THE CANADIAN TELECOMMUNICATIONS

EQUIPMENT INDUSTRY: THE CASE

FOR INVESTING IN CANADA

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Prepared for

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1.0   INTRODUCTION

The Canadian telecommunications equipment industry is a vibrant and dynamic industry that is poised to gain a greater share of world markets. Canadians have recognized the strategic importance of investing in a modern, world-class telecommunications infrastructure. Telecommunications, in concert with other information technologies, is recognized for its importance in improving the efficiency and competitiveness of all sectors of the economy. Furthermore, telecommunications in its own right, is recognized as an important economic activity which creates wealth and provides high quality employment. The drive to develop a world-class telecommunications infrastructure in Canada has encouraged the development of a strong telecommunications equipment sector.

The Canadian telecommunications system is among the most advanced in the world. With one of the highest telephone penetration rates, Canadian telecommunications service providers and their customers have always been among the first to demand and adopt new technologies and equipment. With a domestic trend towards further deregulation and competition, the excellence and innovation demanded of Canadian telecommunications suppliers will increase, thus compelling them to develop flexible new products based on advanced technologies.

Canada is a nation oriented towards international trade. It enjoys good trading relationships with most countries. With a free trade agreement in place with the U.S., and another being negotiated with Mexico, Canadian companies have ready access to these markets. Canada's international posture also enables Canadian companies to source parts and components with ease from leading companies throughout the world.

The Canadian telecommunications equipment industry has capitalized on its strong domestic base to expand into world markets. While the Canadian market still plays a key role in the industry, it is not uncommon to find companies deriving over 90% of sales from exports. In the process of moving into world markets, Canadian suppliers have developed a reputation for supplying innovative, high quality products.

Canadian governments have recognized the strategic importance of the telecommunications industry for the Canadian economy. In order to ensure that Canada continues as a world leader in the provision of telecommunications products and services, governments have encouraged and participated in the development of initiatives designed to ensure the continued success of the industry. Examples include programs to improve the support for R&D, initiatives to improve the skill levels of the workforce, programs to support and enhance international trade and efforts to increase the linkages between the academic community, government agencies, the telecommunications equipment industry and the microelectronics sector.

Government policy is particularly supportive in the area of R&D. Governments have realized that investing in R&D is required to maintain technological leadership and have developed policies to encourage R&D. By co-ordinating and encouraging the formation of R&D consortia, governments have created a shared commitment to the continued success of the telecommunications equipment industry. In addition, Canadian governments have demonstrated their commitment by supporting university research, by directly investing in and performing R&D in government laboratories, and by providing generous tax credits for R&D.

Canada currently permits competition in data communications, private line voice services, terminal equipment including PBXs, value-added services, resale of private-line carrier-provided facilities and services, mobile services including cellular telephone service, and is considering further resale competition and opening public-switched long-distance services to competition.

Increased competition in telecommunications services will open up new opportunities in the domestic market for both equipment and services and will hone the competitive skills required to compete internationally. Increased global competition will compel Canadian companies to pursue new markets and new alliances with other companies, domestic and foreign, in order to increase market share worldwide through shared development and marketing efforts and, in some cases, through broader product line offerings and expanded customer bases.

In pursuit of these goals, Canadian industry seeks investment and strategic partnerships to assist in financing the development of new technologies and to facilitate entry into new markets. This report describes the Canadian telecommunications equipment industry and the supporting infrastructure, and demonstrates that there are substantial opportunities and advantages for investment in or establishing strategic partnerships with Canadian telecommunications equipment firms.

2.0   THE CANADIAN TELECOMMUNICATIONS EQUIPMENT INDUSTRY

2.1   Statistical Overview

The Canadian telecommunications equipment industry comprises some 500 companies spread across the country, with the greatest concentrations in Ontario and Quebec. The industry is dominated by one multi-national enterprise, Northern Telecom, which manufactures a wide range of telecommunications products in its Canadian and foreign-based plants. The industry is further characterized by a number of smaller equipment companies and several systems integrators. Many of the smaller companies produce specialized equipment and sub-assemblies which are incorporated into various telecommunications systems and equipment. Canadian companies manufacture equipment in all product categories including public switching, transmission, cable, satellite systems, data equipment, private switching such as PBXs, customer premises equipment and mobile systems including cellular telephone equipment.

Canadian telecommunications equipment production amounted to approximately $5.4 Billion in 1989. The Canadian market itself was approximately $4.4 Billion in 1989, of which approximately 80% was supplied by Canadian companies. Exports were approximately $2.0 Billion and imports $0.9 Billion. The industry employed some of 42,000 people in 1989.

2.2   Markets for Canadian Production

Canadian companies sold primarily into the domestic and the U.S. markets in 1989 (Exhibit 2-1). Canadian companies sold $3.4 Billion in Canada and captured 78.6% of the domestic market. Of the $2.0 Billion that was exported (approximately 37% of production), $1.4 Billion was exported to the U.S.

Unprecedented new opportunities for telecommunications equipment suppliers are emerging from changing world markets. The telecommunications environment is becoming increasingly competitive. Over the past several decades, slowly at first and now more rapidly, telecommunications monopolies around the world are being swept away by deregulation and competition. Countries such as the U.S., Japan and the U.K. have led the way in opening up the telecommunications service environment to competition. Canada and other nations have followed this same trend. Deregulation has generally been accompanied by a loosening of the traditional close relationship between domestic telephone companies and equipment suppliers. The consequence is a growing world market for both telecommunications service providers and equipment suppliers.

Exhibit 2-1
Canadian Major Telecommunications Equipment Markets (1989)

REGION	ESTIMATED MARKET SIZE ($Billion)	ESTIMATED CANADIAN SALES ($Billion)	PERCENTAGE SHARE OF MARKET
Canada	4.4	3.4	78.6
U.S.A.	39	1.4	3.6
Europe	39	0.28	0.7
Japan	8.8	0.01	0.1
Other	34.8	0.31	0.9
TOTAL	126	5.4	4.3

The dominant feature of the emerging market is a commitment to reliability, more features, lower cost, flexibility and user responsiveness. Having realized the strategic value of telecommunications, large telecommunications customers are demanding services that enable them to design, manage and control their telecommunications networks. Providing telecommunications services is also becoming a global enterprise. Given their extensive reliance on the efficient and effective exchange of information, multi-national enterprises are demanding global communications capabilities with no limitations. Many are establishing or extending their own private networks to meet their requirements. To meet this challenge, service providers are themselves evolving into international businesses that offer high quality services worldwide. Emerging out of this trend are competitive global networks provided by individual carriers and consortia. Competition has, in fact, evolved from domestic markets into the international arena, providing unprecedented opportunities for service providers.

At the leading edge, companies are responding to the requirements of customers for managed network services. Major business customers not wishing to be in the telecommunications business themselves, are looking to outsource their total telecommunications requirements more effectively and at lower cost.

These trends lead to increased opportunities for equipment suppliers. Customer demand for more customization and control are met by increased intelligence in the network, ranging from the customer's terminal to network switching and control elements. Adding intelligence and control also stimulates the value-added products and services market. Managed network services offer an opportunity for telecommunications network equipment suppliers to directly supply products and services to end users. Canadian equipment suppliers are actively pursuing these opportunities.

Two major requirements for telecommunications equipment exist in the world. The first is infrastructure improvements for those countries with inadequate facilities. Strategic alliances enable companies to create "product families" to satisfy the requirements of these countries. The second major requirement is for value-added products and services that build on and expand the capabilities of the existing infrastructure. To succeed in this market, it is essential to have close contact with customers. Successful suppliers in this field are also turning to strategic alliances to forge closer links with both service providers and end users.

The key thrust of the Canadian industry is to expand exports. In so doing, it is seeking new opportunities that arise from the developing competitive environment, changing market requirements and the growing need for infrastructure improvement that is emerging around the world.

Many of the companies in the industry are already highly export oriented. Some companies export over 90% of their production. Many of these companies are either world leaders in their chosen niches or are strong competitors. Most of these companies make good use of the Federal Government export support programs, such as the Program for Export Market Development, as well as of assistance provided by many of the provincial governments.

2.3 Areas of Canadian Expertise

Canada has a long history as a pioneer in telecommunications technologies. Today, the Canadian telecommunications equipment industry continues its historically strong performance in all equipment categories. The following provides a brief overview of the current activity and state of the Canadian industry. Details of the achievements of some of the companies that comprise the industry are presented in Appendix A.

Public Switching

Public switching includes equipment used by telecommunications carriers in their long distance and local switching systems to direct the flow of individual communications between desired locations. This also includes the software which is increasingly used to control individual switching operations as well as overall network monitoring and traffic control functions. This category usually constitutes the most expensive single component of a network.

This equipment category accounts for 32% of the total Canadian production in the industry. The leading Canadian company is Northern Telecom, which was the first company in the world to announce and deliver a complete family of fully digital switching and transmission equipment. Northern Telecom's international success is based on

leading-edge technology and commitment to service. Other companies provide selected product lines, for example, Mitel Corporation recently announced a digital end office switch for rural communities with a 500-2000 line requirement.

Private Switching

Private switching includes switching equipment usually located on a customer's premises, such as Private Branch Exchanges (PBXs), Private Automatic Branch Exchanges and Key Telephone Systems. This segment constitutes 19% of the total Canadian production of telecommunications equipment.

