Communications Research Centre

STRATEGIC RESEARCH PLAN 1992

Communications Canada

1. Communications Research Centre (Canada)

Department of Communications

COMMUNICATIONS RESEARCH CENTRE

STRATEGIC RESEARCH PLAN

1992

Leadership and Excellence in Communications Research

In 1989 a Committee of the National Advisory Board on Science and Technology, headed by Pierre Lortie, undertook a thorough study of all aspects of R&D in federal laboratories. Some of the research branches of CRC were among the six laboratories examined in detail in this study, and these were found to be of very high quality. Lortie's report, published in 1991, comprised an excellent diagnosis of impediments to the management of R&D in federal laboratories. Although not all of the Lortie recommendations were suitable for DOC, many of them were sound and the Department decided that we should view them as an opportunity to remove many of the impediments which had been identified. Accordingly, the Deputy Minister requested that a set of proposals be developed for CRC which would be largely consistent with the Lortie Report, and which would be appropriate to meet the particular needs of CRC. During this process, an open dialogue was created which involved virtually all staff of the research branches, many other employees within and outside CRC and major clients and advisory boards. The resulting proposals had widespread support among CRC staff. Treasury Board subsequently approved additional authorities needed by the new research institute, giving CRC greatly increased autonomy, flexibility in exploiting and using revenues from intellectual property, in obtaining revenues from other sources, and in arrangements for collaborative research.

CRC must now strive to achieve recognition as the federal focus for communications research, and through a clear vision and mission develop an expanded client and resource base. This Strategic Research Plan is one of the first concrete expressions of how CRC plans to implement its new vision and mission, and how it will shape its future. It sets out the strategic thrusts to be undertaken over the next few years, the rationale for their inclusion in a federal research laboratory, and the specific goals that we hope to attain.

I wish all the management and staff of CRC the very best of success in this exciting and innovative endeavour under our new vision "Leadership and excellence in communications research".

R.W. Breithaupt
Interim President
April 1, 1992

CRC's Values and Principles

- ***Service***
  To meet communications research needs both within and outside the federal government is our highest goal.

- ***Excellence***
  To achieve the highest standards of excellence in our R&D programs to ensure that we will remain a leader in the communications research community.

- ***Our Environment***
  To provide a challenging environment in which superior performance and innovative initiatives are encouraged and rewarded, professional development opportunities are provided, and participative leadership is fostered.

- ***Creativity***
  To encourage exploratory R&D to ensure an ongoing source of new ideas and skills, as well as to provide the creative environment necessary to attract and retain the best researchers .

- ***Intellectual Capital***
  To maintain our intellectual capital by emphasizing the medium to long- term R&D needed to address public and private sector needs.

- ***Collaboration***
  To collaborate with others so as to maximize synergy with the R&D performed by universities, industry, and other research organizations.

- ***Technology Transfer***
  To promote the marketing, diffusion and exploitation of our technologies through technology transfers, licensing, training, scientific exchanges, and standards activities.

- ***Publications***
  To disseminate our research results widely through appropriate media, symposia, workshops, and library services.

- ***Ethics***
  To adhere to professional standards and codes of ethics.

- ***Management***
  To manage our activities effectively with due regard for economy, efficiency, and the achievement of objectives, through teamwork and shared values.

Strategic Research Plan 1992

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Part I: The Opportunity and the Challenge

"The departmental S&T establishments perform roles that are critical to the efficient functioning of modern societies and reflect their complexity and the heterogeneity of situations. A large proportion of these activities are undertaken to support policy advice, develop testing methodologies and support industry in process and product approval. Other intramural S&T activities produce unique, large and sophisticated data bases, our public knowledge infrastructure, that inform both government and business decisions. And, a few establishments operate in formal or informal partnerships with industry to provide strategic technological advances for medium and long term time horizons or operate major facilities required by both government and industry. Finally, some establishments are simply service organizations which provide engineering support to private sector firms or other government departments and agencies.

By expanding knowledge, science becomes a tool for fulfilling government responsibilities and achieving government objectives; it provides information for timely and effective policy and regulatory decisions and establishes the public knowledge infrastructure which is critical to many business and economic development activities. As the quality of science improves, so does the reliability of information and the probability that the choices made are the best ones. It is incorrect to postulate that government is simply a funder of S&T. It is an important user, and the significance and impact of its regulatory and decision-making roles as well as the public goods nature of a substantial portion of its output mean that government S&T must be as good as that anywhere else - in industry, in universities and in private organizations."

