures of DEC, IBM and CDC in Canada are not known.

Exhibit 7-2

Current Funding Estimates
$000's

	1983	1984
1. NSERC grants*	3000	?
2. DND activity**	400	400
in-house contracts	100	
3. EMR activity*** in-house	100	500
4. NRC****	400	400
5. CIAR*****	250	250
6. Provincial	250	?
Total	4,500	?

* assumes 20% of NSERC estimate of $14M for operating grants, strategic grants, infrastructure support, equipment and scholarships

** assumes 4 people ¼ $100,000/person for salaries, overhead, supporting equipment

*** extrapolated from discussions

**** assumes 3-4 full time people

***** announced SPAR Aerospace contribution

7.4 Considerations of Alternatives for Response

7.4.1 Non-Response

The non-response alternative could be defined as allowing developments in MT, NLP, and AI to continue without particular objectives or focus.

7.4.2 Modest Increase in Support for Established Activities

The delineation of this alternative could consist of setting in place mechanisms for ensuring increased funding for the current research establishments (both university and government). Some likely isolated areas for modest increased support could include:

1. Machine Translation per the P. Isabelle plan of 1981 funded by SS
2. NLP - supported by DOC activities in Office of the Future
3. Expert Systems - as required by EMR, DND
4. Robotics and AI - according to plans already set by NRC

7.4.3 A National Plan

The final alternative is the development of a national plan requiring short and long term research goals and short and long term development objectives, industry sector involvement, mechanisms for cooperation with other countries, federal/provincial coordination and potentially the establishment of centres of excellence. An assessment of appropriate funding levels and manpower would have to be undertaken. Ideally, AI should be set in a context of other strategic technologies.

A consultative committee considering the concept of a national plan, generally supported the notion. Exhibit 7-3 shows some sample issues raised at the meeting in this regard, demonstrating the large variety of opinions and concerns to be weighed in addition to the material gathered in the process of carrying out this study.

Exhibit 7-3

Consultative Committee Issues Regarding a National Plan for Artificial Intelligence

1. "defense of current positions of strength ie. communications position"
2. "concentration on niche vs. competing directly"
3. "in new technology development perimeter expands very rapidly with huge gaps left monitoring will find holes"
4. "where should we be assisting people to go"
5. "AI as a building block of a large economy"
6. "we need to have an idea of what will happen if we don't have a national plan"
7. "we should have pragmatic goals - ie. to bring the cost of translation from 25¢/word to 10¢/word"
8. "we need to adapt universities to future needs and require post secondary strategy for next 20 years"
9. "we should avoid focussing on simply software - notion of a large scale plan"
10. "we need new and novel mechanisms for supporting and encouraging small companies in this area"
11. "we need a certain scale of human interaction - real enterprises of scale attract people from around the world"
12. "are we prepared to accept another national program?"
13. "we should define a good large scale project vs narrow MT objective so that public can perceive value and some success"
14. "it would be wise to have long term commitment ie. 10 years so that people can plan"
15. "we should use existing institution(s)"
16. "we should give the Canadian public short term deliverables based on long term goals"
17. "critical size for AI was defined as: a VAC 780, 6 professors, 6 support staff, a university locale, and a computer network".

8. Assessment of Opportunities

Exhibit 8-1 shows a summary assessment of opportunities versus the criteria set out in the introduction. Clearly the machine translation and image analysis opportunities are very interesting by this measure; but it must be emphasized:

1. That MT and image analysis are part of AI and have to be viewed that way--that a diversity of approaches to these fields fed by AI research, is crucial to their success in the long term.

2. That even though MT and image analysis are important to Canada, so are a lot of other areas of AI--such as expert systems applied to resource management, medicine, and education.

The companion reports in this study, notably the State of the Art Review and the review of Technological Thrusts, offer evidence of a sharp focussing of international attention upon Artificial Intelligence technology and of a rapidly rising level of research and development activity, as each country struggles to secure the strongest possible foothold in tomorrow's information-driven economy.

