Communications Research Centre
Centre de recherches sur les communications

1994-1995 ANNUAL REPORT

25 Years of Leadership and Excellence in Communications R&D

Industry Canada
Industrie Canada

Canada

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Our Mandate

"To conduct communications and related research and development to serve the national need, with or on behalf of Industry Canada, other federal government departments and agencies, provincial governments, academia, and the private sector."

Our Mission

"To conduct communications and innovative engineering which contribute to the orderly development and accessibility of communications technologies, systems, and services for the benefit of all Canadians."

Our Vision

"Leadership and excellence in communications research."

Photo : John Colbert

CRC then and now.

Jacques Lyrette *Bill Dunbar*

President's Message

Celebrating 25 years of leadership and excellence in communications R&D — that was our theme for the last year. In keeping with that theme, we accomplished a great deal while enjoying the anniversary festivities. ■ During the year we held two very successful open house events; one targeted to our Industry Canada colleagues and the other focussed on our industrial associates. We also created a new companion organization, the Friends of CRC, for former employees and close associates. ■ It was a year notable for team effort in support of government and industry initiatives. Activities ranged from providing valuable assistance to the Canadian space industry in obtaining approval for two significant multi-year satcom programs, to improving the corporate bottom line for private sector companies which licensed our latest technologies. The Innovation Centre, designed to stimulate the transfer and commercialization of CRC technologies, has been a great success. After less than a year of operation, seven clients were hosted and expansion plans are now being developed to accommodate the demand. ■ Through its increasing collaboration with industry, CRC is supporting the federal government's goal of building a more innovative economy, while forming partnerships that enhance our research programs. ■ I join our Chairman in expressing my thanks to the staff for their tremendous dedication. We will continue our tradition of excellence over the next 25 years.

Jacques Lyrette, President

Chairman's Message

As Chairman of the Board, I am pleased to present the Communications Research Centre's annual report for the 1994-95 fiscal year. ■ This report covers our 25th anniversary and I would like to take this opportunity to thank the staff, both past and present, who have contributed to the CRC's successes and to a well-deserved reputation as a leader in communications R&D. ■ We can proudly reflect on our many achievements — from our pioneering work in radio science and satellite communications, to our latest broadband ATM initiatives. Our work has not gone unnoticed. In fact, other research organizations are looking at what we do as a model of how government R&D should be managed. ■ I want to thank the volunteer members of our Board of Directors for their wisdom and advice in helping shape CRC's strategic course for the future. In particular, I would like to recognize outgoing board members, Roland Doré, Pierre Perron, George Smyth, Sheelagh Whittaker and William Fitzgerald who have been with the board since its creation in 1992. Their time, energy and perspectives were of great value in establishing CRC as a research institute. ■ In conclusion, I'd like to welcome new board members Arthur Carty, President of the National Research Council and Mac Evans, President of the Canadian Space Agency. It's a pleasure to be serving with you on behalf of CRC.