- NABST: Revitalizing Science and Technology in the Government of Canada

In creating a new research institute to respond to the recommendations of the National Advisory Board for Science and Technology (NABST), the Government of Canada and the Department of Communications have undertaken an experiment which will change the

management regime to permit the development of a new R&D culture within government. CRC is presented with a broad new opportunity - relaxation of administrative constraints, revenue retention, the ability to seek new and more varied clients, and a completely revised management structure.

It is now the challenge of the Communications Research Centre to respond to the words of NABST. We must ensure that our research and development programs are supportive of government policies, help achieve government objectives, and advance the public knowledge infrastructure in accordance with the national need.

This initial Strategic Research Plan is an interim document which presents a first response to the opportunity and challenge presented to the new research institute. It reflects the recommendations of the "Transition Team", whose approval has paved the way for the creation of the institute. The new vision and mission for CRC are enunciated within the context of the existing long term research activities, which are presented along with their rationale. During 1992, a thorough review of needs, capabilities and opportunities will be carried out, and will result in the first true strategic research plan for CRC in 1993.

CRC's Vision and Mission

The primary goals of the Department of Communications are to ensure that:

- Canada's communications systems evolve in an orderly manner, at the forefront of global developments, to serve all Canadians at affordable costs; and
- Canadians have the freedom to choose from a wide selection of Canadian cultural products and information services among the broad international choice being carried through our communications systems.

To express these goals, the Department summarizes its mission by the phrase

Nation-building: helping Canadians share their ideas, information, and dreams.

As a research institute of the Department of Communications, the Communications Research Centre contributes to the realization of the departmental mission. Its mandate is to conduct communications and related research and development to serve the national need, with or on behalf of the Department of Communications, other Federal Government departments and agencies, provincial governments, academia, and the private sector in order to:

- develop and promote communications technologies, systems, and services;
- support the efficient use and management of the radio frequency spectrum;
- contribute to the development of national and international standards in communications technologies, systems, and services;
- provide communications research and development services, advice, and facilities;
- transfer technology to Canadian industry for exploitation;
- contribute technical expertise in support of government policy initiatives; and
- facilitate and participate in international research and development agreements.

Accordingly, the mission of the Communications Research Centre is

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

with a corresponding vision, shared by all employees

Leadership and excellence in communications research.

Success Criteria

To gauge the quality and effectiveness of the research work carried out at CRC, we have defined a number of success criteria against which results can be measured.

- ***Development of New and Enhanced Services***
  What new and enhanced services are available to the Canadian public as a result of CRC innovations?

- ***Spectrum Conservation and Utilisation***
  How has CRC contributed to spectrum conservation and improved utilisation?

- ***Technological Advances***
  What have been the contributions of CRC to technological advances?

- ***Overall Client Satisfaction***
  Has CRC provided its clients with value for money and met their needs? Has it retained existing clients and attracted new ones?

- ***Enhancement of Scientific/Engineering Knowledge Base***
  How many papers/reports have been published, is the quality of CRC papers world-class, has it contributed to a better understanding of selected areas of work? Has CRC trained young scientists through active participation in research projects?

- ***Standards***
  How has CRC contributed to the establishment of new standards to promote the rational introduction of new technologies and services?

- ***Transfer of Technology***
  How many patents/licenses were granted, how has CRC contributed to job creation/preservation in industry, did it create/enhance domestic industrial capabilities, has it helped make industry more competitive?

Part II: Research Areas

As part of its overall recommendations, the Transition Team recommended that by April 1, 1992, an interim organization be put in place for CRC which would evolve to a final structure over the next 6 to 18 month period. This interim organizational structure includes four research areas of approximately equal size. MSAT is included as a separate item because of its special (sunset) nature.

BROADCAST TECHNOLOGIES

Broadcasting is expected to change dramatically within the next decade. Already high definition television (HDTV) and digital radio broadcasting (DRB) systems are being tested, but further improvements in both video and audio broadcasting are expected. Proposed television improvements range from enhancements to present-day systems to fully digital, entirely new television. Digital radio is expected to replace current AM and FM services, and may provide more than two-channel stereo sound. Spectrum for both HDTV and DRB has recently been allocated by WARC 92 and some of these broadcasting services could begin by the middle of this decade.

While these are new technologies for delivery of the traditional television and radio services, the nature of broadcasting services themselves is expected to change as the decade unfolds. Service providers will begin to use the convergence of broadcasting with computers and telecommunications to provide new information retrieval services and probably new interpersonal communications services, as well as new forms of radio and television distribution.