Northern Telecom and Mitel Corporation, which are significant suppliers in this market segment, export their products around the world. Mitel, for example, is ranked 6th in the world in the PBX market and is the only telecommunications equipment in the world to have sold more than 150,000 PBX systems. DBA Communications Systems Inc. has the distinction of having its key telephone systems provided as rental units by a large number of U.S. independent telephone companies.

Mobile Equipment

Mobile equipment includes mobile communications equipment of all sorts, such as traditional paging and wide-area mobile systems and the more recent cellular telephone systems. Canadian production in this category grew at a real annual compound average growth rate of approximately 32% over the 5-year period to 1989. Moreover, an estimated 65% of Canadian production was exported in 1989.

Canadian companies have traditionally had a strong position in the mobile area due to the local presence of advanced and demanding Canadian customers. The following are examples of major manufacturers that have located R&D and/or production facilities in Canada:

- ° The Mobile Data Division of Motorola Canada Ltd. has established itself as the world's leading supplier in bridging the gap between computing, data communications and radio-based networks. The Division has introduced several innovative devices including the integrated mobile data terminal, portable data terminal and a self-contained radio modem.

- ° NovAtel Communications Ltd., which has a significant presence in the international cellular equipment market, designs and manufactures a complete line of cellular mobile radio telephones and systems and has the distinction of the first commercial application of cellular inter-system hand-off in the U.S.

°   Ericsson GE Communications Inc. supplies cellular telephone equipment
         and is responsible for carrying out R&D on cellular networks. According
         to Mr. Lionel Hurtubise, President of Ericsson GE Communications Inc.,
         "Ericsson's business experience in Canada in the last few years has been
         excellent and in particular in establishing an excellent design and technical
         support group. We now support all of our North American cellular
         switches from Montreal and in addition have design responsibility for a
         significant portion of our world-wide cellular development".

The local environment has also encouraged the formation of many smaller organizations
that are dedicated to serving niche markets. Gandalf Mobile Systems, Inc. is a typical
example of a Canadian success story in this sector. This company is the leading supplier
of taxi data dispatch systems in the world with over 25 installations serving in excess of
10,000 mobile users.

Satellite Systems

Satellite systems include the satellites and earth stations which are used as part of
the public switched telephone network or private networks. Canada boasts the first
nation-wide domestic satellite communications system and continues to excel in this
advanced field.

Spar Aerospace is a major supplier of satellite systems having been project manager or
prime contractor on more than 30 programs and 61 satellites, and having delivered
turnkey earth stations for satellite communications to more than 30 countries. Spar was
also recently chosen as the prime contractor for the Canadian mobile satellite MSAT.
Other Canadian suppliers in this sector have developed world-class reputations for their
ability to identify and satisfy the requirements of niche markets. For example, COM
DEV Ltd. has its multiplexers installed in 106 spacecraft in more than 30 international
programs. It supplies over 65% of the Western World's requirements for multiplexer
and switching equipment for communications satellites. Skywave Electronics Ltd.
developed the world's first L-Band Briefcase Satellite terminal and established interim
commercial service on Inmarsat. International Datacasting Corporation introduced to
the market the first economical digital audio satellite transmission system for radio
networking.

Data Switching and Transmission Equipment

The data switching and transmission equipment category encompasses equipment
used in data communications including data terminals and local and metropolitan area
networks. This equipment category represents about 10% of the Canadian production
for the industry and experienced a real annual compound average growth rate of 11%
over the five-year period to 1989.

The rapidly evolving nature of this equipment category has enabled several innovative companies to capture markets through the timeliness and excellence of their products. Gandalf Technologies Inc. is a prime example of the innovative nature of the firms in this area. Gandalf designs, manufactures, and supplies a broad range of information networking products, systems and services. For example, it designed and manufactures the first true hybrid networking system to connect all users and resources in multi-vendor environments, the Starmaster intelligent network processor.

Transmission Equipment

Transmission includes all equipment utilized for the actual carriage of communications between various points in a network, such as the channelling and microwave systems equipment located at central offices as well as at repeater stations. The total production of the companies active in this segment constitutes approximately 18% of the total Canadian telecommunications equipment production.

The requirements present in this segment enables companies to pursue either niche or broad market strategies. The prominent company in the field is Northern Telecom which has the capability of supplying a broad range of transmission equipment. Newbridge Networks Corporation has a strong presence in the design and manufacture of universal voice and data multiplexers for the digital trunk market. In the microwave transmission field, Harris Farinon Canada, which manufactures the Quadralink product line, and SR Telecom Inc., which is a world-leading manufacturer of subscriber radio systems, are significant players.

Cable Equipment

This equipment category includes copper wire and coaxial cables and fibre optics cables and associated electronics. It comprises 10% of Canadian production and grew at a real annual compound average growth rate of approximately 9% up to 1989.

Northern Telecom is a leading supplier of fibre optics and communications cables. Canada Wire and Cable Limited manufactures a wide range of wire and cable products. Its division, Canstar Communications, also offers a completely integrated capability to engineer, install and test complete turnkey lightwave communications systems. Opto-Electronics Inc. is a major supplier throughout the world of high speed fibre optic test and measurement instrumentation.

Customer Premises Equipment (CPE)

CPE includes equipment, other than Private Switching, located on customer premises, of a more individual nature, such as telephone handsets, telex and facsimile machines, cordless telephones and ISDN terminal equipment. Both Northern Telecom and Mitel have active positions in this cost competitive sector.

2.4   The Availability of Skilled Human Resources

The industry can draw upon an extensive, country-wide system of universities and colleges for the skilled people it requires. Each year, Canadian universities and technical colleges graduate over 26,000 engineers, computer scientists and technicians (see Exhibits 2-2 and 2-3). The Canadian educational system produces highly qualified scientific, engineering, marketing and technical personnel. Additionally, given the multi-cultural nature of Canada, the industry has available a wide range of linguistic capabilities for its international marketing efforts.

Exhibit 2-2

Technical Graduates 1988

Discipline	B.Sc/B.Eng.	M.Sc./M.Eng./Ph.D.
Electrical Engineering	1997	444
Computer Science	2753	363
Mathematics	2229	285
Civil Engineering	981	393
Mechanical Engineering	1857	279
Other Engineering	1629	465

Exhibit 2-3

Community College Technical Graduates 1988

Discipline	
Engineering Technologies	5005
Electrical/Electronic Technologies	3729
Computer Science and Mathematics	3290

Source: Statistics, Canada 1988-1990

Canada's new labour force entrants are very competitively priced. In a 1990 comparison of American and Canadian technical graduates, Canada had the most competitive salary cost in each of three categories surveyed. (See Exhibit 2-4).

Exhibit 2-4

Median Salary of Recent Graduates (CDN $), 1990

Discipline	CANADA	U.S.
Engineering	53,100	60,400
Physics/Computer Science	31,000	41,300
Technology Management MBA	40,000	59,000

Source: The University of Ottawa and Chemical Engineer 1990

The importance of the availability of skilled people within Canada is underscored by the comments of two leading industry participants:

° Mr. Ted Strain, Former Chairman of Motorola Canada Ltd., and now Chairman of the Canadian Telecommunications Action Committee stated, "The strength of the Canadian telecommunications equipment industry is its people - a good supply of creative people."

° Mr. Terence H. Matthews, Chairman of Newbridge Networks Corporation stated, "The company's success is due to the expertise and commitment of its employees."

2.5 Research and Development

The Canadian telecommunications equipment industry is the most R&D intensive industrial sector in Canada. It accounts for approximately 17% of total Canadian industrial R&D. Exhibit 2-5 presents 1989 worldwide R&D expenditures for 12 of the publicly-traded companies in the industry. These companies spent $1.1 Billion on R&D, or 13% of revenues. Of this amount, about $780 Million was spent in Canada. The R&D expenditures of privately-held companies generally ranged from 10% to 20% of revenues.

The extensive Canadian research infrastructure that supports this industrial activity is described in a later section.

Exhibit 2-5

**1989 R&D Expenditures of Selected
Canadian Telecommunications Equipment Companies**

COMPANY	REVENUES[1] ($ Million)	GROSS R&D EXPENDITURES[2] ($ Million)	R&D EXPENDITURES/ REVENUES (%)
Canadian Marconi Company[3]	$ 15.2	$ 1.7	11.2 %
Develcon Electronics Ltd.	$ 11.3	$ 2.4	21.2 %
Gandalf Technologies Inc.	$ 167.4	$ 17.9	10.7 %
Glenayre Electronics Ltd.	$ 108.3	$ 8.0	7.4 %
Memotec Data Inc.[4]	$ 72.4[5]	$ 11.9	17.7 %
Mitel Corporation	$ 432.1	$ 55.3	12.8 %
MUX LAB Inc.	$ 7.4	$ 0.8	10.9 %
Newbridge Networks Corporation	$ 67.4	$ 11.7	17.4 %
Northern Telecom Ltd.[6]	$ 7,161	$ 948.0	13.2 %
SPAR Aerospace Ltd.	$ 233.2	$ 20.0	8.6 %
SR Telecom Inc.	$ 29.8	$ 6.1	20.5 %
TIE/Communications Cda Inc.[4]	$ 66.7	$ 3.4	5.0 %
TOTALS:	$ 8,367	$ 1,088	13.0 %

Source: Company annual reports

Notes: (1)   Worldwide revenues
              (2)   Worldwide R&D expenditures (includes contracted R&D)
              (3)   Estimated amount for telecommunications (assumed to 5% of total)
              (4)   1988 figures
              (5)   Product revenues only
              (6)   Converted to Canadian dollars @ 1.1728
                         70% of R&D employees are in Canada.

