THE CASE FOR INVESTING IN CANADA

THE CANADIAN TELECOMMUNICATIONS EQUIPMENT INDUSTRY

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1.0 INTRODUCTION - INDUSTRY OVERVIEW

The Canadian telecommunications industry is a vibrant and dynamic industry that is poised to gain a greater share of the world market. Canadians have recognized the strategic importance of investing in a modern, world-class telecommunications infrastructure. The Canadian telecommunications system is among the most advanced in the world. With one of the highest telephone penetration rates, Canadians have always been among the first to demand and adopt new technologies and equipment. This has encouraged the development of a strong telecommunications equipment sector.

The industry, comprised of about 500 companies spread across the country, is Canada's most R&D intensive industrial sector.

In 1990, the industry shipped $7.4 billion in products of which about $2.7 billion was exported. The majority of the $4.7 billion in domestic sales was consumed by the telecommunications and mobile communications service providers.[1]

Canada's telecommunications carriers generated over $14 billion in revenues in 1990. Long distance resellers contributed an additional $80 million. In 1992, Unitel Communications Inc. and BCRL Group were authorized to compete as long distance facilities-based carriers.

The rapidly growing mobile communications sector generated over $1 billion in revenues in 1990. The two cellular operators generated the majority of these revenues. With over 750,000 cellular subscribers, Canada has one of the highest subscriber penetration rates in the world. Canada has also taken an early lead in the emerging advanced personal communications area with the recent authorization of four companies to provide personal cordless telephone service, enabling Canadians to use a small, low-power handset at home, in public places or at the office. The personal cordless telephone market in Canada is expected to exceed $1 billion within the next 5 years.[2]

The Canadian telecommunications industry has capitalized on its strong domestic base to expand into world markets, with some companies deriving 90% of their sales from exports. In this competitive international environment, Canadian suppliers have garnered a reputation for supplying innovative, high-quality products. Investment in the Canadian telecommunications equipment industry affords a geographic base with substantial international trade opportunities. The North American Free Trade Agreement (NAFTA) provides ready access to a market of 360 million people - substantially larger

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1 Source: Information Technologies Statistical Review, Industry, Science and Technology Canada, 1992.

2 Source: Radio Advisory Board of Canada and NGL estimates.

than that of the European Community.

Increased global competition compels Canadian companies to pursue new markets and alliances with domestic and foreign companies in order to increase international market share. Canadian industry seeks investment and strategic partnerships to assist in financing the development of new technologies and to facilitate entry into new markets.

Canada's modern economy, stable political system, supportive government policies, particularly in the area of R&D, and world-class technological infrastructure combine to produce a favourable environment in which to develop new products and seek out new markets.

As such, there are substantial opportunities for investment in, or establishing strategic partnerships with the Canadian advanced communications and related microelectronics industry.

2.0 THE CANADIAN TELECOMMUNICATIONS INDUSTRY

2.1 Statistical Overview

The Canadian telecommunications industry comprises some 500 companies spread across the country, with the greatest concentrations in Ontario and Quebec. The industry is dominated by some 30 firms, including the largest Canadian company, Northern Telecom, which manufactures a wide range of telecommunications products. Many smaller companies have unique capabilities and market niches.

Canadian telecommunications equipment and related microelectronics production amounted to approximately $7.4 billion in 1990 (Exhibit 2-1), with exports of approximately $2.7 billion. The industry employed about 55,000 people in 1990. 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.

2.2 Markets for Canadian Production

Canadian companies sold primarily into the domestic and the U.S. markets in 1990 (Exhibit 2-2). Canadian companies sold $4.7 billion in Canada and captured 78.4% of the domestic market. Of the $2.7 billion that was exported (approximately 37% of production), $1.9 billion was exported to the U.S.

The key thrust of the Canadian industry is to expand exports. Most 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 assistance provided by many of the provincial governments.

Exhibit 2-1: Canadian Production by Equipment Category

Equipment	Canadian Production ($ million)	% of Total Sector Production	Growth Rate
Public Switching	$1,897	25.7%	9.0%
Transmission	430	5.8%	1.0%
Cable	641	8.7%	13.3%
Satellite Systems	81	1.1%	-9.3%
Data Communications	626	8.5%	15.5%
Private Switching	1,032	14.0%	1.2%
CPE	172	2.3%	6.7%
Wireless/Mobile	1,214	16.5%	36.6%
Related Microelectronics	1,285	17.4%	n/a
Total	$7,378	100%	9.6%

Source: A Proposal Towards a Strategic Plan for the Canadian Telecommunications Equipment Industry, NGL Consulting Ltd. for Industry, Science and Technology Canada, June 29, 1990, Part I, Page 14 (Updated to 1990 using Compound Average Growth Rates). Five-year compound annual growth rates are based on current dollars. Related microelectronics estimates represent the total 1990 shipments of electronic parts and components (SIC 3352), Information Technologies Statistical Review, Annual 1991, Industry, Science and Technology Canada.

Exhibit 2-2: Canadian Major Telecommunications Equipment Markets (1990)

Region	Market Size ($ Billion)	Canadian Sales ($ Billion)	Market Share (%)
Canada	6	4.7	78.4
U.S.A.	50	1.9	3.8
Europe	50	.39	0.8
Japan	19	.02	0.1
Other	49	.39	0.8
Total	$174	$7.4	4.3%

Source: Market size estimates are from CEC studies converted to Canadian dollars. Canadian sales are estimated using 1989 ratios from the report "A Proposal Towards a Strategic Plan for the Canadian Telecommunications Equipment Industry" - Part II, NGL Consulting Ltd. for Industry, Science and Technology Canada, June 29, 1990, Part II, Page 7.

2.3 Areas of Canadian Expertise

Canada has a long history as a pioneer in telecommunications technologies and services. The innovative capacity of the industry has made possible a number of significant technological achievements, such as:

- 1876: Telephone invented by Alexander Graham Bell, a Canadian;
- 1876: World's first long distance call;
- 1948: World's first commercial microwave relay system;
- 1971: World's first domestic digital microwave network;
- 1972: World's first national geostationary satellite telecommunications network;
- 1985: World's longest fibre-optic communications network;
- 1990: World's largest contiguous cellular network; and
- 1992: First country to license personal cordless telephone (PCT) service that will provide two-way communications capability at home, at work, and at public locations using the same telephone set.

Today, the Canadian advanced communications and related microelectronics industries continue their historically strong performance in all equipment categories. The following provides a brief overview of the current activity and state of the Canadian industry.

Public Switching

This category accounts for 26% of the total Canadian production. The leading Canadian company is Northern Telecom. Other companies provide selected product lines.

- Northern Telecom was the first company in the world to announce and deliver a complete family of fully digital switching and transmission equipment. Northern Telecom is also a leading supplier of digital switches to NTT.

- Mitel Corporation recently announced a digital end office switch for rural communities with a 500 to 2000 line requirement.

- Positron Industries Inc., a leading supplier of 911 Emergency systems, recently was awarded a major contract to supply its equipment to Mexico.

- Cardi Inc., the major supplier of central office monitoring system (COMS) for Bell Canada, has licensed the Turkish Branch of Northern Telecom (NETAS) to manufacture and sell its system.

Private Switching

This segment constitutes 14% 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 is ranked 6th in the world in the PBX market and is the only telecommunications equipment manufacturer in the world to have sold more than 150,000 PBX systems. In 1990, Mitel provided the world's first Digital Private Network signalling system between British Telecom offices in London and New York.