Canada, with a large broadcast network reaching virtually all Canadians, has a major stake in ensuring that future advanced broadcast services evolve to meet its needs, sustain its industrial infrastructure and support is national identity. However, before new services can begin, spectrum has to be allocated, standards developed, regulations established, and policies designed. In addition, to reap the full economic and technical benefits possible with the introduction of advanced broadcast services, the underlying technologies must be developed and exploited by industry. The goal of the Broadcast Technologies research program is to support the Department in achieving these objectives. To accomplish these objectives, the research program will focus on three major areas:

- Advanced Video
- Advanced Audio
- New Broadcast Services

Advanced Video

In this research program we undertake investigations into advanced television technologies with particular interest in the impact of digital techniques on system design, signal coding and compression, transmission and spectrum utilization. In the near term we will continue to collaborate with the Canadian Broadcasting Corporation (CBC), the Advanced Broadcast Systems of Canada (ABSOC), and several private sector companies in Canada in this research. As well, we will collaborate with the Advisory Committee on Advanced Television Systems of the Federal Communications Commission, the Advanced Television Test Center (ATTC)

and the Cable Television Laboratories in the United States in the evaluation of proposed advanced television emission systems with a view of establishing a North American standard that will meet Canadian requirements. In particular, we are conducting the subjective testing as part of this collaborative effort. We will also undertake research into the use of digital compression techniques for the present television system in order to reduce spectrum requirements, an issue which is of great interest to Telesat, Cancom and several cable television operators. This work will also create opportunities for the introduction of additional services over terrestrial off-air channels, cable networks and satellites. We will carry out psychophysical research that will lead to a better understanding of the human visual system and peoples' viewing behaviour, which could lead to more effective and more spectrum efficient television systems in the future.

With the proliferation of television system alternatives, many opportunities will exist to exploit related CRC technologies. Digital to analog converters for receiving television over cable and satellite networks, and standards converters to translate program material from one format into the other are typical examples.

In the longer term we will focus our research on digital transmission of HDTV over integrated broadband networks. We will also investigate higher quality video, including stereoscopic television, as well as highly compressed, and highly spectrum efficient systems that may be required for multimedia personal communications services.

Advanced Audio

In this research program we undertake investigations that will be important to making decisions on the best technologies and systems to be adopted for digital radio broadcasting services and other audio systems in Canada. In the near term, in collaboration with the Centre Commun d'Études de Télédifusion et Télécommunications (CCETT) in France and the Institut für Rundfunktechnik (IRT) in Germany, we will direct a major effort towards the definition of system parameters that will permit the shared use of the L-Band for satellite and terrestrial radio services directed to vehicular, portable and fixed receivers. There is very high interest by both private and public broadcasters to introduce digital radio as soon as possible in order to provide a higher quality and service reliability than is possible with AM and FM radio. We will continue co-operation with the CBC and the Canadian Association of Broadcasters (CAB) in conducting tests to collect channel propagation data to develop spectrum planning and allocation tools for use by the DOC and broadcasters. We will also carry out research on wideband digital transmission for vehicular reception to establish standards for digital audio broadcasting. An important aspect will be to investigate CD-quality sound compression methods to establish system parameters. We will carry out, in collaboration with partners from Europe and Australia, the subjective testing of various audio compression systems in

support of establishing an international standard at the CCIR. Research in advanced audio will also take into account the sound requirements for television systems.

Present-day two-channel stereo sound systems cannot fully represent the live environment. Our longer term research will therefore concentrate on multichannel systems. Of particular concern will be issues such as spectrum efficiency and compatibility with mono- and two-channel systems and the configuration of multichannel sound that will provide the listener with a realistic spatial sound environment.

New Broadcast Services

In this research program we investigate the convergence of broadcast with computer and telecommunications technologies as they will influence concepts for new broadcast services. These services, are generally based on data transmission and many of them are user-interactive requiring an uplink channel, which may be shared with other telecommunications services, or provided through specially allocated spectrum in the broadcast bands. The requirement for additional program-related and unrelated services is already reflected in the planning of advanced broadcast systems by including additional data streams. We will conduct research in collaboration with organizations in Canada and the United States to identify the requirements to accommodate services efficiently and flexibly and ensure that the necessary features for imbedded conditional access systems are provided.