Bill Dunbar, Chairman

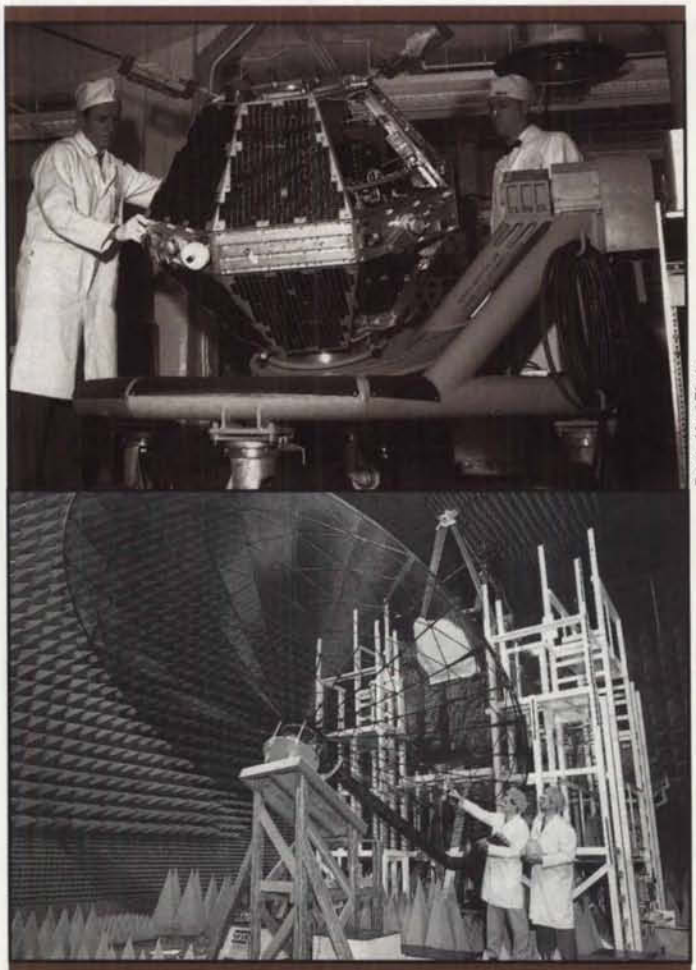
COMMUNICATIONS SYSTEMS RESEARCH

PROGRAMS AND HIGHLIGHTS

Since the 1960s, the Communications Research Centre has been Canada's primary research institute for satellite communications. Satellite communications complements terrestrial systems to provide Canada-wide telecommunications and broadcast services. ■ Over the years, the CRC has played a major role in developing Canada's world-leading satellite communications systems through technology and applications development, and major space flight programs. In 1995, MSAT will be launched, opening a new era of mobile communications services throughout Canada. This program was initiated by the CRC and later transferred to industry. ■ In mobile satellite communications, CRC has expanded its working relationships with Canadian industry and international organizations such as Inmarsat and the European Space Agency through technology transfers, contracting-in and collaborative agreements. ■ In collaboration with the Canadian Space Agency, CRC has developed plans to implement two major satcom development programs; one associated with mobile services and the other for delivery of multi-media services. ■ These programs, totalling $167 million and part of Canada's long-term space plan, will help Canadian industry access the fast-growing market for mobile and personal satellite communications equipment and services.

COMMUNICATIONS COMPONENT TECHNOLOGIES ■

CRC has unique expertise and facilities to promote industrial capability in microwave and millimetrewave circuits and antennas, integrated electronics, optoelectronics and photonics — all key components of communications technologies. Particular attention is given to emerging personal wireless communications using both satellite and terrestrial delivery systems. ■ In its microelectronics fabrication facility, CRC specializes in the miniaturization and integration of signal processing electronics using advanced technologies. Examples include small integrated antennas and



Scotty Yool Photo

Top: *ISIS I satellite undergoing testing in 1968 prior to launch.*

Bottom: *TMI Communications' D'Arcy Grant (left) and CRC's Allister Pederson examine MSAT antenna reflector during pre-flight tests carried out in the David Florida Laboratory, 1995.*

circuits operating at millimetrewave frequencies for wideband satellite communications and for inside buildings. A current R&D thrust is the development and use of combinations of integrated microwave, digital optoelectronic and photonic technologies.

SATCOM EXTENSION OF NETWORKS ■ CRC's work continued to expand in the field of remote teleconferencing using satellites to extend networks. Numerous applications demonstrations were run, including CRC's participation in "Connecting the North," a multi-media conference sponsored by NorthwesTel Inc. which connected several northern locations via satellite. ■ CRC continued to work with industry on the development of improved technology for transmission of ATM via satellite. CRC also participated in an international military collaboration to link ATM networks by satellite.

SATCOM TECHNOLOGY TRANSFER ■ Technology transfer to Canadian industry is an important part of CRC's ongoing R&D programs. CRC was involved in a number of contracting-in activities related to mobile and personal satellite communications. These activities ranged from systems design studies to prototype antenna development. ■ Early in the year CRC achieved another engineering first in aeronautical mobile satcom technology. A new technique was developed for steering an aeronautical antenna to ensure it correctly points towards the satellite as the aircraft maneuvers. This technique is based upon a three-dimensional earth magnetic field sensor, developed and patented by CRC. It was flown with an antenna also designed by CRC, aboard an Ontario Air Ambulance where it continues to operate. ■ This technology was one of two licensed to CAL Corporation during the year — the other was a mobile terminal secure voice interface technology. These have allowed CAL to gain market lead in these areas for the North American mobile satcom system, MSAT.

SUPPORT FOR ANIK E2 RECOVERY ■ CRC provided technical support to Telesat Canada Inc. to assist with the recovery of the Anik E2 satellite which lost attitude control in January 1994 as a result of a severe electro-magnetic storm. CRC's contribution was to measure the yaw of the Anik E2 using the polarization angle of a reference signal from the satellite. Anik E2 was restored to commercial service during the summer of 1994.

ADVANCED SATCOM PROGRAM ■ The Advanced Satcom Program was approved by Cabinet in May 1994 as part of the Long-Term Space Plan. Its implementation is being

John Colbert Photo

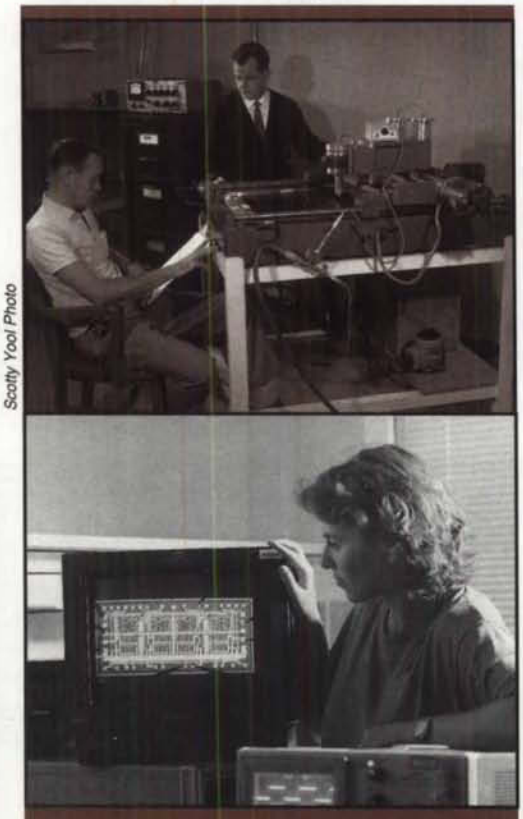
UHF linear phased array antenna system flown aboard a Canadian Forces DC-3 in 1969.