- TSB International Inc. is the principal supplier of PBX interface hardware and software to the BT PBX Maintenance Program.

Wireless and Mobile Equipment and Systems

Mobile and wireless equipment represents about 17% of Canada's total production. Canadian production in this category has grown by over 30% annually since the mid-1980s. An estimated 65% of Canadian production is exported. 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, and was awarded a $5.6 million contract with Deutsche Bundespost TELEKOM to provide the first wireless data public network in Germany.

- Northern Telecom's dedicated wireless technology manufacturing facility produces digital cellular and advanced personal communications equipment.

- Ericsson GE Communications Inc. supplies cellular telephone equipment and is responsible for carrying out R&D on cellular networks. Ericsson has established an excellent design and technical support group in Montreal and supports all of its North American cellular switches from Montreal. In addition, it has design responsibility for a significant portion of Ericsson's worldwide cellular development.

The local environment has also encouraged the formation of many smaller organizations that are dedicated to serving niche markets:

- METOCEAN Data Systems Inc. is the world's largest manufacturer of drifting buoys and ARGOS transmitters.

- Cycomm International Inc. developed the first complete cellular voice privacy system, now regarded as the de facto standard by major cellular service providers.

- Telesystems SLW manufactures ARLAN, an advanced spread spectrum radio local area network which is already certified by the U.S. Federal Communications Commission and the Canadian Department of Communications for sale without a radio licence. It has recently released a wireless system that is fully compatible with existing Ethernet systems.

- Gandalf Mobile Systems, Inc. is the leading supplier of taxi data dispatch systems in the world with over 25 installations serving in excess of 10,000 mobile users.

- Dataradio Inc. was the first to introduce a 9600 baud radio modem for synchronous systems applications.

- Silcom Research Ltd. is a leading edge R&D company specializing in advanced wireless communications products for portable, mobile or fixed applications.

- Orcatron Manufacturing Ltd. is recognized as the world leader in underwater voice communications in terms of both clarity and range (up to 10 km).

Satellite Systems

Canada boasts the first nation-wide domestic satellite communications system and continues to excel in this advanced field. Canadian space policy has stimulated the development of world-class companies. Canadian suppliers in this sector have developed world-class reputations:

- Spar Aerospace is a major supplier of satellite systems having been project manager or prime contractor on more than 61 satellites, and having delivered turnkey earth stations for satellite communications to more than 30 countries. Spar is the prime contractor for the Canadian mobile satellite - MSAT and the remote sensing satellite - RADARSAT.

- COM DEV Ltd. has its multiplexers installed in 106 spacecraft. It supplies over 65% of the Western world's requirements for multiplexer and switching equipment for communications satellites. Recently, it signed an MOU with Motorola to collaborate on the initial definition of Ka-band subsystems for the worldwide personal communications Iridium satellite system. COM DEV will also supply on-board signal processors for ESA's European Mobile Satellite.

- Calian Technology Ltd. sold the world's first INMARSAT B&M ACSE system to BT.

- 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.

- NII Norsat International Inc. is the largest supplier of satellite signal amplifiers in North America.

- Ultimateast Data Communications is a designer, manufacturer and distributor of communications products for use in satellite, mobile, marine and aeronautical systems.

Data Communications Equipment

This category represents about 9% of Canadian production and has consistently grown at a rate of over 10% over the past 10 years. The rapidly evolving nature of this equipment category has enabled several innovative companies to capture markets through the excellence of their products:

- Gandalf Technologies Inc. manufactures a broad range of information networking products, systems and services. For example, it supplied the first true hybrid networking system to connect all users and resources in multi-vendor environments, the Starmaster intelligent network processor.

- Develcon Electronics Ltd., chosen to install NASA's Kennedy Space Center network to carry all of the Center's data for about 10,000 users, is a leading Canadian supplier of LAN internetworking, data communications, and ISDN equipment.

- EDA Instruments Inc. has installed major data communications networks for the U.S. Internal Revenue Service and for the U.S. General Services Administration.

- Microplex Systems Ltd. developed the industry's fastest TCP/IP print server.

- Mux Lab, the first company to develop a powered star-wiring panel for IBM System 3X and As/400 via unshielded twisted pair cable, has recently introduced a premises wiring management system for managing wiring of large networks with hubs, terminal servers, gateways, and routers. This system is now controlling a major Japanese construction firm's LAN cabling network across 13 cities in Japan.

- TIL Systems Limited is a major supplier of end-user hardware and software to the stock exchanges in Paris, Brussels, Madrid and Toronto. TIL has installed more than 10,000 devices at county offices of the U.S. Department of Agriculture.

Transmission Equipment

The total production in this segment constitutes approximately 6% of the total. The prominent company in the field is Northern Telecom which has the capability of supplying a broad range of transmission equipment. However, several other companies provide world-class products:

- Newbridge Networks Corporation which has a strong world presence in the design and manufacture of universal voice and data multiplexers for the digital trunk market, has recently formed alliances with MPR Teltech of Burnaby, B.C. and Advanced Computer Communications of Cupertino, California to develop and manufacture ATM networking products.

- Norpak Corporation is the co-developer and recognized leader for both the North American Basic Teletext Standard (NABTS) for inserting data into unused bandwidths of a television signal; and the North American Presentation Level Protocol Syntax (NAPLPS), the emerging standard for bandwidth efficient graphics.

- SR Telecom Inc., a pioneer and world-leading manufacturer of subscriber radio systems, has recently entered into licensing agreements with manufacturers in Greece and India. SR Telecom's systems are now used in 68 countries.

- Bayly Communications Inc. is a major supplier of digital multiplex equipment to the Rogers Cantel cellular communications network.

- Positron Industries Inc. has contracts with all the major regional telephone companies in North America.

Cable Equipment

This category comprises about 9% of Canadian production and is growing at an annual rate of approximately 9%.

- 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.

- MPB Technologies Inc. won a major international contract to develop the world's first undersea branching multiplexers, to be put into operation in the optical fibre Trans Atlantic Telecommunications System.

- Opto-Electronics Inc. is a major supplier throughout the world of high-speed fibre optic test and measurement instrumentation.

Customer Premises Equipment (CPE)

While Northern Telecom and Mitel dominate this cost competitive sector, several other companies have active positions in Canada and abroad:

- 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. DBA's SmarTalk product became the first telephone system offered in the U.K. that does not require Preconnection Inspection Service by BT.

- Dees Communications Engineering Ltd. is a recognized leader in Meridian Digital Centrex enhancement. Dees recently signed a multi-million dollar agreement with Motorola to develop six new products to enhance Motorola's secure telephone terminals.

- Computer Talk Technology Inc. is the leading supplier of interactive voice response systems in Canada, with a 41% market share. Its talking computers are used for a variety of applications including home banking by telephone, credit card authorization, and telephone licence shopping.

- EyeTel Communications Inc. is a world leader in the development of videophones and desktop video equipment.

Related Microelectronics Equipment and Software

The Canadian advanced communications industry is supported by a strong microelectronics industry, an industry which produced $1.3 billion in related components. This sector is comprised of over 60 companies involved in the design and manufacturing of semiconductor devices, optoelectronic components and electronic ceramics. The Canadian market is in excess of $2.5 billion which when combined with the high niche-orientation of many of the Canadian companies, creates ample opportunities for business expansion into Canada.

- MPR Teltech Ltd. is Western Canada's largest high technology research and development company providing a full range of R&D and systems integration services to the advanced communications industries in Canada and world wide. A subsidiary of B.C. Tel, MPR employs more than 500 experts in a wide range of telecommunications and related electronics and computer technologies.