As this report on opportunities indicates, Canada confronts the environment with an all too common situation characterized by:

- a comparatively strong scientific base, largely centered in Universities and considerably fragmented, albeit with some promising attempts to coalesce the scientific effort;

Exhibit 8-1

Summary Assessment of Opportunities

Criteria	MT	NLP	ES	Robotics	Machine Vision
1. Competitive Canadian capability	X*	X	some	some	X
2. Domestic market	X	X	X	small	X
3. International market niche	X	?	many	perhaps but high competition	X
4. National need	X	X	X	some	X
5. Industrial capability	?	limited	some areas	not strong	X
6. Institutional framework	X	X	not yet	X	X
7. Goals	X	can develop	could have some	?	X
8. Access to foreign tech	X	X	X		X
9. Neglect by international community	X	no	no	no	
10. Link to other	X	X			X
Conclusions	high priority, viewed as part of NLP and AI	major effort needed	major effort needed	allow to happen	high priority

* denotes judgement that criteria is satisfied

- an as yet low level of "demand" interest on the part of the Canadian private sector, and some embryonic supply capabilities, particularly in the software sector;

- some importing of hardware;

- emerging interest in the field at government level in respect of technology policy, potential user requirements, and developing research (laboratory) interest.

- the likelihood that many of the broad requirements that will emerge with respect to the new technological front will be of national and regional socio-economic priorities, such as medical diagnostics, computer-aided learning, bi-linguialism and skill re-training. This leads to the conclusion that, in Canada, government will be involved, or need to be involved in the area of AI technology not only as a general stimulator but also directly as a agent for systems, products and services.

8.1 Government Leadership

Government leadership is required in two areas:

1. support for research and academia

2. procurement for development

8.1.1 Support for Research and Academia

As we have seen, a number of excellent small research endeavours in AI and NLP exist in Canada, covering the fields of intelligent data bases, robotics, image processing, natural language interfaces, education and medicine, as well as pure research areas such as logic and theoretical AI. We believe it is important to support these endeavours at a substantially increased level in order to ensure that Canada keeps abreast of this rapidly expanding technology. The support of AI research in Canada has been extremely low in comparison with that of other countries, as a result of which we have lost many of our highly trained graduate students to the US and have failed to create a sufficient awareness of promise of AI within the R&D community. A higher level of support is needed in order both to ensure a base of basic science to feed the expected market demand and to ensure an adequate supply of trained professionals.

In the US, where the per capita level of funding in computer science in general is much higher than in Canada, AI is supported at an extremely high level and by the military and NSF. If Canada is to compete successfully in information technology it must make a strong effort to encourage basic research, to train professionals and to retain them in this country.

8.1.2 Procurement for Development

In the United States, military procurement has historically played such a role, defining and contracting for products of an advanced nature and providing almost coincidentally a product and technology basis from which contiguous commercial market can be developed.

In the Canadian context, it might be suggested that, in terms of applied R&D, a key role of government in respect of AI technology should be to advance its own requirements as rapidly as possible and to act as a major purchaser of goods and services, ensuring only that the industrial response to the requirements generates as much technology development as possible to the Canadian industrial and economic base. This procurement role is critical, not only in articulating genuine demand but also imposing all the business disciplines that develop from satisfying performance specifications and contracted delivery schedules. Another key advantage which develops from this concept of government as the purchaser is that the mechanisms and procedures are already in place, so that actions with respect to AI need not be unduly time consuming.

This pursuit of a Government procurement strategy, as part of an overall national thrust aimed at the enhancement of technological effort and at the achievement of market position, involves the attempt to ensure that all or as many as possible of the factors making for "opportunity" as defined in the introduction to this report, are shaped by the preliminary actions. Thus, within the context of meeting a specific technical requirement, the purchase contract might well include provisions for:

- consciously building up a Canadian industrial capability;
- securing an effective linkage in that specific area, between the industrial supplier and the appropriate scientific capabilities in the University sector;
- requiring the selected contractor to define export potential for the technology;
- requiring a linkage with an appropriate government laboratory;

In short, requiring of the selected contractors that, in the course of satisfying the specific demand under purchase, that he also be responsive to the broader strategy of advancing national capabilities in AI technology.