Aeronautical satcom antenna developed by CRC for the Ontario Ministry of Health's Air Ambulance Program. 1994.

managed by CRC with industry contracting currently under way. It will provide multimedia communications services, including high quality voice, wideband data, video and images to a variety of portable and small fixed terminals. A definition phase is underway which will outline plans for a joint venture between the federal government and the private sector. The plan should be completed by late 1995 with implementation beginning in 1996. CRC supports this program through internal system studies and R&D activities related to satellite on-board signal processing and Ka-band terminal development.

MICROWAVE AND MILLIMETREWAVE AND HIGH SPEED CIRCUITS AND ANTENNAS ■ Through collaborative R&D agreements and contracts exploiting CRC's expertise in microwave technologies, several Canadian firms have developed new RF product capabilities. A contract with Electronic Integrated Systems Inc. for the development of an X-Band planar antenna array was completed and has been instrumental in the company securing major contracts. Advanced MMIC measurement support was supplied to Northern Telecom on a military radar project. Under a contract from Spar, a very low loss coupler using high temperature superconducting film was demonstrated. Working with Bell Northern Research and several universities, CRC assumed a key role in developing millimetrewave integrated circuits for wideband wireless communications inside buildings. ■ Through cooperation with the Massachusetts Institute of Technology, CRC has obtained one of only eight computing machines worldwide which operate on a new approach to numerical analysis known as Cellular Automata. The approach is radically different from existing methodologies and CRC will be the only agency applying it to electro-magnetic analysis. Orders of magnitude speed improvement are anticipated. ■ A novel very high efficiency cavity-backed antenna element was developed and is being patented. A real-to-quadrature converter CMOS ASIC for a narrowband digital radio was completed and gave over 50 percent better speed performance than its closest commercial equivalent.

OPTOELECTRONICS TECHNOLOGIES ■ CRC began work with several major Canadian partners on a demonstration experiment which will dramatically increase the information-carrying capacity of an optical network by using multiple wavelengths on a single optical fibre. This will provide a cost-effective solution to meet future bandwidth demands for multi-media and other specialized services. ■ Progress was also made on the development of a fully-integrated optoelectronic switch and associated on-chip optical waveguides, in partnership with TRLabs. The technology used in these switches has potential applications in radio-to-fibre interfaces, communications phased-array antennas and ATM network management functions.



Scotty Yool Photo

Top: *DRTE-built coordinatograph used for hybrid designs in late 1960's. Wayne Coyne (left) and Jim Moffat.*

Bottom: *CRC's Ewa Lisicka-Skrzek tests laser driver circuit using Alessi probe station.*

RADIOCOMMUNICATIONS AND BROADCAST RESEARCH

PROGRAMS AND HIGHLIGHTS

RADIOCOMMUNICATIONS TECHNOLOGIES ■ The rapidly expanding demand for wireless radio communication in Canada is creating privacy and congestion issues that require technical solutions. To find those solutions, CRC conducts research into terrestrial radiocommunications systems to meet both civilian and military requirements. Research is also conducted into radio networks and narrowband speech compression techniques.

RADIO SCIENCES ■ CRC is the only organization in Canada conducting comprehensive research on the propagation of electromagnetic waves and the effects of radio noise, electromagnetic compatibility and other factors, such as the performance of antennas in their operating environments on radiocommunications. Research in radio sciences assists the federal government in planning the efficient use of Canada's radio spectrum. CRC's research and advice also provides technical support for the development and adoption of new national and international standards.

BROADCAST TECHNOLOGIES ■ Digital technologies will soon give consumers access to an unprecedented range of information and entertainment via television and radio services. Internationally, many organizations are working toward creating a new generation of broadcast systems. Canadians have a major stake in ensuring that future broadcast services evolve to meet their needs. In CRC's unique facilities, researchers are investigating advanced broadcast and related technologies to help define standards, manage the spectrum, develop broadcasting and telecommunications policies, and support industry through technology transfer.

COMMUNICATIONS NETWORKS ■ Future communications networks will provide a wide range of services including remote sensor monitoring, electronic commerce, distance education and new types of entertainment. CRC's research program responds to Canada's civilian and military requirements, including: the definition and promulgation of standards; the development of a state-of-the-art communications infrastructure; the protection of Canada's interests in international negotiations; and the transfer of technology to industry.