- Gennum Corporation designs, manufactures and markets electronic components including cross-point switches for use in switching and routing of video signals. Gennum equipment was used to switch the television signals at the 1992 Barcelona Olympic Games.

- International Epitek Inc. is a leading designer and manufacturer of custom thick film hybrid circuits, and surface mount assemblies for customers producing telecommunications products.

- Opto-Electronics Incorporated is the original manufacturer of the world's fastest photodetector and diode laser light sources.

- Les Industries CMAC Inc., which has become Canada's largest contract manufacturer in only five years, recently acquired two submarine systems plants in the U.K. from Northern Telecom. The company specializes in hybrid microcircuits and backpanels.

- MPB Technologies is developing the world's first undersea branching multiplexers to be used in the optical fibre Trans Atlantic Telecommunications System.

- Optotek Ltd. has strong capabilities in the design and processing of advanced optoelectronic semiconductors.

- PPM Photomask Inc. provides a one-stop, fast turnaround prototype wafer foundry service in thin film and integrated optics devices.

Like its telecommunications industry, Canada's multi-billion dollar microelectronics industry is recognized as being of world-class calibre. Over the years, the communications industry has served as the catalyst for the microelectronics sector. The presence of Bell Northern Research and other research labs created the critical mass for the first generation of semiconductor and silicon companies. Today, this competence is well distributed across the country due to the achievement by Canadian-based firms of prominent positions in several niche markets. Over 70% of the industry's manufactured production not destined for domestic use in communications equipment is exported to the United States, Europe, and Japan. Virtually all the industry's major players, including IBM, General Electric, NCR, Hewlett-Packard, Philips, and Control Data, have manufacturing and R&D facilities in Canada.

2.4 Key Support Industries

Canadian companies, research institutes and universities have world-class technologies and technical expertise to complement the advanced communications industry. Key areas of support include software and systems integration as well as advanced industrial materials.

Software and Systems Integration

Information processing and systems integration are the backbone of a growing telecommunications industry. In addition to traditional applications like central switches and PBXs, new applications of knowledge-based systems are expected to proliferate in the coming years. Software is also a key area in the development of robotics.

The Canadian informatics and software industry is one of the fastest growing in the economy. The industry consists of approximately 5,600 firms which employ 35,000 people. Although highly successful software producers can be found in every province, they are concentrated in Ontario, Quebec, Alberta, and British Columbia. Canada's strengths lie in the development of specialized software applications and customized software.

Systems integrators now play a key role in the advanced communications area, particularly in data communications. Systems integrators range from large companies such as MPR Teltech to small companies that are application-specific.

Advanced Industrial Materials

The applications of advanced industrial materials to the advanced communications industry are far reaching.

Canadian industry consists of a wide range of firms dedicated to the production of functional and structural advanced materials. There are over 50 manufacturers in Canada in the area of advanced ceramics alone. These range from IBM, which produces hybrid ceramics circuits, to Hamilton Porcelain, which produces ceramic parts made of alumina, zirconia, and boron nitride powders. The fuel for Canada's materials industry is its huge and largely untapped mineral resources used in advanced composites.

2.5 The North American Free Trade Agreement (NAFTA)

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. In addition, 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.

Under the North American Free Trade Agreement (NAFTA) which will come into effect January 1, 1994 at the earliest, the free trade zone will include Mexico. Under NAFTA, all duties on information technology products will be eliminated on trade within North America, allowing such goods to flow freely within the continent. As well, there will be an immediate elimination of tariffs on most telecommunications equipment, and Mexican trade barriers on enhanced telecommunications services will be eliminated in July, 1995.

3.0 RESEARCH AND DEVELOPMENT

3.1 Industrial Research and Development

The Canadian advanced communications industry is the major performer of industrial R&D in Canada. It accounts for approximately 17% of total Canadian industrial R&D. In 1989, the worldwide R&D expenditures for 12 of the publicly traded companies in the industry was $1.1 billion, or 13% of revenues. The R&D expenditures of privately held companies generally ranged from 10% to 20% of revenues.[3]

Bell-Northern Research (BNR) is the largest Canadian-based industrial research and development organization, with worldwide employment of 7,800, of which 4,900 are located in Canada, and the remainder are in the U.S. and the U.K. BNR's R&D budget was $612 million in 1990 compared to $576 million in 1989. BNR is 70% owned by Northern Telecom and 30% owned by Bell Canada. Almost all its R&D is done on behalf of its two parents.

MPR Teltech, with annual revenues of about $50 million and 500 employees is the largest telecommunications-related contract research and development organization in Canada, and has the largest industrial R&D capability in Western Canada. It recently signed a technology transfer agreement with a Korean company and more recently has entered into a strategic partnership with Newbridge Networks to commercialize its ATM technology. MPR Teltech is actively pursuing strategic alliances with high-tech research and development organizations around the world.

Canada has developed an extensive public research infrastructure to support its advanced communications and microelectronics industrial activities.

3.2 University and Government Research

There are 31 Canadian universities and colleges that conduct research in advanced communications, related software and microelectronics research. Some of the key research topics and areas of expertise include:

- underwater acoustic communications;
- high speed protocol processing;
- wireless personal communications;
- optical switching, transmission and related materials;

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[3] Source: A Proposal towards a Strategic Plan for the Canadian Telecommunications Industry, NGL Consulting Ltd., Page 31.

- digital subscriber access;
- intelligent buildings;
- high-speed VLSI circuits;
- broadband communication;
- voice recognition;
- microwave signal processing;
- advanced personal satellite communications systems; and
- multi-media distributed database systems.

As shown below, Canadian universities and community colleges graduate over 25,000 engineers, computer scientists, and technicians each year. Many of these new graduates go directly into the labour force; others continue at university, participating in leading edge research.

University Graduates, 1990		
Discipline	B.Sc./B.Eng.	M.Sc./M.Eng./Ph.D.
Computer Science	2,194	394
Mathematics	2,064	325
Civil Engineering	949	328
Electrical Engineering	1,902	515
Mechanical Engineering	1,826	261
Other Engineering	2,379	695
Total	11,314	2,518
Community College Technical Graduates, 1990		
Discipline		
Computer Science and Mathematics	2,997	
Electrical/Electronic Technologies	2,909	
Engineering Technologies	4,830	
Chemical Technologies	635	
Transportation Technologies	246	
Total	11,617	

Source: Statistics Canada: 1990-1991

Exhibit 3-1 provides a general overview of advanced communications research areas currently being studied in each of these institutions. A detailed list of topics is presented in Appendix A. In addition, Exhibit 3-2 lists the universities in Canada that have established Industrial Research Chairs.

In recent years a number of researchers have organized themselves around government supported "Centres of Excellence" programs and created R&D alliances among universities and with industrial and government researchers. Exhibit 3-3 lists the Canadian university Centres of Excellence in advanced communications and related microelectronics.

Similarly, Exhibit 3-4 presents the key university/industry/government R&D alliances associated with advanced communications and related microelectronic technologies.

In addition, research is carried out in various government research laboratories (see Exhibit 3-5). Research is being undertaken 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 industry to compete effectively during the coming decade.