Research is required to ensure successful realization of the opportunities presented by new services to broadcasters. Our research will focus on user interface designs for fixed and mobile environments, on identifying new service concepts, on developing new configurations for two-way transmission, and on ensuring that sufficient spectrum capacity is provided with the flexibility required for the new services.

Specifically, we will investigate access and control of multimedia information bases through natural language and speech recognition means. The research collaboration we have established with outside organizations will be continued and extended. We expect to trial a new broadcast service using the natural language/multimedia technology. As well our research will address the requirements for advanced traveller information systems which provide traffic, road condition and other information to a mobile environment. This is a new area of service opportunity for radio broadcasters. In the longer term, such services are expected to be integrated into proposed intelligent vehicle highway systems. We expect to collaborate with federal and provincial departments of transport, large municipalities and the private sector.

COMPONENTS AND DEVICES

The Communications Devices and Components Research Branch is concerned with the research and development of generic microelectronic, optoelectronic and electrophotonic device and processing technologies necessary for the sophisticated signal processing functions demanded by future civil and military communications and information technology systems. Through these research activities we are firmly committed to ensure the availability of the component and circuit technologies necessary to fulfil CRC's mission to provide accessible communications services for the benefit of all Canadians.

The incorporation of advanced microelectronic and electrophotonic devices and components within the next generation of communications and information technology systems will provide numerous strategic and commercial opportunities and tremendous potential for sales growth. While some of these technologies may be accessible from offshore sources, their cost is high and there are no means by which Canadians can control the directions of the future developments that will address Canadian priorities. This control can only be realized through the creation of a domestic industrial capability to develop the devices that will meet our particular national requirements. These technologies are still evolving, and their commercial development can involve considerable risk. This, coupled with the high capital cost of design and laboratory facilities, can make entry into this technological area very difficult for small or medium-scale Canadian industries. With our comprehensive microelectronic processing facilities and with almost 20 years experience in the design, fabrication and testing of such components, CRC is well placed to carry out high-risk research for the development of these vital technologies which can then be transferred to Canadian industry for exploitation.

Our principal objective is to carry out timely research and development on the design, fabrication, packaging and reliability testing of a broad range of electronic, optoelectronic and electrophotonic devices, components and circuits. The R&D programs undertaken by the Branch in these areas contribute to the technology base of electronic or photonic devices and components for the management and utilisation of the radio frequency spectrum, and upon which high-capacity and high speed communications systems can be developed and incorporated into a Canadian information network. These research activities also address potentially large commercial opportunities for lower rate communications systems such as MSAT, cellular radio and digital radio broadcasting. Our devices and components will be vital for the effective use of the large bandwidth in optical communications systems, as well as bandwidth reduction techniques for the implementation of a high quality, Advanced Television system.

We work closely with other government departments and agencies such as the Department of National Defence, Transport Canada, the National Research Council of Canada, Industry, Science and Technology Canada, and the Canadian Space Agency.

Our research program is divided into three closely related areas:

- Advanced Circuit and Component Design Technology
- Microelectronic Device and Processing Technologies
- Advanced Optical Communications Components and Systems

Advanced Circuit and Component Design Technology

As new fabrication and processing technologies and subsequently, new device structures emerge, novel design methodologies and software must be developed. Our research in advanced circuit and component design technology is directed toward the design, testing and application of high performance microwave devices and integrated circuits for use in terrestrial and satellite communications, and in electronically-steerable antennas and radars, to offer improved services, performance and reliability.

Gallium arsenide (GaAs) monolithic microwave integrated circuit (MMIC) and miniature hybrid microwave integrated circuit (MHMIC) technologies offer significant advances in size, weight, cost, performance and reliability. In addition, the convergence of these with digital and optoelectronic devices promises the realization of sophisticated "systems on a substrate". Communications equipment that can greatly benefit from future developments in these technologies include transmitters and receivers for mobile communications, microwave repeaters, radar transmit/receive modules, receivers and transmitters for EHF and L-band which can be used for in-building and satellite communications, and subscriber radio systems. The design and fabrication of low-cost active GaAs microwave integrated circuits will also make possible the development of frequency-agile, adaptive phased-array antennas for use in personal communications systems.

Microelectronic Device and Processing Technologies

The objective of the microelectronic device and processing technologies research program is the development, fabrication and testing of new materials, structures, devices and circuits, particularly those based on GaAs or other compound semiconductors, for use in advanced digital and analogue communications and signal processing systems.