2.6 Canadian Microelectronics and Software Capabilities

The increasing use of digital technology has resulted in the blurring of the boundary between telecommunications and computer technologies. The rapid growth of the telecommunications equipment industry was fuelled in the past by its ability to access silicon-based integrated circuit devices.

Canada has developed a strong microelectronics industry to meet its needs. Manufacturing technologies are optimised to meet immediate product needs and cover a wide range of users' technological needs. Present assembly technologies cover a breadth of technologies and development efforts are under way to develop high density packaging. Industry-standard computer-aided-design systems are used in the design process. This, combined with good, focused software support and training at universities, has resulted in an excellent design capability. In the area of applications technologies, there are strong links between systems and silicon engineers in vertically integrated companies. Moreover, most companies have developed their product base through interaction with foreign customers and are hence aware of customers' requirements. Finally, as demonstrated in the following chapter, the microelectronics industry is supported by an excellent research capability.

The other key support element is software, which plays an important role in both firm operations and product content. Canada has the skilled people and the educational and training facilities necessary to adequately meet the anticipated requirements of the industry.

2.7 The Canada/U.S. Free Trade Agreement

Under the Canada/U.S. Free Trade Agreement, which came into effect January 1, 1989, almost all tariffs between Canada and the United States on telecommunications products manufactured in either country have been removed or are being phased out.

Tariffs have been removed on telephone sets, PBX's, key telephone systems, central office switches and radio transmission equipment. For other telecommunications products, tariffs will disappear by January 1, 1993, or earlier. Tariffs have been removed on all microelectronic devices.

The Agreement also permits unhindered reciprocal access for Canadian and American business travellers to the other's market.

3.0   RESEARCH AND SUPPORT INFRASTRUCTURE

Canada has developed an extensive research infrastructure to support of its telecommunications and microelectronics industrial activities. In addition, Canada provides generous support through direct support programs and through income tax measures that make it attractive to do business in Canada.

3.1   Research Infrastructure

There are many individual researchers in Canadian universities who specialize in telecommunications and related software and microelectronics research. Such research is carried out at 27 universities across Canada. Details are provided in Appendix B.

In recent years a number of researchers have organized themselves around government supported "Centres of Excellence" programs and created R&D alliances amongst universities and with industrial and government researchers (see Exhibits 3-1 and 3-2). In addition, the federal and several provincial governments carry out directly related research in various government-owned and operated research laboratories (see Exhibit 3-3). Details of these research activities are presented in Appendix B.

Universities, governments and industry have committed many millions of dollars to these research activities. Research is being undertaken to develop leading edge technologies in areas such as broadband and wireless communications, digital networks, fibre optics, satellites, software, artificial intelligence and the next generation of microelectronics components. This work will position the telecommunications/microelectronics industry to compete effectively during this and the coming decade.

3.2   Government Technology Development Programs and Tax Incentives

Canadian companies may also utilize a number of government programs to assist in the development of technology and its commercialization. In addition, Canada provides generous tax incentives to conduct R&D. Companies of any size who qualify may use these programs and tax incentives.

Exhibit 3-4 provides a summary of key government support programs of interest to the telecommunications/microelectronics industry. The Strategic Technologies Program, which includes telecommunications equipment as a component of information technologies, supports pre-competitive R&D and applications projects. Microelectronics R&D is supported by the Microelectronics and Systems Development Program and by the defence-related programs. The Industrial Research Assistance Program provides a wide range of R&D support to small and medium-sized enterprises.

Exhibit 3-1

University Centres of Excellence in Telecommunications

PROGRAM	AREAS OF RESEARCH
Institute for Telecommunications Research Montreal, Que.	○ Broadband and wireless communications
Microelectronic Devices, Circuits and Systems for Ultra Large Scale Integration Toronto, Ont.	○ Next generation of microelectronic systems
Telecommunications Research Institute of Ontario Kanata, Ont.	○ Network architecture and access, protocols and software engineering, electromagnetic signal processing and systems, mobile and satellite communications, photonic networks and systems, electromagnetic compatibility and interference
Laser and Lightwave Research Centre Toronto, Ont.	○ Laser spectroscopy, lightwave engineering and non-linear optics
Information Technology Research Center Toronto, Ont.	○ Artificial intelligence, microelectronics, communications mathematics, software and graphics
Centre for Material Research Kingston, Ont.	○ Composites and new materials, optoelectronics
Manufacturing Research Corporation of Ontario Oakville, Ont.	○ Next generation of computer-aid manufacturing systems

Exhibit 3-2

Telecommunications-Related
University/Industry/Government R&D Alliances

ALLIANCE	DESCRIPTION
Alberta Telecommunications Research Centre Edmonton, Alta.	° Founded by the University of Alberta, the Government of Alberta and Bell-Northern Research ° Research in three major areas: Network and Systems, Photonics, and Wireless Communications
Wireless Communications Research Centre Vancouver, B.C.	° Supported by the Government of British Columbia and Vancouver-based companies ° Research and training centre for RF engineers
B.C. Advanced Systems Institute Burnaby, B.C.	° Funded by the Federal and British Columbia Governments ° Supports collaborative research among British Columbia universities and industry in advanced systems disciplines, such as artificial intelligence, robotics, computer science, telecommunications and microelectronics
Canadian Microelectronics Corporation Kingston, Ont.	° Non-profit corporation funded by the Natural Sciences and Engineering Research Council of Canada ° Provides services to universities related to the design and testing of integrated circuits
Solid State Optoelectronics Consortium of Canada Ottawa, Ont.	° Consortium which includes the Institute for Microstructural Sciences, Bell-Northern Research, Litton, Alberta Telecommunications Research Centre, MPR and EG&G Canada Ltd. ° Undertakes precompetitive research on the monolithic integration of electronic and photonic devices
Canadian Semiconductor Design Association Kanata, Ont.	° Mandate to improve the international competitiveness of Canada's microelectronics industry ° Program co-ordinator and facilitator between a consortium of Ontario microelectronics companies, universities and the Canadian Microelectronics Consortium

Exhibit 3-3

Telecommunications-Related
Government Laboratories and Sponsored Organizations

LABORATORY/ ORGANIZATION	DESCRIPTION
Communications Research Centre Ottawa, Ont.	° Operates under the Federal Department of Communications ° Undertakes research in communications technologies, communications devices and components, and broadcasting technologies
Canadian Workplace Automation Research Centre Laval, Que.	° Operates under the Federal Department of Communications ° Devoted exclusively to R&D in all aspects of office automation
National Optics Institute Ste. Foy, Que.	° Sponsored jointly by the Federal and Quebec Governments ° Principal areas of research include the design and fabrication of optical systems, opto-electronics in the visible and infrared ranges, and image analysis and vision systems
Institute for Microstructural Sciences Ottawa, Ont.	° Part of the National Research Council ° Collaborative development with industry of opto-electronic integrated circuits and work on quantum effect structures and devices, silicon-germanium superlattices and devices and on infrared sensitive materials
Alberta Research Council Edmonton, Alta.	° Sponsored by the Government of Alberta ° Capabilities for evaluating materials for electronics and telecommunications
Centre de Recherche Industrielle du Québec Ste. Foy, Que.	° Sponsored by the Government of Quebec ° Conducts telecommunications-related research in signal processing for video, television and teledistribution, voice compression and noise correction.

Exhibit 3-4

Key Government Support Programs

PROGRAM	DESCRIPTION
Strategic Technologies Program	° Provides financial support for industry-led R&D and technology application alliances in information technologies and advanced industrial materials
Microelectronics and Systems Development Program	° Provides financial support for R&D on innovative generic components and information technologies
Industrial Research Assistance Program	° Provides financial and technical assistance to increase the calibre and range of industrial R&D in Canada
Defence Industry Productivity Program	° Provides financial assistance to develop strong defence-related industries through support for R&D, source establishment, capital assistance and market feasibility studies
Defence Industry Research Program	° Provides financial assistance to promote and improve the research and technological capability of the Canadian defence industry, to widen the industrial base and to promote and assist strategic industries

The Canadian income tax act contains attractive tax incentives and special tax measures that companies may utilize to reduce the costs of doing business. Canada has the most generous R&D tax incentive system of all advanced industrialized nations. Special tax incentives are available to encourage corporations to undertake industrial R&D. For example, an investment tax credit is provided for investment in certain depreciable assets. The credit is calculated as a percentage of the acquisition costs of an eligible asset, and is claimed as a credit against federal income tax otherwise payable. The credit applies mainly to investment in machinery and equipment, although some plants and buildings are also eligible. The income tax act permits 100 percent deduction for current R&D expenses (such as salaries and other operating costs), as well as capital expenditures made on R&D machinery and equipment, in the year incurred. Qualifying R&D expenditures must be experimental in a scientific or technological sense.

In addition, Canada also allows an investment tax credit on qualifying R&D expenses incurred in Canada. The rate of the credit is 20 percent of R&D expenses, except for Atlantic Canada, where it is equal to 30 percent. This credit applies to current expenses as well as capital expenditures on equipment and specialized structures used in qualified R&D activities. In addition, some of the provinces offer an R&D tax credit which is a percentage of the federal tax credit.