NEAR-FIELD PREDICTION TOOL ■ A software package for spectrum managers has been developed which displays spatial contours of signal levels (either total E field or power density) originating in specific transmitting antennas used in urban and residential areas. It also displays signal-level contours of equipment immunity and safety standards. Outside the latter, electronic equipment should operate properly without interference and with an adequate safety margin. ■ The package uses a Method of Moments algorithm to perform calculations on

Gilles Gagnon and André Vincent analyze the results of MPEG-2 video compression, 1994.

a series of data bases which model specific antenna configurations such as AM broadcast arrays, and VHF/UHF folded dipole arrays on conducting towers.

Propagation for Satellite Communications ■ CRC and the United States' National Aeronautics and Space Administration (NASA) are conducting Ka-band (30/20-GHz) propagation measurements in Vancouver using the Advanced Communications Technology Satellite (ACTS). CRC obtains and analyzes the propagation data in collaboration with the University of British Columbia, and NASA has provided a specially-designed ACTS Propagation Terminal in exchange for data-sharing privileges. The data will be used to develop propagation prediction models for the design of satellite communication systems, especially at the Ka-band frequencies now under consideration for a variety of satellite communication applications.

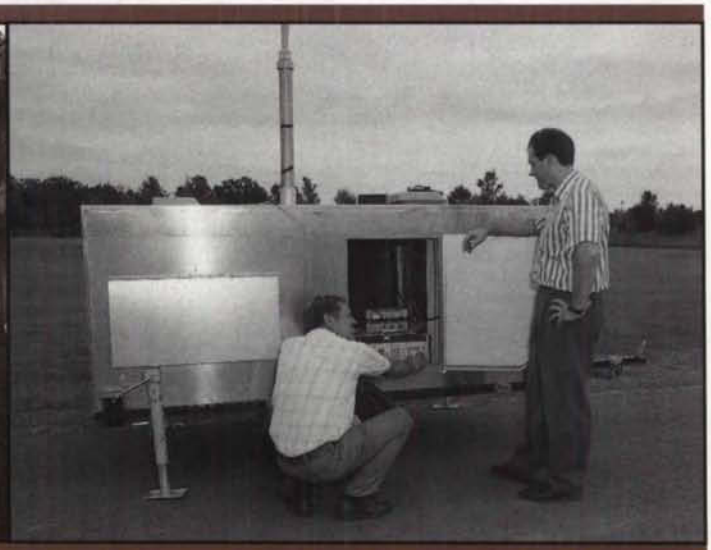
Advanced Broadcast Coverage Software ■ Industry Canada is responsible for planning and allocating Canada's radio spectrum. In support of that function and with a view to transferring technology to industry, CRC developed coverage prediction software that utilizes the unique properties of the multicarrier modulation used for digital broadcast radio. This software predicts the performance of proposed emission formats in the context of international standardization of digital radio. It is being used by Industry Canada and the Canadian industry to plan future digital radio services. This software has been licensed in Australia, and a number of other countries are considering using it to prepare for the advent of digital radio.

DRB Channel Characterization ■ Results of channel characterization measurements carried out by CRC at a number of sites in Canada are being used in the United States in the modelling of VHF/FM, 1.5 GHz and 2.3 GHz channels. These models will permit the testing of proposed digital radio broadcasting systems by the Electronic Industries Association.

Digital Television Implementation ■ With digital High Definition and Standard Definition television a near reality, CRC is providing crucial information to various segments of the industry to achieve interoperability between over-the-air, cable and satellite broadcast services based on open and international standards. ■ CRC's research results have prompted both Canadian and U.S. broadcasters to examine the Coded Orthogonal Frequency Division Multiplexing (COFDM)

John Colbert Photo

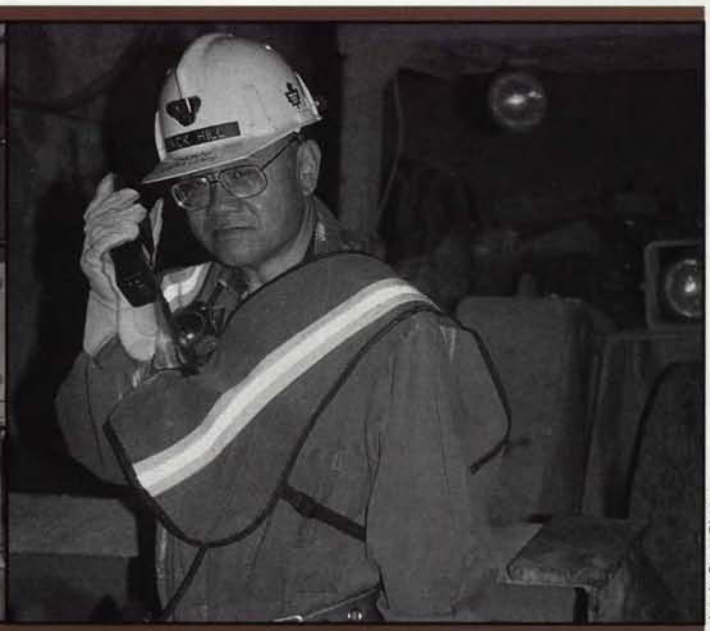
CRC's Dr. Jack Belrose (right) and Tom Ohno conducting low frequency radio experiments at Smith's Point, Nova Scotia, 1970.