The field of microelectronic device and processing technologies offers a broad spectrum of opportunities for materials and device research and development. This includes the development of techniques for the growth and characterisation of uniform, high quality compound semiconductors such as gallium arsenide (GaAs), as well as the development of

methods for the growth and characterisation of complex multi-layer quantum wells and heterostructures. Opportunities for device research include the design, modelling and fabrication of novel devices and device structures such as the Heterojunction Bipolar Transistor (HBT) and the High Electron Mobility Transistor (HEMT) which will be required for microwave and high speed digital integrated circuits. Fabrication of these devices and circuits will require the development of stable processing technologies such as photolithography, reactive-ion etching, and metallisation. An important component of this research will also be comprehensive reliability testing to determine the long term performance of these new devices as well as their resistance to harsh climatic or radiation environments, both key factors in devices and circuits for satellite and other high reliability applications.

Advanced Optical Communications Components and Systems

Our goal is to develop techniques and processes for the design, fabrication and test of reliable, high performance optoelectronic and electrophotonic devices, components and fully integrated circuits which in turn will enable the design of advanced communications systems, high speed signal processing systems and advanced optical computers.

Modern fibre-optic communications technology has opened up a large number of opportunities for optoelectronics and electrophotonic research and development. A fibre-to-the-home service, that can deliver vast quantities of information and entertainment programming on a single strand of glass fibre, will require development of many new optoelectronic and electrophotonic components that are rugged and can operate reliably for many years in a wide variety of environmental conditions. Other important areas of opportunity include radiation-resistant, broadband switching networks for on-board satellite signal processing as well as oscillators, phase shifters and high power, tuneable lasers for the control of phased-array antennas.

To this end, we are carrying out research to develop generic semiconductor materials, and device and processing technologies. We will devote considerable effort to the development of materials and processes for the integration of electronic, optoelectronic and optical distribution functions onto a single chip, thereby reducing cost and improving the ruggedness and reliability of these components. We also plan to develop new, non-linear optical materials and structures that can be used for the fabrication of optical logic components and switching networks for application in ultra high speed optical computers and neural networks for advanced civilian and military signal processing.

RADIO SCIENCE AND COMMUNICATIONS

The Radio Physics Laboratory was established at Shirleys Bay in 1953. Our current program in Radio Science, unique in Canada, studies fundamental limits to the reliability and operational performance of radio communications systems. From our detailed understanding of these limits, which are set by propagation, interference, radio noise, and electromagnetic compatibility, we provide objective and unbiased advice which the department uses to ensure the efficient use and management of the radio frequency spectrum. We also provide technical expertise for Canadian positions at Administrative Radio Conferences, and we participate actively in the deliberations of the CCIR. We collaborate with the Canadian Space Agency in research to improve our knowledge of processes that affect electromagnetic waves in the ionosphere.

The term Radio Communications refers to uses of the radio spectrum which do not involve satellites. Most of our R&D in radio communications is done for the Department of National Defence (DND) under the Defence Recoverable Program. The terrestrial communications research program, the major element of the Recoverable Program, represents essentially all of the non-satellite communications R&D being carried out by or for DND. We do have, however, small but significant non-military in radio communications: Civil Radio Communications and SHARP (Stationary High Altitude Relay Platform).

We conduct about half of our R&D in close collaboration with military sponsors who have identified a particular requirement which would benefit from medium-term research. A major goal of our program, therefore, is client satisfaction. The other half of the work is longer-term research, with the overall objective of maintaining and developing the expertise and capabilities required to address medium-term issues in the future. A second major goal of the program is technology transfer to permit the exploitation of technologies developed under this program.

We carry out Radio Science and Communications R&D under these topics:

- Radio Propagation and Prediction
- Indoor and Mobile Communications
- Electromagnetics and Non-Ionizing Radiation
- Military Terrestrial Communications
- Civil Radio Communications
- SHARP

Radio Propagation and Prediction

Our knowledge in radio propagation and our expertise in applying this knowledge for system design is used both within the department for the development of spectrum utilisation policy

and by others who have a need for propagation information. To maintain and expand this expertise, we carry out extensive experimental measurements and devote significant effort to developing models that describe the measured effects and can be used in system design. In the near-term, we will emphasize studies of atmospheric effects at EHF frequencies which will soon be used for satellite communications, we will continue research to improve our ability to predict system parameters for the heavily-used VHF and UHF bands, and we will study new techniques for improving HF communications in our Arctic regions.

Indoor and Mobile Communications

Because of the increasing wide-spread interest in wireless local area networks and in personal communications, we are conducting research specifically concerned with propagation and EMC problems for these applications.