4.0   CASE HISTORIES

A number of U.S. companies have recognized the investment potential of Canadian firms and the synergies that can be gained from strategic alliances. The following provides two case histories of U.S. companies that have committed to involvement with Canadian telecommunications equipment firms.

4.1   Norlite Technologies Inc.

Norlite Technologies Inc., based in Kanata, Ontario, produces a family of telecommunications hardware components and specialized software programs, blended into a totally integrated office telephone and computer system. This system allows small to medium sized organizations to conduct full, in-house outbound or inbound telemarketing and teleservice activities. The product design lends itself to existing small business computer networks that may already be installed.

Norlite today employs 17 personnel, and has recently completed beta testing of several of its products with important customers, including telemarketing firms in British Columbia, Ontario and California. Product development and marketing is managed directly by Norlite.

SCI Systems, Inc. is a public company that specializes in the contract manufacturing business, and supplies electronic components to major computer and telecommunications suppliers throughout the world. In 1987, when SCI first entered into the strategic partnership with Norlite's executives, its sales were US$552 million. In 1990, sales for the first time exceeded US$1 billion. SCI has 24 manufacturing and research and development facilities worldwide, and has a strategic plan that calls for international diversification. It currently employs over 10,000 personnel. SCI is not new to foreign investment, and has facilities in several countries including Canada, Mexico, Ireland, Scotland, Thailand and Singapore. SCI's largest customers in past years have included IBM Corporation, Seagate Technology Inc. and Apple Computer.

SCI has been a supplier to Canadian firms such as Mitel Corporation and Comterm Inc., and was approached in 1987 by a group of telecommunications executives with a proposal to establish Norlite to "integrate telephone switching equipment into standard desktop personal computers", says Louis Payant, Vice President and General Manager of Norlite. "We believed that SCI could offer high quality volume manufacturing capabilities for these new cards. SCI at the time wanted to have more products in the OEM area, was actively seeking markets for its own proprietary PC computer family, and had established a venture fund to finance potential business that would fit with these criteria".

Originally, SCI sought a third Canadian partner, and found a co-investor in The British Columbia Telephone Company (BC Tel). Norlite was established with strong financial backing from these two corporations, and with funds from the Norlite executives. In 1989 BC Tel left the consortium, and SCI assumed a controlling position in the business.

Today the Norlite management team has a high degree of autonomy in management decisions regarding product design, marketing and sales. SCI consults closely with the company on all business matters, and has made available to the firm its expertise in several areas, including finance, manufacturing, operations and strategic planning. SCI has agreed that Canadian innovation in telecommunications is second to none. "We recognized the strength of Canada in telecommunications long before the Norlite opportunity arose, through our involvement with other Kanata based companies", said Olin King, Chairman and CEO of SCI. "We continue to see benefits from Norlite and the international telecommunications industry in general, because it's a key area to fuel continued growth of SCI."

SCI explained that it was seeking multiple benefits from the relationship with Norlite, including more OEM manufacturing of proprietary products, markets for its own technologies, and a venture capital return. Its objectives in all these areas are likely to be realized in the next two to five years.

The managements of both companies acknowledge that relations are cooperative and cordial, and that communication works well in spite of the Canada/U.S. border, which the Free Trade Agreement has all but removed. SCI believes that the Norlite executives know their products and markets very well, and Norlite acknowledges that SCI is the best possible strategic partner for it to have, due to its size, understanding of the product development cycle, and knowledge of high quality volume, low cost manufacturing.

4.2 Newbridge Networks Corporation

Newbridge Networks Corporation, with headquarters in Kanata, Ontario, is an international telecommunications equipment company, specializing in the design, manufacture and marketing of voice and data communications systems for global networks. Its unique integrated digital networking products enable corporations and common carriers to build, expand and manage worldwide communications networks.

Newbridge has experienced extraordinary sales growth for its new line of switching and networking products, which are both powerful and affordable in the minds of major customers. Sales were $1.3 million, $17.5 million, $68 million and $122 million for the fiscal years 1987, 1988, 1989 and 1990, respectively. Sales for the first two quarters of FY91 were $78 million. The company manufactures most of its products in Canada, but exports 90% to international markets, mainly the U.S., Europe and the Pacific Rim.

Newbridge was founded in March 1986 by Terence H. Matthews, a co-founder of Mitel Corporation. He provided initial funding for technology development in the amount of $14 million. In addition, employees invested $4.3 million during the first two years of operation. During 1988 and 1989, Newbridge completed a series of equity private placements with employees and outside investors totalling $50 million. The outside investors comprised individual, corporate and institutional investors from the U.S., the U.K. and Canada.

Today Newbridge is still majority Canadian owned, although its shares are held by investors in many countries. In July 1989 the company raised an additional $48 million in its initial public offering, and currently trades on the Toronto Stock Exchange, and is quoted on the NASDAQ National Market System.

Newbridge has three important strategic investors who acquired initial equity positions of approximately 10% each prior to Newbridge's initial public offering. They are E.I. du Pont de Nemours and Company ("du Pont"), New York Life Insurance Company Limited and Schroder International Trust, administered from London, England.

The largest and most strategic investor is du Pont, who became aware of Newbridge through a review of the company's products by du Pont's communications networking people. Du Pont was considering utilizing Newbridge products in its own corporate communications network. It was discovered through a series of technical and business meetings between the management of both companies that strategic opportunities existed between them for cooperative research and development.

One such area was automotive multiplexing. Du Pont is a leading suppliers of electronic switching systems for the automotive industry, and in 1989 Newbridge had a family of state of the art multiplexer products that impressed du Pont engineers. A cooperative agreement was entered into calling for the companies to evaluate research areas of mutual interest.

Newbridge has benefitted significantly from du Pont's investment and strategic relationship. Firstly, it received approximately $7 million of investment during its formative growth period which it utilized for continued R&D activities and to expand operations. Secondly, du Pont is now an important user of Newbridge communications products. Thirdly, du Pont placed on Newbridge's Board of Directors a key individual, Michael A. Toomey, who has since brought valuable experience and business insight to the company. Finally, the opportunities for cooperative research and development projects represent an avenue for Newbridge to explore new market areas for its technologies on a funded basis with an important industry partner as a customer.

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For du Pont, it acquired a strategic position, in a new enterprise which in a relatively short span of time, has become an industry leader in communications networks. Secondly, its investment has appreciated since the initial series of investments were made.

APPENDIX A

**CAPABILITIES OF KEY
CANADIAN TELECOMMUNICATIONS EQUIPMENT COMPANIES**

CAPABILITIES OF KEY
CANADIAN TELECOMMUNICATIONS EQUIPMENT COMPANIES

In responding to international competitive pressures, the telecommunications equipment industry worldwide and in Canada is being restructured along the following lines:

(1)   Product development companies that seek excellence in the development of specific products and applications for niche markets;

(2)   Systems integrators that work with end users to satisfy their telecommunications requirements; and

(3)   Broad-line equipment suppliers that supply a wide range of products, generally for the telecommunications carrier market.

The capabilities of selected key Canadian companies are grouped into these three categories.

A.1   PRODUCT DEVELOPMENT COMPANIES BY MAIN EQUIPMENT AREA

DATA SWITCHING AND TRANSMISSION EQUIPMENT

Gandalf Technologies Inc.

°   Gandalf Technologies Inc. designs, manufactures and supplies a broad range of information networking products, systems and services.

°   The company is a leader in the data communications industry and it "firsts" include:

-       Design and manufacture of local and medium distance modems;
-       Design and commercial manufacture of a data switching system (PACX);
-       Design of a data switch capable of handling up to 1,024 full-duplex channels (2,048 attachments operating at 9.6 Kbps asynchronous/19.2 Kbps synchronous);
-       Incorporation of digital signal processing technology in modem design;
-       Use of digital large-scale integration technology in limited distance modems;
-       Design and manufacture of a fully distributed network switch, the PACS 2000, capable of supporting 25,000 subscribers; and
-       Design and manufacture of the first true hybrid networking system to connect all users and resources in multi-vendor environments, the Starmaster intelligent network processor.

Dataradio Inc.

°   Dataradio Inc. designs and develops systems for data transmission by radio communications for point-to-multipoint applications. With products in use in 20 countries, Dataradio has achieved many milestones including being the first to introduce:

-       a 2,400 baud packet switched radio systems featuring store and forward repeaters in 1980;
-       a modem with CCITT X.3/X.28 terminal interface and the first to incorporate a five-port multiplexer in 1985;
-       a 9,600 baud radio mobile modem for use on standard land mobile or marine channels, as well as the first radio modem to combine both serial and parallel data in the same error correcting unit in 1986;
-       a 9,600 baud radio modem for synchronous systems applications supporting SNA, HDLC, SDLC and bi-synchronous protocols in 1987.

EDA Instruments Inc.

°   EDA, which produces data communications equipment used to link computer systems and terminal devices together at low cost through high speed X.25 digital communication networks, has achieved the following:

-       Signed major OEM supply agreements with Scitec Communications Limited, Australia; Telindus Networks, Belgium; and Ascom-Zelcom AG, Switzerland;

-       Installed major data communications networks for the Internal Revenue Service (USA); for the General Services Administration (USA); for Union Carbide (Linde Division - USA); and DHL Courier (Europe);

-       Certification to manufacture defence products meeting AQAP-4 (NATO) military specifications.

Develcon Electronics Ltd.

°   Develcon's principal products are data networking and switching systems to connect various data entry and processing equipment into central or geographically distributed homogeneous networks of communications devices;

°   Develcon was chosen to install NASA's Kennedy Space Centre network to carry all of the Centre's data for about 10,000 users.