CRC's Bob Hahn (left) and Pierre Melançon set up mobile receiver for land mobile propagation measurements, 1994.

Scotty Yool Photo

DRTE's Don Selin (seated) speaks into the microphone inside a mobile earth station as an unidentified Canadian Army officer looks on, 1967.



Lewis Scott Photo

CRC's Sherman Chow demonstrates underground mine rescue communcations prototype during trials at INCO's Creighton Mine, Sudbury, 1995.

technology as an alternative to the currently proposed VSB and QAM technologies. ■ CRC has expanded the capabilities of its video processing laboratory and research can now be carried out on the technical and human aspects of 3-D television, the next step beyond digital HDTV.

UNDERGROUND EMERGENCY COMMUNICATIONS ■ Working in collaboration with the Mining Industry Technology Council of Canada, CRC researchers developed a portable radio communications system for emergency rescue of injured workers and for firefighting in underground mines. The system uses radio repeaters that are strategically deployed as the emergency teams progress down drifts, providing reliable and continuous communications between team members and surface crews.

IMPROVED SPEECH CODING ■ CRC was invited by the U.S. National Security Agency to participate in a consortium to develop a new 2.4 kbps speech coding algorithm for secure telephones. This algorithm will replace the currently used technique which has low speech quality. CRC researchers have developed a promising candidate technique and are completing the hardware implementation for evaluation by the consortium. The technique also has significant potential in narrowband radio applications.

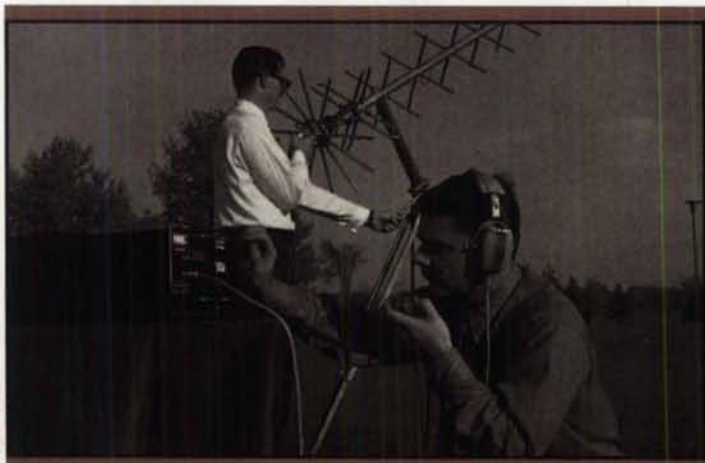
BROADBAND INDOOR RADIOCOMMUNICATIONS ■ CRC is collaborating with the Canadian Institute for Telecommunications Research and TRLabs in radio propagation research to support the design and development of multipoint broadband communications networks for use indoors. To enable large transmission bandwidths to support high digital data rates, such links must operate at millimetrewave frequencies. CRC has conducted research into radio echoes, power loss with transmission distance and through obstacles in the radio path, and radio signal fading. In collaboration with Carleton University, CRC is also managing the design, development and implementation of a prototype radio link that will be established to test and demonstrate the capabilities of indoor broadband communications systems.

BUILDING PARTNERSHIPS TO DEVELOP COMMUNICATIONS TECHNOLOGY

DEFENCE COMMUNICATIONS ■ For many years CRC has had an agreement with the Department of National Defence (DND) to conduct R&D projects in networking, radio-communications, satellite communications and microelectronics. ■ An important feature of this program is the leverage obtained through collaborative R&D with Canadian military allies. Multinational technology development projects demonstrating global interoperability of military networks and broadband multimedia networking applications were key components of this year's program. ■ Significant progress was made in demonstrating advanced techniques for interference rejection and channel equalization for HF communications. This technology is now being transferred to industry. ■ Satellite communications R&D carried out for DND included development of onboard signal processors for improving robustness, with emphasis on optical and advanced spread spectrum techniques. Extensive system analysis was performed for the Canadian Military Communication Satellite Project.

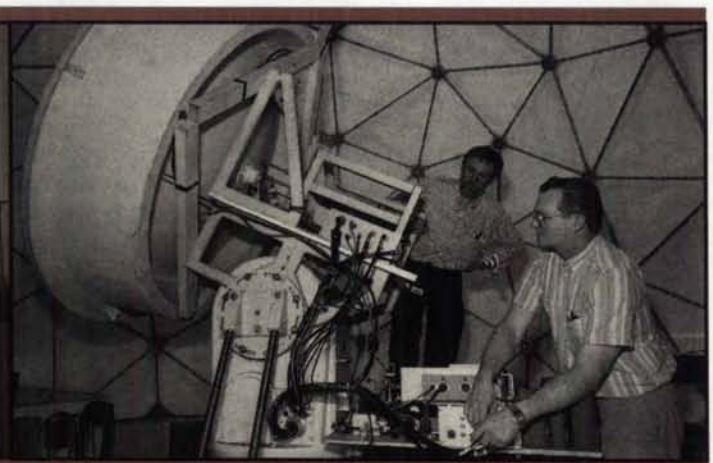
BUSINESS DEVELOPMENT ■ Since 1992, the CRC has taken advantage of new authorities to market its intellectual property and unique facilities and to enter into collaborative R&D with industry, other government agencies and universities. ■ CRC's business activity in the area of contracting-in and intellectual property licensing continued to grow, yielding revenues of approximately $2.3 million in 1994-95. Of that total, $1.2 million was generated through 70 research or technical service agreements.