Exhibit 3-1
Advanced Communications Research at Canadian Universities and Colleges

Organization	Switching	Transmission & Data Communications	Cable	Satellite Communications	CPE	Wireless & Mobile	Microelectronics
Victoria	X	X				X	X
British Columbia	X	X				X	X
Simon Fraser		X	X			X	X
Alberta	X	X	X		X	X	X
Calgary	X				X	X	X
Saskatchewan		X				X	X
Regina		X			X		
Manitoba		X				X	
Lakehead						X	
Windsor	X	X					X
Western		X				X	X
Guelph					X		X
Waterloo	X	X	X		X	X	X
McMaster	X	X	X		X	X	X
Toronto	X	X	X	X	X	X	X
Ryerson	X	X					
Queen's	X	X	X	X		X	X
Carleton	X	X		X	X	X	X
Ottawa	X	X		X	X	X	
Québec (Hull)		X	X				
INRS	X	X			X		X
Polytechnique	X	X	X			X	X
Montréal		X				X	
Concordia	X	X				X	X
McGill	X	X	X	X			X
Sherbrooke		X					X
Laval		X	X			X	X
New Brunswick					X	X	
Nova Scotia	X	X		X			X
Dalhousie	X	X					
Memorial		X				X	

Exhibit 3-2
Industrial Research Chairs at Canadian Universities Associated with Advanced Communications and Related Microelectronics

Subsector	University	Location	IRC Description
Mobile and Wireless	Victoria	Victoria, BC	Radio Frequency Engineering
	McMaster	Hamilton, Ont.	Microwave Signal Processing
Data Communications	Ottawa	Ottawa, Ont.	Real-Time Multimedia Distributed Database Systems
	Montréal	Montréal, Québec	Communications Protocols
	McGill	Montréal, Québec	Digital Systems Design
Transmission	Alberta	Edmonton, Alta.	Fibre-Optic Communications
	McGill	Montréal, Québec	Photonic Systems
	Laval	Laval, Québec	Optical Communications
Related Microelectronics	Simon Fraser	Burnaby, B.C.	Optical Properties & Characterization of Electronic & Optoelectronic Materials
	Western	London, Ont.	Surface and Material Science
	Waterloo	Waterloo, Ont.	VLSI
	McMaster	Hamilton, Ont.	Optoelectronics and Microelectronic Devices
	Toronto	Toronto, Ont.	Electromagnetics & Optoelectronics
	Carleton	Ottawa, Ont.	High-Speed Integrated Circuits

Source: Research Partnership Program, Industrial Research Chairs, Natural Sciences and Engineering Research Council (NSERC), January, 1993.

Exhibit 3-3
University Centres of Excellence in Advanced Communications

PROGRAM	AREAS OF RESEARCH
Institute for Telecommunications Research (Montreal, Que.)	Broadband and wireless communications
Microelectronic Devices, Circuits and Systems for Ultra Large Scale Integration (Micronet) (Toronto, Ont.)	Next generation of microelectronic systems
Telecommunications Research Institute of Ontario (TRIO) (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
Ontario Laser and Lightwave Research Centre (Toronto, Ont.)	Laser spectroscopy, lightwave engineering and non-linear optics
Information Technology Research Centre (Toronto, Ont.)	Artificial intelligence, microelectronics, communications mathematics, software and graphics
Ontario Centre for Materials Research (Kingston, Ont.)	Composites and new materials, optoelectronics
Manufacturing Research Corporation of Ontario (Oakville, Ont.)	Next generation of computer-aided manufacturing systems

Source: Technology Transfer Services, Services to Business Branch, Industry, Science and Technology Canada.

Exhibit 3-4
Advanced Communications and Related Microelectronics
University/Industry/Government R&D Alliances

ALLIANCE	DESCRIPTION
National Wireless Communications Research Foundation (Vancouver, B.C.)	Provides equipment and services in support of wireless communications research and development
B.C. Advanced Systems Institute (Burnaby, B.C.)	Supports collaborative research among British Columbia universities and industry in advanced systems disciplines, such as artificial intelligence, robotics, computer science, telecommunications and microelectronics
Telecommunications Research Laboratories (TR Labs) (Edmonton and Calgary, Alta; Saskatoon, Sask.)	Research in Networks and Systems, Photonics, Wireless Communications, and Network Access
Canadian Microelectronics Corporation (Kingston, Ont.)	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, TR Labs, MPR and GE. Undertakes precompetitive research on the monolithic integration of electronic and photonic devices
Strategic Microelectronics Consortium (SMC) (Kanata, Ontario)	Research and technical collaboration in device packaging, and application technologies. Specific areas include VLSI, wireless communications, testing and quality control
Canadian Semiconductor Design Association (Kanata, Ont.)	Mandate to improve the competitiveness of Canada's microelectronics industry. Program co-ordinator for a consortium of Ontario universities, microelectronics companies and the Canadian Microelectronics Consortium
Canadian Centre for Marine Communications (CCMC) (St. John's, Nfld.)	Supports research and development of new marine communications equipment, systems and services

Source: NGL Consulting Ltd.

Exhibit 3-5
Advanced Communications-Related
Government Laboratories and Organizations

LABORATORY/ORGANIZATION	DESCRIPTION
Communications Research Centre, Department of Communications (Ottawa, Ont.)	Research in communications technologies, communications devices and components, and broadcasting technologies
Canadian Workplace Automation Research Centre, Department of Communications (Laval, Qué.)	Devoted to R&D in office automation
National Optics Institute (Ste. Foy, Qué.)	Areas of research include the design and fabrication of optical systems, optoelectronics in the visible and infrared ranges, and image analysis and vision systems
Institute for Microstructural Sciences, National Research Council (Ottawa, Ont.)	Collaborative development with industry of optoelectronic integrated circuits and work on quantum effect structures and devices, silicon-germanium superlattices and devices and infrared sensitive materials
Alberta Research Council (Edmonton, Alta.)	Capabilities for evaluating materials for electronics and telecommunications
Centre de Recherche Industrielle du Québec (Ste. Foy, Qué.)	Telecommunications-related research in signal processing for video, television and teledistribution, voice compression and noise correction.

Source: NGL Consulting Ltd.

3.3 Government Technology Development Programs and Tax Incentives

Canadian companies may 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. At present, Canada's federal tax incentives for R&D include full deductibility of current expenses, as well as a 20% investment tax credit. These federal incentives, combined with significant provincial R&D incentives, make Canada's overall tax treatment of R&D among the most favourable in the Western world.

Key Government R&D Programs

There is a wide array of federal and provincial programs aimed at assisting high-technology companies in Canada with technology transfer, product development and export marketing. In addition, direct financial support through such mechanisms as loan guarantees and pre-venture capital investment (equity purchases) are also available. These programs are administered on a case-by-case basis and are valued in the billions of dollars. Examples of some of these programs are listed below. Direct financing is provided through various mechanisms, most notably through provincially sponsored venture funding initiatives such as l'Agence québécoise de valorisation industrielle de la recherche (Québec), the Innovation Ontario Corporation (Ontario), the Alberta Opportunity Company (Alberta), and Discovery Enterprises Inc. (British Columbia). Other financial assistance programs for technology development are also provided by the provincial governments.

- The Industrial Research Assistance Program (IRAP) is a National Research Council (NRC) initiative that provides technical assistance to companies through a national technology network of over 200 field officers across Canada. This program provides facilities, equipment, technologists and funding for collaborative research projects with government, university or foreign laboratories, and companies located in Canada. The objective is to offer industry the means to commercialize the latest technical knowledge, inventions and scientific knowhow.

- The Strategic Technologies Program (STP) is offered by Industry, Science and Technology Canada (ISTC) and provides financial support for R&D and technology application alliances in advanced industrial materials and information technologies. Industry-led alliances can involve universities and research institutes. R&D projects must be pre-competitive and application projects must be pre-commercial.