Telesystems SLW Inc.

°   Telesystems SLW Inc. manufactures ARLAN, an advanced radio local area
        network, which is the first product to be certified by the Federal Communications
        Commission in the U.S. and the first to be approved by the Department of
        Communications in Canada for sale without a radio licence.

°   ARLAN is also listed on the General Services Administration Schedule for use by
        U.S. Government Agencies.

Spilsbury Communications Ltd.

°   Spilsbury specializes in the design and manufacture of HF, VHF and UHF radio
        communications products for voice and data applications.

°   SkyFax 1200, manufactured by R.A.C.E. Technologies Inc., a company majority
        owned by Spilsbury, is fast gaining market acceptance as the world's leading
        product for the transmission of facsimile and medium speed data over HF single
        side band (SSB) radio.

°   SkyFax is a 1,200 baud parallel modem, designed to provide error free
        transmission of facsimile and data, using conventional HF SSB coding. The use of
        sophisticated error correction, compression and encryption techniques make
        SkyFax unique, giving it 100% of the market. With the market potential growing
        from hundreds to thousands of units per year, SkyFax yearly sales could range
        from $1 Million to $4 Million.

PRIVATE SWITCHING

Mitel Corporation

°   Mitel is an international manufacturer whose product portfolio includes PBX and
        key systems, digital and office switching systems, networking and network
        enhancement products, semiconductors and thick film hybrid circuits.

°   Mitel is the only telecommunications manufacturer in the world that has sold more
        than 150,000 PBX systems.

°   The Semiconductor Division is a world leader in both DTMF (Touchtone)
        technology and in its depth and variety of ISDN interfaces. The Division's
        "Express Card", a printed circuit board for IBM and compatible PCs, is used by
        ISDN circuit designers worldwide.

°   The newest product is a compact, feature-rich, digital end office switch that serves
      as a central office switch in rural communities with a 500-2000 line requirement.

°   In May, 1990, Mitel provided the world's first Digital Private Network signalling
      System between British Telecom offices in London and New York.   North
      American and European telecommunications standards were integrated into the
      network, providing more than 30 features, transparently across the network.
      Represents the world's first global "Virtual PBX" network.

°   In Canada and the U.K., Mitel is ranked number two in PBX line shipments, and
      in the total world market, it is ranked sixth.

°   Mitel is rated highest in overall customer satisfaction in PBX systems in North
      America (from Datapro 1989 Ratings of PBX Systems) and retains a top position
      in terms of sales organization, support and after-sales service in the U.K. (from
      "What to Buy for Business" Magazine).

°   On January 30, 1991, Mitel Inc.'s manufacturing and repair facility located in
      Ogdensburg, New York was awarded ISO 9002 quality registration. Mitel Inc. in
      Ogdensburg was the first U.S. telecommunications company and only the second
      company in the U.S. to receive this registration. This ensured Mitel's customers
      that stringent quality policies and procedures exist and are followed. The plant
      pursued world class manufacturing. Mitel received similar registration at its
      Kanata facility on September 30, 1989. All Mitel operations in the U.K. have
      been registered.

°   On January 22, 1991, Mitel introduced two ruggedized commercial
      communications systems designed for the U.S. Navy's Ships Service Telephone
      System. These systems are designed to be the first choice for ship and submarine
      administration interior communications.

MOBILE EQUIPMENT

NovAtel Communications Ltd.

°   NovAtel designs and manufactures a complete line of cellular mobile
      radiotelephones and systems.

°   Pioneered inter-system handoff systems and holds the distinction of the first
      successful inter-system handoff in North America which occurred between
      Edmonton and Calgary.

°   Holds the distinction of the first commercial application of cellular inter-system handoff in the U.S.

°   Awarded a multi-million dollar contract to build Peru's cellular telephone system.

Motorola - Mobile Data Division

°   Motorola's Mobile Data Division has established itself as the world's leading supplier in bridging the gap between the computing, data communications and radio-based networks.

°   The Division has introduced several innovative products including the mobile data terminal, portable data terminal and a self-contained radio modem.

°   Awarded a U.S.$5.6 million contract with the Deutsche Bundespost TELEKOM to provide the first wireless data public network in Germany.

°   Recently announced the Radio Packet Modem 840C-11, a portable and self-contained wireless modem. Mr. Doug Fraser, Product Manager, stated "The RPM 840C-11 goes a long way to remove the magic associated with data on the radio. It is easy to understand and operate because we have modeled the RMP 840C-11 after conventional dial-up telephone wire modems. For example, control of the RPM 840C-11 is accomplished through an extended Hayes™ AT command set. This is an industry first for radio modems".

Gandalf Mobile Systems, Inc.

°   Gandalf Mobile Systems, Inc. develops and markets mobile data communications systems and applications software for various transportation markets such as taxis, couriers and trucking.

°   The company is the leading supplier of Taxi Data Dispatch Systems in the world with over 25 installations serving in excess of 10,000 mobile users.

SATELLITE SYSTEMS

Spar Aerospace Limited

°   Spar's main telecommunications products include satellites and satellite earth stations.

°   Spar is the only manufacturer of satellites in Canada and a major supplier of satellite subsystems for communications and surveillance markets throughout the world.

°   Spar has contributed to the design and manufacture of more than 60 satellites.

°   Prime contractor for the Canadian Space Program - Space Station Freedom, the remote sensing satellite - RADARSAT and the mobile communications satellite - MSAT.

Calian Group

°   The Calian Group consists of two divisions, Calian Technology Ltd. and SED Systems Inc. and has achieved the following accomplishments:

    -     Sale of world's first INMARSAT B&M ACSE systems to British Telecom;
    -     Full AQAP-1 recognition in 1990;
    -     Secured major contracts to design and provide complete real-time-in-orbit Test Systems and Communications Monitoring Systems to Inmarsat, and two contracts for similar systems for Luxembourg's Direct Broadcast Satellite and for British Satellite Broadcasting.

NII Norsat International Inc.

NII Norsat International Inc., which designs, manufactures and distributes electronic products used to receive broadcast signals from communications satellites, is established as a leading supplier of satellite reception equipment for a diverse range of applications worldwide and is the largest supplier of satellite signal amplifiers (LNBs) in North America.

Skywave Electronics Ltd.

°   SkyWave specializes in digital signal processing technology to implement high-performance modems, vocoders and special purpose signal processors. These in turn are used in its system level products, which include transportable satellite ground terminals, multi-channel low-speed digital voice systems, NavLink (an air-

to-ground data link) and GNATS (an aircraft flight following system). Major achievements include:

- Developed the world's first L-Band Briefcase Satellite terminal and established interim commercial service on Inmarsat;
- Developed a family of transportable satellite terminals;
- Developed and marketed the Ground Data Test Unit to be used by Inmarsat for performance testing commercial aeronautical satcom terminals.

COM DEV Ltd.

° COM DEV's major products are microwave multiplexing and switching subsystems for communications satellites.

° COM DEV has its multiplexers installed in over 106 spacecraft in more than 30 international programs.

° It supplies over 65% of the Western World's requirements for multiplexer and switching equipment for communications satellites.

International Datacasting Corporation (IDC)

° IDC designs and manufactures digital communications systems for broadcast of data, digital audio and digital video signals.

° IDC introduced to the market the first economical digital audio satellite transmission system for radio networking.

TRANSMISSION EQUIPMENT

SR Telecom Inc.

° SR Telecom is the pioneer and world-leading manufacturer of subscriber radio systems. The equipment is used to provide telephone and data service to rural or urban areas; and Supervisory Control and Data Acquisition (SCADA) and telephone services for utilities, resources industries, offshore oil platforms and private networks.

° SR Telecom systems are in place in over 60 countries worldwide.

° One leading conglomerate in South East Asia is linking its multi-faceted, multi-

plant operation via a single SR500 system that provides tie trunks between PABX and computers to monitor inventory, maintain accounting, etc. at a traffic rate of 2,500 calls a day over the private network.

CUSTOMER PREMISES EQUIPMENT

DBA Communications Systems Inc.

° DBA designs, manufactures and distributes telephone systems and peripheral products for business communications applications.

° Its SmarTalk 2-line and 3-line series of 8-station key telephone systems are being provided as rental units by a large number of U.S. independent telephone companies, including Contel, Alltel and United Telecom.

CABLE EQUIPMENT

MPB Technologies Inc.

MPB Technologies Inc., which specializes in high technology systems and products and in contract research and development, is a supplier of small to moderate size systems and a major subsystem supplier to prime system contractors and has the following major achievements:

- Winning a major international contract to develop the world's first undersea branching multiplexers ($64 Million). These are to be put into operation in 1991 in the optical fibre Trans Atlantic Telecommunications System.

- Designing and developing the control system, feedback system, data acquisition and various measuring systems for Canada's only major facility for research in fusion energy at the Centre canadien de fusion magnétique.

Opto-Electronics Incorporated

° Opto-Electronics Inc. is a major supplier throughout the world of high speed fibre optic test and measurement instrumentation to leading high technology companies and laboratories involved in industrial and military applications.

° Opto-Electronics Inc. is the original manufacturer of the world's fastest photodetectors and diode laser light sources.

° The Opto-Electronics Millimetre Resolution OTDR (Optical Time Domain Reflectometer) was a recipient of the 1988 Photonics Circle of Excellence Award,

° The TDR30 photon-counting high resolution OTDR system was similarly honoured in 1990 by Photonics Magazine.