ADVANCED TELEVISION ■ In the area of advanced television, CRC assessed the suitability of various video processing algorithms for the development of enhanced NTSC products for Miranda Technologies Inc. and Genesis Microchip Inc. Collaborative research was undertaken with the U.S. National Association of Broadcasters for the evaluation of high speed data broadcasting using the present NTSC television system. ■ CRC entered into an international collaboration for the design and evaluation of a Coded Orthogonal Frequency



John Colbert Photo

TACSATCOM: David Barlow (left) and Ron Yank conduct field trials on the crossed dipole satellite antenna operating at 330 MHz, 1970.



Progression in time...David Barlow and Ray Burrill (DREO) with LES 8/9 (Lincoln Experimental Satellite 8/9) antenna operating at 36/38 GHz, 1995.

Division Multiplexing (COFDM) transmission system involving the COFDM Evaluation Limited Liability, Inc., an organization of Canadian and U.S. broadcasters, and SINTEF, the development arm for the Scandinavian HD-DIVINE HDTV project.

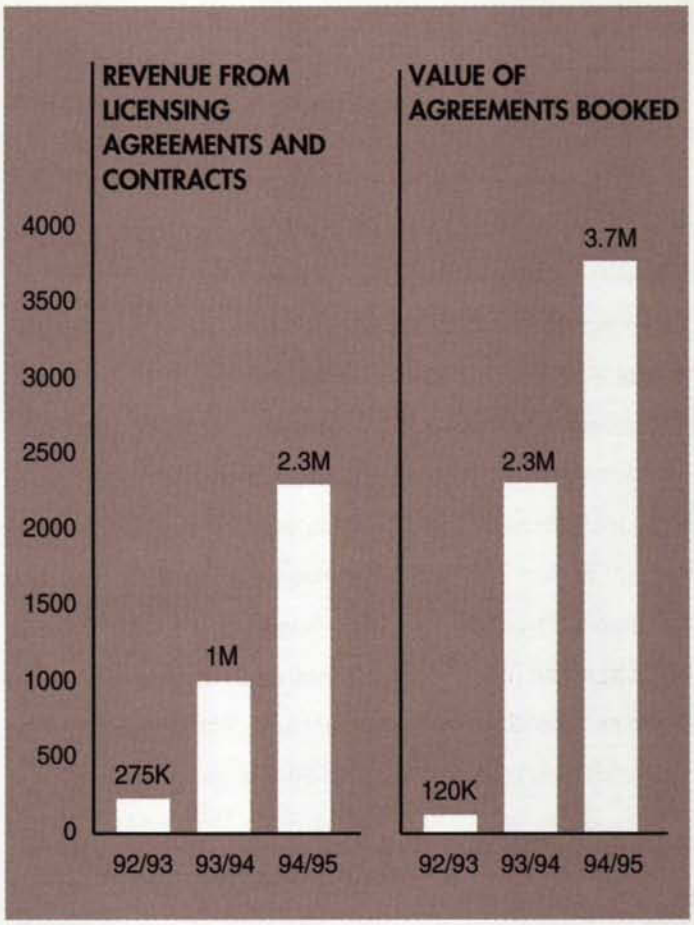
INDUSTRIAL DESIGN OF TEST EQUIPMENT ■ Other contracts of note include the manufacture of two lightwave analyzer test sets for the University of Alberta. The test sets are designed for high frequency characterization of optoelectronic devices and components. The sets are being used by TRLabs of Edmonton and the U of A to test optoelectronic devices and microelectronic circuits. The HF lightwave test set is designed for technicians working in a hybrid environment where fibre optics are integrated into novel, high speed, digital and microwave signal processing systems.

LICENSING OF INTELLECTUAL PROPERTY ■ A significant cross-licence agreement was signed with United Technologies Corporation (UTC) in December 1994 which is expected to generate $2 million in revenue over the next five years. The cross-licence combines CRC and UTC optical fibre Bragg grating processing patents for the purpose of granting sub-licences to third parties.

INTELLECTUAL PROPERTY AGREEMENTS

- There were 212 active intellectual property agreements. From these a total of 68 licences generated more than $340,000.
- Thirty-one new IP licences were granted to small and medium-sized enterprises.
- Applications were filed for three new patents.
- Five new patents were obtained (three U.S., one Canadian, one U.K.)