The government leadership then, in respect of stimulating an intensified national attack in AI technology, will need to embrace the following measures:

- within the Federal "science and technology" envelope, to establish AI as a strategic technology and objective;
- in its role as customer, to identify and proceed with contracted requirements for systems, products and services in AI, including in the contracts provision for the industrial strategy objectives that have been raised;
- to identify and support particular opportunities (in for instance machine translation, where major users and technology suppliers can combine to rapidly develop responses to operational requirements;
- to encourage and support Provincial entities in for instance education and medical research, in respect of advances in AI technology;
- to strengthen the support from NSERC for strategic grants to the "AI" community with the twin goals of supporting promising and encouraging increase in the supply of highly qualified scientific manpower,
- to strenghten existing initiatives to develop university capabilities;
- to actively support the increase in interaction between foreign sources of technology and the Canadian AI community;
- to support nascent developmental and marketing and joint-ventures, on a selective basis, as proposed by the private sector;
- to ensure major research centres exist when special equipment and critical mass of manpower is required.

Undoubtedly, these several strategies will need to be refined as AI technology enters the mainstream of technological, industrial and economic activity. However, as in the case of other countries, it is indisputable that government leadership will need to be displayed to an unusual degree if any significant Canadian potential in AI is to be reached over the next decade.

8.2 Specific Opportunities

Given the requirement for government leadership, the technology thrusts and state of the art provided in this study, and given the level and quality of national capabilities outlined, it is felt that the following Canadian opportunities could be instrumented through the medium of government through basic research support and government procurement activities.

8.2.1 Basic Research Support

To this end we propose that specific programs be instituted to support AI research by:

1. Provision of partial release time for computer science teachers and administrators to pursue AI/NLP/MT research, and provision of post doctoral fellowships for AI.

2. Creation of a new NSERC Strategic Grants Panel for AI.

3. The provision of state of the art computing facilities for AI researchers. These are now cheaper and more powerful than previously but a capital investment of $50k-$150k per researcher is necessary (the level depends on the area of research). This should be recognized in the Strategic Grants program for AI. One or two of the existing AI centres should be funded for AI software development: to maintain, develop and import/export useful software tools. They should be supplied with the necessary infrastructure support to operate on a long-term basis. The need for high level equipment for AI research is also one of the recommendations made by the Waltz report for the US where, as we have seen in the state of the art report, the level of support by industry (in the form of equipment donations) is extremely high compared with Canada.

4. Development of a computer network modeled along the lines of the ARPA network in the US (see appendix on networking);

5. Support for Computer Science through the Computing and Information Science NSERC Grant Selection Committee should be increased by at least 50% per year for the next 3 years.

8.2.2 Procurement

Proposals for procurement activities are as follows:

1. A major effort in second generation machine translation with the lead Mission Department being the Secretary of State, and with funding support from the DND, where requirements are high. This effort could be cast in time frames and phases to permit not only specific hardware objectives, but also to provide for some element of broader, longer-term break-through research and development. In this regard, note emphasis the Secretary of State placed on viewing MT as part of AI in general.

2. A significant effort in NLP and intelligent databases, geared to office automation, databases for medicine, law and other professions, and to provide access to government data for both bureaucrats and consumers, and to command and control requirements in the military. This could include for example DOC and DND.

3. A major effort, partly centered in CCRS, to develop both image analysis and expert systems for applications in the resource sector, as well as in priority areas of medicine and education.

APPENDIX I

COMPUTER NETWORKING FOR CANADIAN COMPUTER SCIENCE RESEARCH

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The virtues of long haul and local area computer networking have been extolled at length elsewhere. In this note, I shall concentrate on the benefits of long haul networking to the Canadian artificial intelligence and computer science research community, examine the current situation and explore the immediate future.

Networking has been promoted on the grounds it facilitates a distributed research environment. The functions of computer networks include messaging, file transfer, remote login, interprocess communications and database access. The research activities supported by these functions include routine communication of personal messages, conference and seminar notices, newsletters, open and closed online conferencing and the like. These could be characterized as meta-research activities. Research tool development such as software distribution, bug reporting and maintenance leads to sharing of the cost of building software systems. Research products including formatted papers can be jointly produced on a network. Research resources such as bibliographic databases, Macsyma, Mycin and the like are made available. These kinds of activity turn out to be the dominant (and crucial) ones on existing research networks such as the ARPAnet and CSnet. Running distributed programs with various modules of the program running at different sites and communicating via interprocess communication - earlier thought be be an important application - tends not to be very common. Given network delays and so on that is not a feasible approach. What is common is to assemble a program at one site from software written at many sites across the net.

The key lies in the fact that when a research scientist lives "on-line", as most computer scientists do now, then the colleague on the other side of the country is almost as accessible as the colleague next door. For artificial intelligence, not only does the science itself benefit but also technology transfer to industrial and government laboratories is greatly facilitated.