Canstar Communications

° Canstar Communications offers a completely integrated capability to engineer, install and test complete turnkey lightwave communications systems. The company is a division of Canada Wire and Cable Limited which manufactures a wide range of wire and cable products.

° Canstar has the exclusive rights to build and market the fused biconical tapered coupler developed at the Department of Communications, Communications Research Centre.

° Canstar was awarded a contract worth $80 million to supply and install a fibre optic communications system to interconnect 107 locations for the New York Transit Authority.

A.2   SYSTEMS INTEGRATORS

RMS Industrial Controls Inc.

° RMS Industrial Controls Inc., which specializes in the transportation communications industry, has commissioned systems for several clients including:

- Toronto Transit Commission, Hamilton Street Railroad and Baltimore Bus Transit Authorities for RMS voice and data communications products (Cadcom series);

- In the rail and light rail market, RMS has provided communications systems (Comsyst series), to B.C. Transit Skytrain, AEG Westinghouse for the Stansted, Changi, Las Colinas and Pittsburgh projects as well as to UTDC for the Scarborough and Detroit projects.

Newbridge Networks Corporation

° Newbridge Networks Corporation designs, manufactures and markets a series of universal voice and data multiplexer products for the digital trunk market.

°   Newbridge is the second largest supplier in the TI/EI multiplexer market, commanding 15% of the $1 billion worldwide market and a similar share of the U.S. market. Newbridge was the first company to introduce integral local area networks and T3 interfaces, and its products have been accepted by most North American telephone companies for their internal networks.

°   Newbridge received the award of "outstanding vendor of the year" in 1990 from Sun Microsystems, one of its largest customers.

°   Newbridge's Kanata, Ontario operation was recently awarded the ISO9002 quality rating by the International Organization for Standardization.

DATAP Systems

°   DATAP is a software manufacturer and systems integration company, focusing on telecommunications network management and intelligent network services. DATAP markets the Advanced Network Management Architecture (ANMA) and the Network Services Platform (NSP) to telecommunications service users and providers, to both control and enhance these customers' networks. DATAP combines its software development and computer systems integration capabilities to provide customers with complete solutions tailored to each unique need.

°   DATAP developed and marketed one of the largest intelligent operator intercept systems used in the U.S. The Personalized Audio Routing and Information System (PARIS), sold to MCI Communications Corporation, provides electronic telephone answering services from seven "nodes" or computer installations across the continental U.S.

TIL Systems Limited

°   TIL Systems Limited manufactures X.25-based full-service telecommunications solutions, including terminal products, network devices, application software and user support services.

°   TIL was recently awarded a $10 Million contract from the U.S. Department of Agriculture to supply Farmers Home Mortgage Administration (FHMA) with communications hardware and software. FHMA, headquartered in St. Louis, MO, has over 2,300 branches which will utilize the TIL solution.

°   TIL provides Telerate International with hardware and software solutions for the delivery of Telerate stock quotation information to their offices and their client offices in over 64 countries world-wide.

A.3   BROAD-LINE EQUIPMENT SUPPLIERS

<u>Northern Telecom</u>

°   Northern Telecom is Canada's only company that falls into this category.
Northern Telecom manufactures a wide range of telecommunications equipment
for telephone companies, private corporations, educational institutions,
government and military agencies, hospitals, offices and residences around the
world. Its products include switching and transmission systems, fibre optics and
communications cables, private switching systems, customer premises equipment,
outside plant and other equipment for public and private networks.

°   Northern Telecom does business in more than 70 countries in North and South
America, the Caribbean, Europe, the Middle East, the Far East, and the Pacific
Rim. It operates 40 manufacturing plants worldwide. R&D is conducted at 21 of
these facilities and by BNR at 6 locations. Northern is now the third largest
equipment manufacturer in the world.

°   Northern Telecom was the first company in the world to announce and deliver a
complete family of fully digital switching and transmission equipment. In the late
1970s, Northern Telecom took the lead with the introduction of the Digital
Multiple Switch (DMS) family of central office switching systems and by
announcing its commitment to the "Digital World" product line. It remains the
world's leading supplier of fully digital telecommunications switching equipment.

°   To permit the interconnection of equipment from many suppliers, Northern
Telecom introduced in November 1982, the OPEN (Open Protocol Enhanced
Networks) World.

°   In support of OPEN World, introduced:

-      In February 1985, the Meridian line of fully digital integrated voice and
data systems and the concept of Dynamic Network Architecture (DNA) for
private and public networks, respectively;

-      In July 1987, introduced DMS Supernode, a powerful, fault-tolerant node
for the public telephone network that dramatically increases the power and
functionality of telephone company central offices.

°   On September 12, 1987 Bell Canada and Northern Telecom placed in service the
world's first DMS Supernode in the public network.

°   In October 1989, Northern Telecom seized a position of global technological

leadership with the announcement of FiberWorld, a new family of fibre optical transmission and switching products.

o   With the introduction of FiberWorld, Northern Telecom became the first global telecommunications manufacturer to offer a family of switching and transmission products essential to the construction, operation, and service of a complete, end-to-end fibre network. It also was the first to create a fibre optic network product line that adheres to the newly developed international fibre optic telecommunications standards - Synchronous Optical Network (SONET).

o   Northern Telecom is planning to launch the world's first digital microwave radio technology that is compatible with fibre-optics systems based on SONET. This technology will permit SONET to be extended to areas of remote or rough terrain where fibre optics cable is not feasible.

o   Northern Telecom was the first North American company to have three plants attain the highest quality rating (ISO9001) given by the International Organization for Standardization.

APPENDIX B

RESEARCH INFRASTRUCTURE

RESEARCH INFRASTRUCTURE

Canada has developed an extensive research infrastructure to support its industrial activities in telecommunications and related software and microelectronics.

B.1   UNIVERSITY RESEARCH

Research in telecommunications and related areas is carried out at 27 universities across Canada. These universities are listed below, along with an illustrative listing of their principal research areas.

1.   **University of Victoria (Victoria, B.C.)**

Research topics:

- Digital communications
- Application of expert systems in communications
- Mobile communications
- Spread spectrum
- Microwave components systems and subsystems
- Cellular radio data communications
- Computer-aided analysis and design of millimetre-wave integrated circuits

2.   **University of British Columbia (Vancouver, B.C.)**

Research Topics:

- Efficient data communications over mobile radio channels
- Protocols and internetworking for satellite networks
- Power and spectrally efficient digital transmission techniques
- Data transmission over noisy and fluctuating channels
- Analysis and designs for intrabuilding communications systems
- The design of VLSI devices, processes and circuits

3.   Simon Fraser University (Burnaby, B.C.)

Research Topics:

o   Digital mobile radio
o   Digital voice technologies
o   Performance analysis and simulation of mobile radio networks
o   Receiver design for coded continuous phase modulation
o   MOS transistors with non-uniform current distribution for ASICs
o   Passive RF/microwave circuits, GaAs monolithic microwave integrated
        circuits, non-linear RF/microwave devices, active RF/microwave circuits

4.   University of Alberta (Edmonton, Alberta)

Research Topics:

o   Coherent optical fibre communications
o   Optical fibre communications systems
o   Coding and modulation for optical fibre communications
o   Applications of optoelectronics matrices
o   Optical coupling to planar waveguides and silocom superlattices
o   Thin-film microstructures and devices

Research Chairs:

o   NSERC/Bell-Northern Research/Alberta Telecommunications Research
        Centre Industrial Chair in Fibre-Optic Communications

5.   University of Calgary (Calgary, Alberta)

Research Topics:

o   Cellular radio amplifier and antenna studies
o   Fibre optic transmission systems and network topologies
o   Telecommunications networks and queuing networks
o   Satellite communications
o   Analog and digital signal processing
o   VLSI circuit design

6.   University of Saskatchewan (Saskatoon, Saskatchewan)

Research Topics:

°   Digital transmission and voice coding
°   Theory and design of printed antennas
°   Distributed VLSI design environment

7.   University of Regina (Regina, Saskatchewan)

Research Topics:

°   Universally transparent fibre optic networks to support the
       telecommunications needs of intelligent buildings, factories and campuses.