CYBERSPACE ■ During the year CRC launched itself into cyberspace with the introduction of a home page on the Internet's World Wide Web. Our address: http://www.crc.doc.ca/



The Technology Transfer Team...

Front (from left to right):
Joe LeBlanc, Paul Wilker, Eric Tsang.

Back (from left to right):
Zaki Muscati, Lewis Scott, Cecillia Cheung, Jeet Hothi.

OPENING CRC'S DOORS

REFERENCE LISTENING ROOM ■ In 1994-95, CRC added the Reference Listening Room to the list of labs that are available for contract use by private interests. This newest testing facility complements the Innovation Centre and Broadband Application and Demonstration Laboratory which became fully operational during the year. ■ The Reference Listening Room is a fully integrated laboratory for conducting tests for the subjective evaluation of mono, two-channel and multichannel audio systems. The lab includes a calibrated listening room which complies with international (ITU-R) standards. Professional quality audio equipment and a custom computer-based playback system allow switching between test stimuli for critical comparison during presentations. The facility has been used by the Electronic Industries Association to test digital audio radio systems that are proposed for standardization in the U.S.

INNOVATION CENTRE ■ The Innovation Centre allows small and medium-sized enterprises and high tech start-ups to locate at CRC for up to two years to access CRC's expertise, technologies and unique facilities. Collocation accelerates the transfer of technologies and assists the development of innovative communications products and services. ■ Companies are provided furnished offices and access to labs and technical support. Opened in November 1994, over the year seven clients were developing technologies related to mobile communications and the information highway.

BADLAB ■ The Broadband Applications and Demonstration Laboratory (BADLAB), was created to further the development of Canada's information highway and to provide a facility where industry could test the interoperability of their products. In collaboration with Telesat, BADLAB was the first R&D facility in Canada to integrate satellite links with high-speed asynchronous transfer mode (ATM) networks to test and demonstrate information highway applications. ■ One of the many BADLAB highlights was an artificial heart biotelemetry demonstration linking doctors from the Ottawa Heart Institute with their colleagues from the Berlin Heart Institute during the G7 Ministerial Conference on the Information Society held in Brussels. The demonstration was carried over Teleglobe Canada's new CANTAT-3 fibre optic submarine cable.

SOME OTHER BADLAB HIGHLIGHTS INCLUDE:

- First national distant education link between Simon Fraser University and University of Ottawa using the CANARIE National Test Network (NTN).
- BADLAB virtual presence at: the Canadian Advanced Technology Association show; Connecting the North; Softworld '94; and INTER COMM '95.
- Three memoranda of agreement signed for broadband application development and demonstration with: MPR Teltech, Teleglobe Canada Inc. and the Chilean Ministry of Telecommunications.

Eric Tsang Photo

Dr. Tofy Mussivand (left) and Dr. Wilbert Keon (centre) of the Ottawa Heart Institute demonstrate artificial heart in CRC's BADLAB, 1995.
CRC's Michel Savoie operates multimedia work station.

RUNNING CRC IS LIKE OPERATING A SMALL TOWN

At 600 hectares in size, the site at Shirleys Bay, west of Ottawa, is much like a small town. ■ There are 72 buildings, 13 kilometres of road, and approximately 400 permanent CRC employees. The site was first used by the Defence Research Board in 1952. Today, National Defence and the Canadian Space Agency, with a combined staff of about 250, also occupy the site.

ESSENTIAL SUPPORT ■ The research community at the CRC is supported by approximately 130 staff who provide corporate and research support services. In addition, another 60 maintain the buildings and operate the site, providing services to CRC, the Defence Research Establishment Ottawa, and to the Canadian Space Agency's David Florida Laboratory. ■ The research scientists and engineers use the expertise of the Model Shop and Technical Services when they require the design and manufacture of prototypes. Procurement and Materiel Management provide purchasing support and manage the substantial assets of the site.

■ Finance oversees the expenditure control systems, and the production of this annual report was a joint project of Communications and Creative Visual Services. Human Resources has an important role to play in any organization and at CRC particular focus is on rejuvenation of the scientific and technical ranks as a high proportion of staff are reaching retirement age.

HUMAN RESOURCE PLANNING ■ During the fiscal year, CRC began implementing its human resources rejuvenation plan to ensure that long-term staffing needs are met. The plan identifies innovative recruitment methods to renew the scientific and technical ranks. It also creates a mentor program to help ensure that research continuity is maintained between scientists. ■ CRC management approved a human resources strategic plan which addressed issues such as rejuvenation, women in non-traditional occupations, and job classification, and provided recommendations for implementing a framework to ensure best human resources management practices.

CRC's team spirit and quest for excellence goes beyond the boundaries of the work place. In February, a dedicated and creative group of employees braved a week of -25 degree temperatures to build an exquisite sculpture for entry in Ottawa's 1995 Winterlude Ice Sculpture Contest. Entitled "Communications From Pole To Pole," the sculpture won first prize in the government category.