The benefits are multiplied when the computer systems on the net are homogeneous. Text formatting systems, messaging software, and research computer programs are all in the same language and formats and can easily be shared. When tools are shared (and, even better, developed in common) then sharing of ideas and paradigms is much easier and more likely to occur.

The current situation in Canadian Computer Science is that every major department and most minor ones run Vax/Unix systems that communicate over the Usenet network that spans North America and Europe. The network is based on automatic dialup phone service from site to site. Its drawbacks are:

1) Expense: the monthly long distance telephone bills can be as high as $1000 for backbone sites.

2) Slow Turnaround: It may take 24 hours to get an answer to a message since it is implemented by polling.

3) Unreliability: Since mail has to go through every site en route it can (and does) get lost. Since there is no delivery confirmation this is a serious problem.

4) Security: There is none but that is not a major problem yet.

5) Message Service Only

6) Incompatibility with CCITT, ARPAnet and CSnet protocols.

Despite all these drawbacks the system has already been of substantial benefit to the community in the few months that it has been operational. The main applications are for personal messaging, conferencing, software distribution, and maintenance and sharing. Given the geography of Canada and the fragile state of Canadian computer science, it is imperative that computer networking be supported and enhanced.

What needs to be done to improve the current situation? There are two options: CSnet and CDNnet. CSnet is the U.S. Computer Science network. Funded by a $5 million grant from NSF, this 5 year project, now in it third year, is intended to solve the same problem in the U.S. It is a logical network spanning Phonenet (similar to Usenet). Telenet (a public X.25 packet network and some ARPAnet sites. Originally intended to cover only U.S. sites it now accepts foreign hosts. Four Canadian Computer Science departments (Waterloo, Toronto, Queens and UBC) have already applied for or been accepted for membership. For example, UBC-Vision polls Rand-Relay about 6 times a day for messages. One of its main advantages is the reliable gateway to the ARPANet where many of our colleagues have accounts.

In terms of the six drawbacks listed above:

1. The phone bills are still high, but could be reduced with Canadian relays. If the CSnet X.25 code were implemented on Datapac it could be cheaper. The annual membership is $5,000.

2. Turnaround is improved since there are only two hops for each message.

3. Much more reliable.

4. Better security.

5. Messages only so far.

6. Compatible with ARPAnet. Good CSnet/ARPAnet gateways exist. However, it is not compatible with the CCITT standards. For example, both ARPAnet and CSnet protocols are English-text based and they do not easily support other than text (ASCII) data. The CCITT standards allow, for example, French, graphics, voice and image based messages.

The other option is the proposed CDNnet (CanaDiaN network), a system under development in Computer Science at UBC supervised by G. Neufeld and P. Gilmore. This network is based on the EAN messaging system being implemented under an NSERC Strategic Grant. The system is designed in accordance with the new CCITT messaging and network protocol standards. It too will operate on X.25 packet networks such as Datapac and switched telephone lines. It is also designed to function over local area networks such as the Ethernet with one station on the net designated as the message server. It is being implemented for several operating systems including Unix. It appears to be cheaper to install and much more efficient in its use of X.25 networks than CSnet.

The CDNnet project is going very well. When it is completed (expected within several months) then operational decisions will have to be made. A CDNnet Corporation could be set up to provide management of software and operations. Gateway machines and directory servers (probably one in Ontario and one in B.C.) to ARPANet/CSnet would have to be established and maintained. The network could be administered on a centralized or decentralized basis, with the CSnet and Usenet models at either end of that spectrum.

It is, at the moment, premature to choose one or the other for the Canadian computer science community as a replacement for Usenet. Usenet exists and it works despite all its drawbacks. If CDNnet were implemented across Canada then we would have an efficient, cheap, reliable, Canadian system with excellent turnaround and international compatibility. On the other hand, much of our communication is north-south and so the gateways to CSnet and ARPAnet will have to be carefully designed otherwise sites will just bypass them and use CSnet independently. Initially any network will be limited to 9.6k baud on Datapac so that the use of the network for wide bandwidth applications such as high resolution image transmission will be limited.

Early in 1984, when the CDNnet software is operating at several test sites across the country, Canadian computer scientists will be in a good position to make a communal decision on which network will best serve our needs. Planning for operational support of the network must start now.