Research Chair:

°   SaskTel/NSERC Industrial Research Chair in Electronic Information
       Systems

8.   University of Manitoba (Winnipeg, Manitoba)

Research Topics:

°   Numerical and experimental antenna impedance matching studies
°   Transmission line analysis

9.   Lakehead University (Thunder Bay, Ontario)

Research Topics:

°   Adaptive forward error control coding for land mobile radio systems

10.   University of Windsor (Windsor, Ontario)

Research Topics:

°   High speed VLSI architectures for digital signal processing

11.   University of Western Ontario (London, Ontario)

Research Topics:

°   Techniques for generation and detection of optical signals

12.   University of Waterloo (Waterloo, Ontario)

Research Topics:

°   VLSI device theory, design, modelling and computer simulations of modern
        semiconductor devices, including their applications to VLSI circuits and
        systems on chips
°   Communications circuits, speech processing
°   Design and analysis of opto-electromagnetic couplers/multiplexer/switches
°   Waveguide dipole antennas, prolate spheroidal antennas and scatterers
°   Integrated services computer communications networks

Research Chair:

°   Bell-Northern Research/NSERC Industrial Research Chair in VLSI

13.   McMaster University (Hamilton, Ontario)

Research Topics:

°   Digital signal processing applied to communications systems
°   Surface acoustic wave (SAW) devices for communications applications
°   Signal processing applied to Sarsat and impulse radar
°   Monolithic microwave integrated circuit research

Research Chairs:

°   McMaster Chair in Antennas and McMaster Fellow in Microwave Signal
        Processing
°   Gennum/NSERC Industrial Research Chair in Monolithic Microwave
        Integrated Circuits
°   Bell-Northern Research/NSERC Industrial Research Chair in
        Optoelectronics and Microelectronic Devices and Materials

14.   University of Toronto (Toronto, Ontario)

Research Topics:

o   Transmission and networking in telecommunications
o   Studies in digital communications
o   Integrated optic devices and optical information processing
o   Spread spectrum packet radio networks
o   Performance issues in broadband integrated services networks
o   Subsurface radars and optical communications
o   Nonlinear digital signal/image processing
o   VLSI technology
o   Algorithms and VLSI architectures for digital communications
o   Satellite communications

Research Chair:

o   Industrial Research Chairs in Microelectronics Technology and Design

15.   Queen's University (Kingston, Ontario)

Research Topics:

o   Digital communications on voiceband, microwave, RF and satellite links
o   Digital mobile satellite and radio communications
o   Modem development
o   Optical communications and photonics
o   Computer communications networks and protocols
o   Applications of VLSI circuits to digital communications, data encryption
       and signal processing

16.   Carleton University (Ottawa, Ontario)

Research Topics:

o   Mobile communications
o   Mixed analog and digital circuits for communications
o   Multiple access techniques for integrated voice and data transmission over
       a broadcast medium
o   Integrated data communications systems and local (wireless) radio networks

> o   Digital communications systems and signal processing
> o   Nonlinear GaAs MMICs for communications
> o   Spread spectrum communications
> o   Microwave devices and circuits
> o   Optical communications circuits

Relevant Information:

> o   Along with the University of Ottawa formed the Ottawa-Carleton Centre for Communications Research

17.   University of Ottawa (Ottawa, Ontario)

Research Topics:

> o   Multimedia broadband communications
> o   Passive millimetre-wave components
> o   Digital transmission techniques
> o   Evaluation of metropolitan area network architectures and services
> o   Real time array processors for wide-band digital signals
> o   Electromagnetic interference and compatibility studies

Research Chair:

> o   Bell-Northern Research/NSERC Industrial Research Chair in Signal Transmission Technology

Relevant Information:

> o   Along with Carleton University formed the Ottawa-Carleton Centre for Communications Research

18.   Institut national de la recherche scientifique INRS - Télécommunications (Verdun, Quebec)

Research Topics:

> o   Fundamental models for communicating systems
> o   Computer vision techniques for telecommunications
> o   Statistical modelling and coding for graphics communications
> o   Image processing for telecommunications
> o   Optimization of telecommunications networks

Relevant Information:

   °   INRS - Télécommunications is a degree granting research institute
established jointly by Université du Québec and Bell-Northern Research

19.   Ecole Polytechnique de Montréal (Montreal, Quebec)

Research Topics:

°   Design, fabrication and testing of new optoelectronic devices
°   Error correcting codes/digital communications
°   High reliability and security encoding
°   Modelling and evaluation of wide-band integrated services digital networks

20.   Université de Montréal (Montreal, Quebec)

Research Topics:

°   Specification, implementation and validation of communications protocols

Research Chair:

°   Federal Department of Communications/IDACOM Electronics/NSERC
Industrial Research Chair in Communications Protocols

21.   Concordia University (Montreal, Quebec)

Research Topics:

°   Studies of optical communications systems
°   Efficient digital point-to-multipoint communications systems
°   Codulation and access techniques for secure wideband networks
°   Distributed protocol design, PLA folding and performance studies for
communications networks
°   VLSI systems
°   VLSI algorithms for network optimization

22.   McGill University (Montreal, Quebec)

Research Topics:

°   Testing and synthesis of VLSI circuits
°   VLSI circuit design and verification
°   Optical waveguides for fibre optic communications
°   Acoustic surface wave devices and acousto-optic interactions

Research Chair:

°   Northern Telecom/NSERC Industrial Research Chair in Digital Systems
        Design

23.   Université de Sherbrooke (Sherbrooke, Quebec)

Research Topics:

°   Efficient generation, transmission and reception of analog and/or digital
        signals

24.   Université Laval (Laval, Quebec)

Research Topics:

°   Communications and signal processing
°   Frequency stabilization of diode lasers and its application to coherent
        optical communications
°   RF signal processing
°   Optical communications

Research Chair:

°   Québec Téléphone/NSERC Industrial Research Chair in Optical
        Communications

25.   University of New Brunswick (Fredericton, N.B.)

Research Topics:

°   Antenna properties

26.   Technical University of Nova Scotia (Halifax, N.S.)

Research Topics:

°   Spread spectrum techniques and their applications
°   Digital modulation and demodulation methods
°   Architectures and VSLI implementation for digital signal processing applications
°   Co-operative project with Bell-Northern Research Ltd. on all-optical switching/modulation element

27.   Memorial University of Newfoundland (St. John's, Nfld.)

Research Topics:

°   Digital communications through band limited channels

B.2   UNIVERSITY "CENTRES OF EXCELLENCE"

A number of researchers, specializing in telecommunications and microelectronic research have organized themselves around major government supported "Centres of Excellence".

1.   The Institute for Telecommunications Research, Montreal, Que.

°   CITR focuses on broadband and wireless communications. Broadband communications includes research on high-speed communications made possible through advances in optical fibre technology and semi-conductor lasers. The researchers will look to maximize the effectiveness of optical telecommunications by incorporating light-switching devices into micro-chips. Fibre systems will be designed with built-in "traffic control" so that each of the thousands of fibre users receive just the needed amount of transmission resources without delaying others. Finally, new software technologies will be developed to manage and maintain communications systems in "real time". The Institute's wireless communications thrust involves research in the development of high-speed voice or data transmission networks in office buildings, factories, and hospitals, improvements in digital cellular radio systems and mobile communications for rural areas.

o   Based in Montreal, Quebec, CITR brings together 30 participants from across the country in a co-ordinated effort to boost Canadian leadership in telecommunications services and manufacturing.

The membership includes:

Alberta Telecommunications Research Centre
Carleton University
Concordia University
INRS-Télécommunications
Université Laval
McGill University
McMaster University
Queen's University
University of British Columbia
Université de Montréal
University of Ottawa
University of Toronto
University of Victoria
University of Waterloo

CITR has developed a close working relationship with a dozen Canadian companies, referred to as Industrial Affiliates:

Bell Canada
Bell-Northern Research
CAL Corporation
Gandalf Technologies Inc.
IDACOM Electronics Ltd.
Memotec Data Ltd.
Mobile Data International
Motorola Information Systems
MPR Teltech Ltd.
Nexus Engineering Ltd.
NovAtel Communications Ltd.
Spar Aerospace Limited

o   CITR is operating on a four-year research grant of $14.7 million.

2.   Micronet, Toronto, Ont.

°   The Microelectronic Devices, Circuits and Systems for Ultra Large Scale
        Integration (ULSI) Network, or Micronet

°   a four year $10.8 million federally funded project

°   brings together university-based researchers from across Canada to
        work along with industry and government researchers on the next
        generation of microelectronic systems

°   researchers are carrying out leading-edge research in ULSI related areas:
        -      use of semiconductor technologies with minimum component
               dimensions of less than a micrometre;
        -      circuit and system design techniques and algorithms relevant to the
               implementation of large scale systems

°   the universities most directly involved with Micronet are:

               University of Toronto (program leader)
               McGill University
               University of Victoria
               Carleton University
               University of Calgary
               University of Manitoba
               University of Waterloo
               University of Windsor
               Université du Québec - INRS-Télécommunications

°   In addition, researchers from other universities such as University of British
        Columbia, Simon Fraser University, University of Alberta, Queen's
        University, Concordia University, Ecole Polytechnique de Montréal and the
        Technical University of Nova Scotia are also involved in the network.

°   The non-university members of Micronet consist of Canada's major
        microelectronic and information technology firms, as well as provincially
        and federally funded laboratories and organizations. The organizations
        involved are:

               Alberta Microelectronic Centre
               Bell-Northern Research
               B.C. Advanced Systems Institute
               Canadian Microelectronics Corporation

Canadian Semiconductor Design Association
Electronics Network of Alberta
Gennum Corporation
Glenayre Electronics
Information Technology Research Centre
MacDonald Dettwiler Associates
MPR Teltech
Matrox Electronic Systems
Memotec Data Ltd.
Mitel Corporation
Newbridge Microsystems Ltd.
NovAtel Communications Ltd.
National Research Council
Northern Telecom Electronics Ltd.
Pacific Microelectronics Centre (A Division of MPR Teltech Ltd.)
Telecommunications Research Institute of Ontario
TRIUMF

3.   Ontario "Centres of Excellence"

°   consists of seven centres altogether

°   a five year $204 million program created to stimulate the production of
        advanced research and to encourage the transfer and diffusion of
        technology to industry

°   each Centre of Excellence is a non-profit corporation, managed by a board
        of directors that is responsible to the Ontario government for the program
        and its financial management. The following centres undertake research
        either directly or indirectly in information technology:

a)   Telecommunications Research Institute of Ontario (TRIO), Kanata, Ont.