- The Microelectronics and Systems Development Program (MSDP) is an ISTC initiative, which offers interest-free loans designed to encourage companies located in Canada to undertake technologically innovative ventures in microelectronics and information technologies systems that will enhance the international competitiveness of Canadian manufacturing, processing or service industries.

- The Program for Export Marketing Development (PEMD) is an External Affairs and International Trade Canada (EAITC) initiative, which offers financial support to Canadian firms for the development and expansion of product markets abroad.

- The Defence Industry Productivity Program (DIPP) offered by ISTC, is designed to develop and maintain strong defence-related industries across Canada that are capable of competing successfully over the long term in domestic and export markets. Contributions are extended towards the eligible costs of R&D, establishment of Canadian suppliers, capital assistance, and market feasibility studies.

- The Defence Industry Research Program (DIRP) provides financial assistance to promote and improve the research and technological capability of the Canadian defence industry, widen the industrial base, and promote and assist strategic industries.

- The Atlantic Canada Opportunities Agency (ACOA) Action Program offers seven main areas of assistance adapted to the special needs of Atlantic Canada. These areas are: loan insurance; interest buy-downs; business support; studies; innovation assistance; new facility establishment; and new product expansion.

- The Western Economic Diversification (WED) Program offers a variety of support mechanisms, ranging from small business assistance to large, systematic industry-wide programs. The Western Economic Diversification Program is targeted towards projects that involve new products, new markets and new technologies, including import replacements and industry-wide productivity enhancements.

Taxation

The Canadian corporate taxation system is highly competitive, providing specific advantages for companies with manufacturing or R&D activities in Canada. Tax in Canada is collected at both the federal and provincial levels. The federal government administers and collects provincial tax for all provinces except Alberta, Ontario, and Quebec. These three provinces generally follow federal corporate income tax legislation in defining taxable income.

The federal budget tabled on February 25, 1992 reduced the overall corporate tax rate for manufacturing and processing firms to 22% effective January 1, 1993 and to 21% effective January 1, 1994. Several recent provincial budgets have emulated the federal initiative by reducing tax rates for small business, as well as corporate tax rates.

This proposed federal corporate rate of 21%, coupled with an average provincial manufacturing and processing tax of 13% offers an average combined tax rate of 34%.

As illustrated in Exhibit 3-6, this compares very favourably to the average corporate taxation rates in the United States and other countries.[4]

In a concerted effort to further improve Canada's international competitive position, the government recently introduced a number of other changes affecting business taxation. The **capital cost allowance rate** for manufacturing and processing machinery acquired after February 25, 1992 was increased from 25% to 30%. At the same time, the government announced that it is prepared to negotiate reciprocal tax treaties with its trading partners to reduce the **withholding tax rate** on direct dividends to 5%.

Exhibit 3-6: Combined Corporate Manufacturing Income Tax Rates

Country/City	Combined Tax Rate (%)
Canada	**34 (Average)**
U.S.	
- California	40.1
- Illinois	37.2
- Michigan	35.5
- New York	40.3
- Pennsylvania	46.2
	39.6
France	
- Paris	42.0
Italy	
- Milan	47.8
U.K.	
- London	33.0
Japan	
- Tokyo	51.6
Germany	
- Dusseldorf	51.8

Source: Industry, Science and Technology Canada, Oct. 1992 and Samson, Belaire/Deloitte & Touche Tohmatsu International.

[4] Source: The Budget Papers, Department of Finance, February 25, 1992, Industry, Science and Technology Canada and Samson, Belaire/Deloitte & Touche Tohmatsu International, Oct., 1992.

Research and Development Tax Incentives

Canadian tax legislation is much more flexible and much more generous with respect to R&D tax incentives than tax legislation in most industrialized countries. This tax treatment makes Canada particularly attractive for large companies seeking to maximize their R&D investment.

The two main tax measures designed by many countries to encourage R&D activity are the **R&D expense deduction** and the **R&D tax credit.** Both the definition of research and development for R&D tax incentive purposes and the list of eligible expenses are fairly consistent across all OECD member nations.

Federal R&D Expense Deduction

R&D expenditures are generally separated into current expenditures, which include salaries of scientific and technical personnel and the cost of materials used, and capital expenditures, which include the cost of equipment and facilities. Although most countries allow current expenditures to be deducted from income in the year they are incurred, there are differences in the ability to write off capital expenditures for R&D purposes in the year they are incurred.

Other things being equal, the net-of-tax cost of R&D is lower in countries that allow immediate or accelerated write-off of facilities and equipment. Canada provides the large R&D performer with the option of immediate write-off of capital R&D expenditure or deferral for claim in a future year. A taxpayer in the U.S. can write off only the depreciated portion of the asset.

Federal R&D Tax Credit

In addition to the expense deduction, the federal government also allows a 20% **investment tax credit** on R&D expenditures. This tax credit may then be used to offset up to 75% of federal taxes payable. In addition, qualifying Canadian-controlled private corporations (CCPC's) are eligible for a 100% refundable tax credit on current expenditures at the rate of 35%. This further enhances Canada's position as an ideal destination for greenfield investment or for a Canada-based joint venture with Canadian partners. In addition, industry is now entitled to claim 65 cents on each dollar of direct R&D salary expenses when calculating intramural R&D overhead costs eligible for investment tax credits. Another recent change allows for a new partial investment tax credit for capital equipment shared by the corporate R&D group with other segments of the business including production and quality control operations.

The competitive federal R&D tax credit system in Canada is complemented by further tax credit incentives that exist in some provinces, especially Quebec, Ontario, Nova Scotia and Manitoba.

In addition to providing significant fiscal advantages, R&D tax treatment in Canada is highly stable. In addition, provincial governments have increased their participation in R&D tax credit programs by broadening the scope of their programs and by increasing their value to R&D performers.

As shown in Exhibit 3-7, reports by both the Conference Board of Canada and the Organization for Economic Cooperation and Development (OECD) have demonstrated the very competitive nature of Canada's R&D incentive programs in comparison with OECD nations.

Exhibit 3-7: International Comparison
After-Tax Cost of $1 R&D Expenditure

Country	After-Tax Cost
Canada	
Newfoundland	0.423
Nova Scotia	0.358
New Brunswick	0.430
Prince Edward Island	0.437
Québec	0.447
Ontario	0.461
Manitoba	0.477
Saskatchewan	0.494
Alberta	0.540
British Columbia	0.502
United States	
California	0.582
Illinois	0.628
Japan	0.494
Italy	0.554
United Kingdom	0.650

Source: Jacek Warda, *International Competitiveness of R&D Tax Incentives*, The Conference Board of Canada, May 1990.

R&D Leveraging

There is a high degree of industry/university interaction in the advanced communications area in Canada. Universities and research centres, in addition to producing a talented pool of scientists and engineers, are geared towards providing specific technical assistance to firms. Combine this expertise and willingness with the various matching programs and R&D tax credit incentives, and a company is well-positioned to strongly leverage its Canadian R&D spending. The value of every R&D dollar spent in a university by a private company in Canada can be equivalent to a real expenditure of six dollars.

The following provides an example of the benefits of Canadian R&D spending:

Company expenditure	$100,000
Government matching	$100,000
University contribution	$100,000
Total Budget	**$300,000**

The university contribution is assumed to include researcher and graduate student time, facilities, equipment, and materials. Conservative estimates provided by the University of Montréal and the University of Ottawa indicate that a university contribution is equivalent to one-half the combined monetary contribution of both the private sector and government.