■ A small committee of women scientists and engineers was created to review the recruiting practices and conditions of work for women in these occupations at CRC. This report was requested by the Board of Directors and will be completed early in the next fiscal year.

EXCHANGE PROGRAM ■ During 1994-95, CRC approved the use of Interchange Canada as its official exchange program. Interchange Canada promotes and facilitates the exchange of employees, through assignments, between the Federal Public Service and organizations in all other sectors of the Canadian economy. Flexibility has been provided to CRC in the payment and recovery of salaries, benefits and other costs associated with negotiating an interchange agreement.

ENERGY MANAGEMENT ■ It costs approximately $2 million annually to provide utility services to CRC. Over the years, utility costs have risen faster than CRC's funding base. Aging buildings and infrastructure have made it necessary to explore options for reducing energy and other operating costs. ■ After a detailed analysis by representatives of CRC, the Federal Buildings Initiative and Government Services, Honeywell Inc. was selected from a short list of suppliers to undertake CRC's energy efficiency retrofit. Upon receiving authority from the Treasury Board, CRC will negotiate with Honeywell for an energy management contract which will be totally financed by energy savings. ■ The annual energy savings is projected to be $628,000, which will accrue to CRC after an eight-year payback period to the contractor.

REVENUES AND EXPENSES

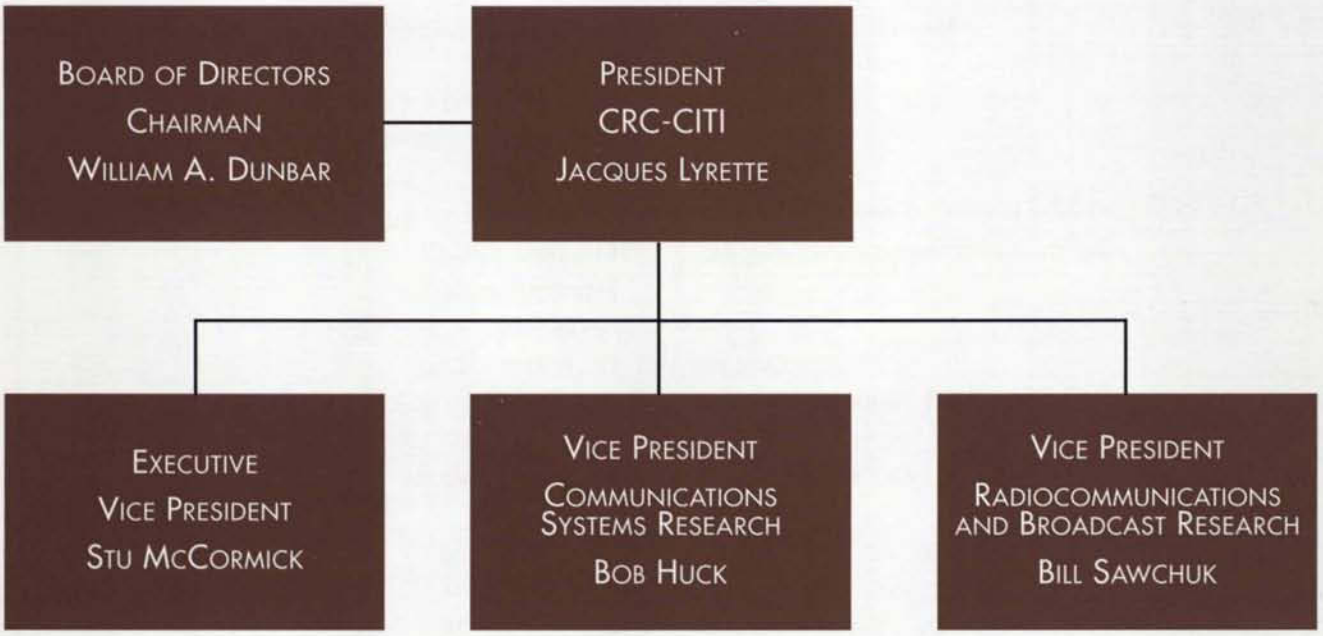
REVENUES

1994/95	($ MILLIONS)
Department of Industry Funding:	31.17
Spectrum Research	1.50
Intellectual Property	.40
Contracting-in	.40
Defence Research	5.90
Site Services	1.60
Total Revenues	40.97

EXPENSES

1994/95	($ MILLIONS)
Research & Development	21.20
Research Support	5.63
Site Services	9.58
Administration	3.16
Subtotal	39.57
Carry over into 1995/96	1.40
Total Expenses	40.97

CRC ORGANIZATION CHART



- Strategy and Plans
- Business Development
- Site Services
- Technical Services
- Corporate Services
- Human Resources

- Mobile and Personal Communications
- Satcom Applications and Projects
- Satcom Systems and Technologies
- Optoelectronic Technologies
- Antenna and Integrated Electronics
- MSAT Program

- Radio Sciences
- Radiocommunications Technologies
- Radio Broadcast Technologies
- Television Broadcast Technologies
- Network Technologies

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