        - 1991/92 research topics

                °   network architecture and access
                °   protocols and software engineering
                °   electromagnetic signal processing and systems
                °   mobile and satellite communications
                °   photonic networks and systems
                °   electromagnetic compatibility and interference

- member universities:

    Carleton University
    McMaster University
    University of Ottawa
    Queen's University

- industrial members

    3M Canada Inc.
    Andrew Canada Inc.
    Bell Canada
    Bell-Northern Research
    CAL Corporation
    Canpolar Inc.
    Com Dev Ltd.
    Gandalf Technologies Inc.
    IBM Canada Ltd.
    Mitel Corporation
    Newbridge Networks Corporation
    Skywave Electronics Ltd.
    Spar Aerospace Limited
    Telesat Mobile Inc.
    Westinghouse Canada

- associate members

    B.C. Advanced Systems Institute
    National Research Council
    Université du Québec à Hull

b)   <u>Centre for Advanced Laser and Lightwave Research</u>, Toronto, Ont.

-    at University of Toronto

-    conducts research in fields such as laser spectrography, lightwave engineering and non-linear optics - significant areas for the electronics, aerospace, robotics, communications and remote sensing industries

c)   <u>Centre in Information Technology</u>, Toronto, Ont.

-      is investigating artificial intelligence, microelectronics, communication mathematics, software and graphics to keep Ontario competitive in the information age

d)   <u>Centre for Material Research</u>, Hamilton, Ont.

-      carries out basic and applied research in areas which include biomaterials for medical applications, composites and new materials, and optoelectronics

e)   <u>Centre for Integrated Manufacturing</u>, Oakville, Ont.

-      is laying the groundwork for the next generation of computer-aided manufacturing systems through research in intelligence and flexible automation, improved design processes and systems management

B.3   UNIVERSITY / INDUSTRY / GOVERNMENT R&D ALLIANCES

In recent years, several ventures, which bring together industry, university and government researchers have been set in place. The principal ones are the following:

1.   Alberta Telecommunications Research Centre (ATRC), Edmonton, Alta.

°   ATRC links academic research with industrial application through joint research projects involving industry, universities and government. Its research facilities encourage joint research in telecommunications to be carried out by industry representatives, university faculty members and graduate students. ATRC is an accredited extension of the graduate schools of the Universities of Calgary and Alberta and the professors have dual appointments at ATRC and at their University.

°   located in Edmonton, laboratory facilities range from optical tables, spectrum analyzers and oscilloscopes to data acquisition and circuit prototype equipment.

°   founded by the University of Alberta, the Government of Alberta and Bell-Northern Research.

o   Current sponsors are:

Industry
-       Bell-Northern Research
-       Alberta Government Telephones
-       edmonton telephones
-       LSI Logic Corporation of Canada, Inc.
-       NovAtel Communications Ltd.
-       Digital Equipment of Canada Limited

University
-       University of Alberta
-       University of Calgary

Government
-       Government of Alberta

o   ATRC's research program is made up of three major components:

-       network and systems
-       photonics
-       wireless communications

2.   **Wireless Communications Research Centre**, Vancouver, B.C.

o   a research and training facility set up in Vancouver for RF engineers

o   funded by Vancouver-based companies and by a $14.5 million contribution from the Government of British Columbia

3.   **B.C. Advanced Systems Institute (ASI)**, Burnaby, B.C.

o   supports collaborative research among B.C. universities and industry in advanced disciplines such as:

-       artificial intelligence
-       robotics
-       computer science
-       telecommunications
-       microelectronics

°   initially funded ($8 million over five years) through the Science and Technology Sub-Agreement of the Canada-British Columbia Economic and Regional Development Agreement

4.   Canadian Microelectronics Corporation (CMC), Kingston, Ont.

°   non-profit organization funded by the Natural Sciences and Engineering Research Council of Canada

°   established in 1984

°   CMC provides services that facilitate the design and testing of integrated circuits for its University members

°   the motivation for its creation was the need for highly trained professionals for employment in the demanding microelectronics industry

°   is a co-operative effort among its members - 28 universities, selected government agencies and a number of industrial firms including:

University of Alberta	University of British Columbia
University of Calgary	Carleton University
Concordia University	Lakehead University
Université Laval	University of Manitoba
McGill University	McMaster University
Memorial University of Nfld.	Ecole Polytechnique de Montréal
Université de Montréal	University of New Brunswick
Technical University of N.S.	University of Ottawa
Queen's University	Université du Québec à Montréal
University of Regina	Royal Military College
University of Saskatchewan	Université de Sherbrooke
Simon Fraser University	University of Toronto
University of Victoria	University of Waterloo
University of Western Ontario	University of Windsor

Applied Microelectronics Inst.	Alberta Microelectronics Centre
Calmos Systems Inc.	Ericsson GE Communications Inc.
Gennum Corporation	IBM Canada Ltd.
LSI Logic Corporation of Cda.	MPR Teltech Ltd.
MITEL Corporation	MOSAID Incorporated
Northern Telecom Electronics Ltd.	NovAtel Communications Ltd.

5. **Solid State Optoelectronics Consortium of Canada**, Ottawa, Ont.

    °   created to undertake user-driven precompetitive research on the
        monolithic integration of electronic and photonic devices through
        innovation in solid state material technology and device design

    °   funded for a five-year period - $40 million

    °   will involve 65 person years at peak

    °   research will utilize GaAs during the first two years; indium
        phosphide will be basis of study by year three.

6. **Canadian Semiconductor Design Association (CSDA)**, Kanata, Ont.

    °   formed in 1985

    °   mandate to improve the international competitiveness of Canada's
        microelectronics industry

    °   program focuses on non-competitive R&D activities

    °   acts as program co-ordinator and facilitator between a consortium of
        Ontario microelectronics companies, universities and the Canadian
        Microelectronics Corporation.

B.4   GOVERNMENT LABORATORIES AND SPONSORED ORGANIZATIONS

The following is a list of government laboratories and sponsored organizations
specializing in telecommunications.

1. **Communications Research Centre (CRC)**, Ottawa, Ont.

    °   operates under the federal Department of Communications in Ottawa,
        Ontario -

    °   employs over 300 scientists, engineers and support staff

  ° CRC is involved in the following three research programs

   - Communications Technologies Research - Research, development and implementation of new terrestrial, satellite and airborne radio communications systems and services

   - Communications Devices and Components Research - Research and development on devices, circuits and components for applications in spectrum-effective communications, high speed data processing and radar systems

   - Broadcasting Technologies Research - Research and development into television; sound and data broadcasting; interactive video services; video program and computer information systems and services and behavioral research

2. **Canadian Workplace Automation Research Centre (CWARC), Laval, Que.**

  ° operates under the federal Department of Communications in Laval, Quebec

  ° devoted exclusively to R&D in all aspects of office automation, including the technological, socio-economic, behavioural, institutional and international aspects

  ° has mandate to ensure:

   - that necessary technology is available at the appropriate time,
   - that Canadian universities take an active interest in the field to provide skilled people to meet the needs
   - that the social, behavioural and institutional impact of the introduction of new technologies is investigated
   - that an awareness is maintained of developments on the international scene and industry and governments are advised of developments and possible actions.

  ° has three major research divisions:

   a) Advanced Technologies, which involves expert systems, application of artificial intelligence and computer assisted translation

b)   Integrated Systems which involves the study of multi-media

c)   Organizational research

° has a highly computerized library which has a database of 40,000 entries, soon to be made available to the public

° has a National Exchange Program

- provides them with $2 million a year
- involves agreements between a university or private company to work at CWARC on a specific project; the company or university provides the personnel
- currently of the approximate 120 people working in the laboratory, only about 40 are civil servants, the rest are from companies or universities.

3.   National Optics Institute, Ste. Foy, Que.

° sponsored jointedly by the Federal and Quebec Governments

° has a mandate to help industry broaden its expertise in the area of optics

° employs over 70 people

° principal areas of research are:

- design and fabrication of optical systems
- opto-electronics in the visible and infra-red ranges, including materials/device fabrication
- image analysis and vision systems

4.   Institute for Microstructural Sciences, Ottawa, Ont.

° operates under the National Research Council in Ottawa, Ontario

° employs 100 scientists and technicians

    °   current programs include:

-     collaboration with a Canadian industrial consortium for the development of opto-electronic integrated circuits
-     operation of a Focused Ion Beam Facility
-     work on quantum effect structures and devices, silicon-germanium superlattices and devices and on infrared sensitive materials

    °   has capabilities in molecular beam epitaxy for GaAs, Si, Ge and InP as well as extensive characterization facilities.

5.   **Alberta Research Council**, Edmonton, Alta.

    °   sponsored by the Government of Alberta

    °   has capabilities for evaluating materials for electronics and telecommunications

    °   has an Electronic Test Centre which can provide tests to military standards, government standards or for any commercial product requirements

6.   **Centre de Recherche Industrielle du Québec (CRIQ)**, Ste. Foy, Que.

CRIQ is a Government of Quebec corporation that supports and stimulates technological development in manufacturing firms. It fulfills its mandate three ways:

-     through applied research work, to answer specific needs of its clientele as well as those initiated at the Centre

-     through the development and improvement of product manufacturing processes and industrial equipment

-     through the collection and distribution of technological and industrial information

CRIQ's telecommunications related research activities including the following:

-     signal processing for video, television and teledistribution
-     voice compression
-     noise correction