In Canada, the after-tax cost of the $100,000 of R&D expenditure would be about $45,000. **Thus, a private corporation working jointly with a university need only spend $45,000 in order to obtain an R&D budget equivalent to $300,000.** This level of leveraging is found in all of Canada's provinces.

4.0 CASE HISTORIES

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

4.1 Newbridge Networks Corporation

Newbridge Networks Corporation of 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, $122 million and $149 million for the fiscal years 1987, 1988, 1989, 1990 and 1991, respectively. 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. 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.

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.

Du Pont was considering utilizing Newbridge products in its own corporate communications network when it was discovered that opportunities existed between them for co-operative research and development. One such area was automotive multiplexing. Du Pont is a leading supplier 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 co-operative agreement was entered into, calling for the companies to evaluate research areas of mutual interest.

Newbridge has benefited significantly from du Pont's investment and strategic relationship. It received investment during its formative growth period which it utilized for continued R&D activities and to expand operations. Du Pont is now an important user of Newbridge communications products. 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. The opportunities for co-operative R&D 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.

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

4.2 Norlite Technologies Inc.

Norlite Technologies Inc. of 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.

SCI Systems, Inc. of Huntsville, Alabama is a public company that specializes in the contract manufacturing business, and supplies electronic components to major computer and telecommunications suppliers throughout the world. 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 people. SCI's largest customers in past years have included IBM Corporation, Seagate Technology Inc. and Apple Computer. In 1990, sales for the first time exceeded US$1 billion.

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." In 1987, SCI entered into the strategic partnership with Norlite's executives.

Norlite today employs 17 people, 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. 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 will ultimately be responsible for manufacturing.

SCI agrees 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 co-operative 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 SCI's size, understanding of the product development cycle, and knowledge of high-quality volume, low-cost manufacturing.

4.3 JDS FITEL Inc.

JDS FITEL Inc. of Nepean, Ontario manufactures passive fibre-optic components and fibre-optic test instruments for the telecommunications industry. The company enjoys an excellent reputation throughout the industry for the quality and reliability of its products, as well as for the high level of service provided to its customers. JDS FITEL Inc. employs 110 full-time staff and has a sales volume in the range of $10 to $30 million.

The Furukawa Electric Co., Ltd. of Tokyo, Japan is one of the world's leading manufacturers of electric wire and cable, nonferrous metals and related products, and had revenues in 1990 of approximately $5 billion. The company is a major manufacturer

of optical-fibre cables. Furukawa Electric has 28 subsidiaries and affiliates abroad and is working to create a comprehensive worldwide production and information network.

In 1990, JDS Optics, which was founded in 1981, and Furukawa Electric entered into a strategic partnership, forming JDS FITEL Inc. According to Dr. Joseph Straus, JDS's Vice-President of Sales and Marketing, "This co-operative arrangement will allow JDS FITEL to capitalize on the manufacturing capability of Furukawa for the manufacturing of components for the fibre-to-the-home market in the future, as well as providing JDS with access to technologies that are beyond the means of small companies." Mr. Hidehisa Miyazawa of Furukawa Electric, who joined JDS FITEL when the partnership was formed as Vice-President, FITEL Products, stated that "I was very impressed by the high level of technology of JDS. The JDS people are excellent and have many ideas for new products."

At the same time, the alliance will benefit both parties from their joint marketing activities in different parts of the globe. Mr. Miyazawa is now working on introducing JDS products into the Japanese market through Furukawa, and JDS is marketing some of Furukawa's products in North America and Europe. The alliance grew from a long-standing personal contact, first made over 10 years ago between key staff of Furukawa Electric and JDS Optics. Based on the positive experiences to date since the partnership was formed one year ago, it appears that the future prospects for this partnership are very promising.

4.4 Telesat Mobile Inc.

Telesat Mobile Inc. (TMI) was incorporated in 1988 to construct and operate Canada's first commercial mobile satellite communications system, providing Canadians with mobile voice and data communications services to land, marine and aeronautical terminals throughout North America including coastal waters. In the spring of 1990, TMI launched its initial service offerings, designed to meet the needs of specific industry applications and to provide full two-way digital messaging, automatic vehicle location and fleet management services for Canadian users throughout North America.

TMI's major shareholders include Telesat Canada and Unitel Communications Holdings. A consortium led by C. Itoh and Co., Ltd. has invested $20 million in TMI for a 20% ownership. C. Itoh, the largest Japanese trading company with an annual turnover in excess of $100 billion, also has other interests in satellite communications through JCSAT. The other members of the consortium are the Long Term Credit Bank of Japan, the Nippon Credit Bank, Nippon Yusen Kabushiki Kaisha, Passengers' Service Co. Ltd., Seino Transportation and Co. Ltd., Matsushita Communication Industrial Co. Ltd. and Cable and Wireless plc.

At the announcement of the formation of TMI, Mr. Eldon Thompson, former President and Chief Executive Officer of Telesat, said, "The birth of TMI is the beginning of a new age in mobile communications." Mr. Koya Mita, Director and General Manager of C. Itoh and Co., Ltd., said, "For the first time in history, Canada and Japan will co-operate in the field of telecommunications services. It is a great honour to be able to participate in this significant partnership. Together with the other members of the Japanese Group we hope to contribute to the success of TMI."

APPENDIX A

UNIVERSITY RESEARCH IN ADVANCED COMMUNICATIONS AND RELATED MICROELECTRONICS

UNIVERSITY RESEARCH

Research in advanced communications and related microelectronics is carried out at 31 universities and colleges across Canada. These organizations are listed below, along with an illustrative listing of their principal research areas.

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

Research Topics:

- Wireless communications
- Personal wireless communications
- Underwater acoustic communication navigation and sensing
- Digital filters and array aperture functions
- Analysis, design and implementation of digital filters
- Network reliability
- Microwave and millimetre-wave component design
- Linearization of optical transmitters and their application in direct detection and heterodyne.

Research Chair:

- Industrial Research Chair in Radio Frequency Engineering

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

Research Topics:

- Wireless personal communications systems
- Digital communication over mobile radio fading channels
- Coding/decoding for mobile communications
- Applied diffraction theory and antennas
- OSI protocol test suite engineering
- High speed protocol processing
- Testability and management of communications software
- Parallel processing
- Digital communication systems
- Object-oriented distributed systems and communications
- Automatic monitoring of cable television signals
- Integrated electro-optic modulators and lasers in gallium arsenide
- Film cooling of turbine blades

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

Research Topics:

- Channel coding and modulation for digital mobile communications
- Information dissemination in communication networks
- Distributed systems
- Speech coding for telecommunications
- Optical properties of electronic and optoelectronic materials

Research Chair:

- Industrial Research Chair in Optical Properties and Characterization of Electronic and Optoelectronic Materials

4. University of Alberta (Edmonton, Alberta)

Research Topics:

- Modulation techniques for digital cellular radio
- Advanced transmission techniques for digital subscriber access
- Local and metropolitan area protocol design
- High speed communication networks
- Integrated optoelectronic switch
- Advanced optical fibre communications and signal processing
- Optical fibre communications systems
- Optical waveguides on silicon
- Ohmic contacts to III-V semiconductors

Research Chairs:

- NSERC/Bell-Northern Research/Telecommunications Research Labs Industrial Research Chair in Fibre-Optic Communications

5. **University of Calgary (Calgary, Alberta)**

Research Topics:

- Cellular radio communications
- Adaptive two-stage likelihood estimation for cellular radio
- Indoor radio communications
- Local area network protocols
- Multidimensional processing and telecommunications
- Applied electro-magnetic theory and measurements
- Airborne vector gravimetry and horizontal gradiometry

6. **University of Saskatchewan (Saskatoon, Saskatchewan)**

Research Topics:

- Mobile radio modulation techniques
- Digital transmission and synchronization
- Photoconductor films
- Properties of amorphous As-Se-Tc photoconductor films

7. **University of Regina (Regina, Saskatchewan)**

Research Topics:

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

8. **University of Manitoba (Winnipeg, Manitoba)**

Research Topics:

- Integrated antennas
- Numerical and experimental antenna impedance matching studies
- Transmission line analysis

9. **Lakehead University (Thunder Bay, Ontario)**

Research Topics:

- Hand-off control for microcellular communication system
- Adaptive forward error control coding for land mobile radio systems

10. University of Windsor (Windsor, Ontario)

Research Topics:

- Artificial neural networks
- High-speed VLSI architectures for digital signal processing

11. University of Western Ontario (London, Ontario)

Research Topics:

- Radio-wave propagation
- Techniques for generation and detection of optical signals
- Diamond film R&D

Research Chair:

- Industrial Research Chair in Surface and Material Science

12. University of Guelph (Guelph, Ontario)

Research Topics:

- Local area networks and VLSI design methodology
- Automatic modular synthesis of VLSI systems

13. University of Waterloo (Waterloo, Ontario)

Research Topics:

- Thin wire antenna systems
- Waveguide dipole antennae, prolate spheroidal antennae and scatterers
- Coded communication systems
- Local area network design & development
- Entropy coding for text, audio, and image sources
- Statistical model building and applications to automatic speech recognition
- Communications circuits, speech processing
- Window-based application sharing for computer supported cooperative work
- Integrated services computer communications networks
- Computer communication systems
- Image processing
- Network topologies

- Broadband communications
- Design and analysis of optoelectromagnetic couplers/multiplexer/switches
- Guided-wave modelling
- Guided-wave optoelectronic fibre optical devices
- VLSI device theory, design, modelling and computer simulations of modern semiconductor devices, including their applications to VLSI circuits and systems on chips

Research Chair:

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

14. McMaster University (Hamilton, Ontario)

Research Topics:

- Array antennas: microstrip and digital
- Integrated microstrip phased array antennas
- Radar detection of small targets in an ocean environment
- Robust array signal processing
- Hands-free telephone
- Digital signal processing applied to communications
- Concurrent and distributed computing system
- Ultra-high-speed optical networks
- Photodetectors for optoelectronic integrated circuits
- Optical waveguide devices and optoelectronic integration
- High frequency circuits
- High-speed sampling of electrical signals

Research Chairs:

- Bell-Northern Research/NSERC Industrial Research Chair in Optoelectronics and Microelectronic Devices and Materials
- Industrial Research Chair in Microwave Signal Processing

15. University of Toronto (Toronto, Ontario)

Research Topics:

- Spread spectrum packet radio networks
- Electromagnetics and antennas with space applications
- Space robotics and control
- Local and metropolitan area networks
- Digital communication and signal processing
- Digital signal/image processing
- Source and channel coding for efficient information transmission
- Polyspectra techniques in digital communications
- Digital system architecture and design
- BISDN performance models
- Photonics science and technology
- Ultrafast optics and photonics
- High-speed integrated circuit design
- VLSI architecture for digital communications
- BiCMOS compatible high-voltage devices and circuits
- Tritium pumped solid state light emitters
- Photoconductive properties of polycrystalline Cdse

Research Chairs:

- NSERC/Bell Canada Industrial Research Chair in Electromagnetics
- NSERC/Bell-Northern Research Chair in Optoelectronics

16. Ryerson Polytechnical (Toronto, Ontario)

- Digital audio signals
- Traffic control in BISDN

17. Queen's University (Kingston, Ontario)

Research Topics:

- Microcellular low-power digital communications techniques
- Continuous phase frequency shift keyed lightwave systems
- Secure private-key encryption algorithms
- Computer communications
- Interconnection networks and multi-computer architectures
- Digital communication signals and systems
- High-rate data communications

- Coherent optical receiver
- Fast wavelength switched, optically amplified coherent lightwave systems
- Continuous phase modulation for on-board processing based future communications satellites
- Ultra-high capacity lightwave systems
- Semiconductor light sources and modulators
- Lightguide modelling
- High-speed CMOS circuits

18. Carleton University (Ottawa, Ontario)

Research Topics:

- Wireless indoor communications
- Digital radio interference reduction
- Noise cancellation
- Mobile and portable radio networks
- Ubiquitous communication systems
- Universal, secure and efficient telecommunication systems (USETS)
- Adaptive digital communications techniques for wireless and wireline channels
- Satellite communications frequency hop systems
- Digital image processing
- Network reliability
- Distributed computing
- Mixed analog and digital circuits for communications
- Validation-directed communications software engineering
- Object oriented design of real-time systems
- Wide Area Network Diagnostician (WAND)
- Fault management in communication networks
- BISDN - ATM networks
- Knowledge based techniques in communication network & software maintenance
- Monolithic Silicon Component VLSI in communication
- High-speed integrated circuits
- Design tools for VLSI

Research Chairs:

- Industrial Research Chair in High-Speed Integrated Circuits
- Industrial Research Chair in Computer-aided Engineering

Relevant Information:

- Together with the University of Ottawa, formed the Ottawa-Carleton Centre for Communications Research

19. University of Ottawa (Ottawa, Ontario)

Research Topics:

- Spread-spectrum optical local area networks
- Radio communications
- Mobile satellite systems interference
- EHF personal satellite communications
- Metropolitan area networks
- Image coding using vector quantization
- Multi-resolution video/image sequence coding
- Digital signal processing & applications in communications
- Multimedia distributed database systems
- Data communications
- Testability-directed formal specifications and designs of communicating processes

Research Chair:

- Industrial Research Chair in Real-Time Multimedia Distributed Database Systems

Relevant Information:

- Together with Carleton University, formed the Ottawa-Carleton Centre for Communications Research

20. Université du Québec à Hull (Hull, Québec)

Research Topics;

- Communication protocols
- Data communications (protocol design and validation)
- Fault tolerant distributed systems
- Fibre optics

21. Institut national de la recherche scientifique INRS - Télécommunications (Verdun, Québec)

Research Topics:

- Continuous speech recognition
- Computer vision for telecommunications
- Telecommunication network control
- Traffic engineering of ISDN networks
- Distributed algorithms for telecommunications networks
- Broadband networks
- Optimization processes for X-ray mask fabrication

Relevant Information:

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

22. Ecole Polytechnique de Montréal (Montréal, Québec)

Research Topics:

- Microwave technology
- ISDN error control
- All-optical integrated-optics switches for communications and signal processing
- Fibre optic communications
- Integrated optic amplifier/power divider/demultiplexer
- Microwave and optic electronic integrated circuits
- Electrical characteristics of CMOS
- Heterojunction electrical and photonic devices
- VLSI circuits

23. Université de Montréal (Montréal, Québec)

Research Topics:

- Transportation and telecommunications

Research Chair:

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

24. Concordia University (Montréal, Québec)

Research Topics:

- Spread spectrum networks
- Digital wireless communications systems
- Broadband underwater acoustic channels
- Analog and digital electronic networks
- Transfer protocols for distributed systems
- Interconnection network models
- Broadband ISDN with implementations in neural networks
- Broadband networks
- VLSI and multiprocessor signal and image processing
- VLSI and communications network design
- Parallel algorithms for VLSI layout

25. McGill University (Montréal, Québec)

Research Topics:

- Dynamics and control of tethered satellites
- Dynamics and control of satellite spacecraft
- Robotic systems in space
- Speech and image coding for noisy channels
- Digital coding of speech
- Transmission and telecommunications networks
- Switching and interconnection network design
- Fibre optic communications and sensors optical waveguides and devices

Research Chairs:

- Northern Telecom/NSERC Industrial Research Chair in Digital Systems Design
- Industrial Research Chair in Robotics
- Industrial Research Chair in Photonic Systems

26. Université de Sherbrooke (Sherbrooke, Québec)

Research Topics:

- Digital communication system through power carriers
- Semiconductor III-V research

27. Université Laval (Laval, Québec)

Research Topics:

- Radio communications
- Image compression
- Laser & semiconductor frequency stabilization instrumentation & fibre optic applications
- Optical communications
- Laser-manifold for multiwavelength communications systems
- Optically excited LED devices

Research Chair:

- Québec Téléphone/NSERC Industrial Research Chair in Optical Communications

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

Research Topics:

- Antenna and propagation studies
- Visually mediated human-computer interaction

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

Research Topics:

- Wave propagation and digital satellite communications
- Optical switching, computing and processing
- Compound semiconductor guided-wave optical switching/modulating devices

Industrial Research Program:

- NSERC/Burchill Industrial Research Chair in High-Speed Communications Technology

30. Dalhousie University (Halifax, N.S.)

Research Topics:

- Broadband integrated networks

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

Research Topics:

- Effective radio-acoustic communications systems
- Digital processing of images
- Development of fault tolerance techniques in digital systems

APPENDIX B

REFERENCES AND CONTACTS

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REFERENCES

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High-Speed Integrated Circuits	W.M. Snelgrove	Carleton University Dept. of Electrical Engineering 1125 Colonel By Drive Ottawa, Ontario K1S 5B6 Tel: 613-788-2381 Fax: 613-788-5708

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Digital Systems Design	V.K. Agarwal	McGill University Electrical Engineering 3480 University St Montreal, Quebec H3A 2A7 Tel: 514-398-7136
Photonic Systems	S. Hinton	McGill University Electrical Engineering **see above** Tel: 514-398-1749
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Telecommunications Research Institute of Ontario (TRIO)	Peter Leach President	340 March Road, 4th Flr Kanata, Ontario K2K 2E4 Tel: 613-592-9211 Fax: 613-592-8163
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Ontario Centre for Material Research (OCMR)	Dr. J.P. McGeer Managing Director	P.O. Box 1146 Kingston, Ontario K7L 4Y5 Tel: (613) 545-6519 Fax: (613) 545-6510
Manufacturing Research Corp. of Ontario	Dr. Grant Allan President	1075 North Service Road W Suite 201 Oakville, Ontario L6M 2G2 Tel: 416-847-0170 Fax: 416-978-7207

University/Industry/Government R&D Alliances

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B.C. Advanced Systems Institute	Brent Sauder, Ex. Dir.	#450, 1122 Mainland Vancouver, B.C. V6B 5L1 Tel: 604-689-0551 Fax: 604-689-0141
Telecommunications Research Laboratories (TR Labs)	Glenn Rainbird President	Suite 800, 10611 98th Ave Edmonton, Alberta T5K 2P7 Tel: 403-441-3800 Fax: 403-411-3600
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Solid State Optoelectronics Consortium of Canada	P.H. Dawson Director General	National Research Council Montreal, Road, Building M50 Ottawa, Ontario K1A 0R6
Canadian Semiconductor Design Association	Alan Aitken President	340 March Road 4th Floor Kanata, Ontario K2K 2E4 Tel: 592-1470 Fax: 592-8163
Canadian Centre for Marine Communications (CCMC)	Brian Whitehouse Communications Dev. Officer	PO Box 8454 St. John's, Newfoundland A1B 3N9 Tel: 709-579-4872 Fax: 709-579-0495

Advanced Communications-Related

Government Laboratories and Organizations

Communications Research Centre c/o Department of Communications	Mike Palfreyman, Director, General Comm.	3710 Carling Avenue PO Box 11490, Station "H" Ottawa, Ontario K2H 8S2 Tel: 613-998-2351 Fax: 613-990-7988
Canadian Workplace Automation Research Centre c/o Department of Communications	M. Drouin Deputy Director Gen.	1575 Chomedy Blvd Laval, Quebec H7V 2X2 Tel: 514-682-3400 Fax: 514-686-1990
National Optics Institute	Dr. Charles Beaulieu President	369 Franquet Street Sainte-Foy, Quebec G1P 4N8 Tel: 418-657-7006 Fax: 418-657-7009
Institute for Microstructural Sciences National Research Council	Dr. Peter Dawson Director General	Building M-50, Montreal Rd Ottawa, Ont. K1A 0R6 Tel: 613-993-9369 Fax: 613-957-8734
Alberta Research Council	Dr. Ted Heidrick Head, Manufacturing Technologies	250 Karl Clark Road Edmonton, Alberta T6H 5X2 Tel: 403-450-5400 Fax: 403-450-5477
Centre de Recherche Industrielle du Québec	Claude Morin Communications	333, rue Franquet Sainte-Foy, Québec G1V 4C7 Tel: 418-652-2213 Fax: 418-652-2251

Advanced Communications-Related

Government R&D Programs

The Industrial Research Assistance Program (IRAP)	Dr. Dennis Cooper	National Research Council Building M55, Montreal Road Ottawa, Ontario K1A 0R6 Tel: 613-952-1079 Fax: 613-993-1790
The Strategic Technologies Program (STP) c/o Biotechnology Directorate Chemicals and Bio-Industries Branch		Industry, Science & Technology Canada 235 Queen Street Ottawa, Ont. K1A 0H5 Tel: 613-954-3020 Fax: 613-952-4209
The Microelectronics and Systems Development Program (MSDP) c/o Programs and Planning Directorate Information Technologies Industry Branch		Industry, Science & Technology Canada 235 Queen Street Ottawa, Ontario K1A 0H5 Tel: 613-996-7155 Fax: 613-995-5773
The Program for Export Marketing Development (PEMD) Export and Investment Programs Division		External Affairs & International Trade 125 Sussex Drive Ottawa, Ontario K1A 0G2 Tel: 613-996-7155 Fax: 613-995-5773
The Defence Industry Productivity Program (DIPP) Program Administration and Analysis Aeronautics Branch		Industry, Science & Technology Canada 235 Queen Street Ottawa, Ontario K1A 0H9 Tel: 613-954-3526 Fax: 613-954-3375
The Defence Industry Research Program (DIRP)	Dr. John Ross Director, Industry & University Research Program	Department of National Defence 101 Colonel By Drive Ottawa, Ontario K1A 0K2 Tel: 613-952-5829
The Atlantic Canada Opportunities Agency (ACOA) Action Program	Michelyne Paulin Manager	644 Main Street PO Box 6051 Moncton, New Brunswick E1C 9J8 Tel: 506-851-2271 Fax: 506-851-7403
The Western Economic Diversification (WED) Program		Canada Place 1500-9700 Jasper Ave. Edmonton, Alberta T5J 4H7 Tel: 403-495-4164 Fax: 403-495-6876

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