The mobility and flexibility promised by personal wireless communications requires a flexible and comprehensive understanding of the use of radio inside buildings. We are conducting experiments to determine the characteristics of such radio channels and their compatibility with similar systems operating in nearby buildings. We are studying the effects of reflections from walls, furniture, and even people. We will use these measurements to devise models to improve our understanding of the propagation phenomena and to predict digital system performance for various scenarios.

We are studying the application of digital communications techniques to land mobile communications in which the highly variable nature of the signal makes it difficult to transmit information at a high rate. We will conduct comprehensive experiments to permit us to model the characteristics of this radio channel, and permit optimum radio system design.

Electromagnetics and Non-Ionizing Radiation

We demonstrated that antenna systems are strongly affected by their working environments from studies of the radiation patterns of AM broadcast antennas. Because the efficiency of a communications system depends strongly on its antenna, we are developing techniques to deal with this problem in some particular cases. For example, we are completing a study of VLF/LF transmitting antennas, which are large structures supported by many towers, and we are conducting research necessary for the design of an HF antenna for Fisheries and Oceans patrol vessels.

Many countries have standards relating to the safe limits for exposure to non-ionizing radiation such as from a radio antenna. These limits are only poorly understood, as is evidenced by widely varying values adopted over the years by different countries, and by the gradual reduction of the limits. The anticipated proliferation of personal communications

devices raises questions concerning the long term effects of radiation from these devices. We plan to carry out preliminary investigations to determine if, given our limited resources, a viable research program could be undertaken.

Military Terrestrial Communications

Our research in Military Terrestrial Communications comprises areas of particular interest to DND taking due regard of its role in peacekeeping and Canadian sovereignty. Particular emphasis is placed on specialized communications techniques and systems required for communications with and within the Canadian Arctic regions, where population densities are extremely low and the Arctic ionosphere often causes severe difficulties for HF communications. Globally, as part of the modernization of communications systems, networks are becoming more and more important. A significant part of the research program is therefore dedicated to the specialized networking requirements of military communications systems. A third major area of R&D is on the specialized modulation and coding techniques which will be required to provide reliable and secure communications in the military environment. Finally, we apply our expertise in digital voice coding to the problems of providing intelligible voice communications under very difficult conditions.

Civil Radio Communications

Although the Civil Radio Communications Group is presently very small, it has a very interesting and successful record of identifying niche technologies and developing them to the point they can be exploited by industry. Some examples are enhancements to the RACE HF system and SkyFax - a facsimile system for HF radios. There is a clear need for the improvement of communications within mines, for both operational and safety reasons, and we are working in cooperation with mining companies to apply new technologies to this problem. Some potential products have already been identified, which should be possible to develop over the next few years. Although we have been investigating the application of cryptography to consumer communications for some time, it is just beginning to receive significant interest from industry. We are continuing effort in this area in anticipation of a great demand for this technology in the "information age", to provide both privacy and authentication of messages.

SHARP

The Stationary High Altitude Relay Platform (SHARP) is a concept that we have been developing at CRC for about ten years. It envisages an unmanned aircraft (the platform)

flying in a circle at an altitude of about 20 kilometres. This platform would receive its power from a highly-focussed microwave beam from the ground, and would be capable of flying on station for months at a time. From its operating altitude, it would have a service radius of more than 300 kilometres. It could carry various payloads such as communications systems for regional communications services, radar for surveillance, or instrumentation for atmospheric monitoring. Although we have demonstrated the feasibility of microwave-powered flight (a world first in 1987), and in spite of efforts of the private sector, the funding required to proceed with this work in Canada has not yet been secured. Unless we are successful in finding significant funding within a very short time, the program will be dropped.

SATELLITE COMMUNICATIONS

Satellite communications has been an important part of CRC's mandate from its beginning in 1969. Over the years, the emphasis has changed from the fixed satellite service and direct broadcasting (e.g. CTS/Hermes) to mobile communications. We expect the major global thrusts in satellite communications over the next decade to be in the expansion of personal and general mobile communications services, in increasing spectrum utilization efficiency through new modulation and coding methods, and in the extension of satellite services into higher frequency bands. Many new research opportunities exist to support these initiatives and, with an experienced staff of forty and five main activity areas, we are well-positioned to contribute effectively.

The mobile satellite (MSAT) program requires the provision of substantial technology development support to the program. One example is the engineering of a method for using secure telephones (required by government users) with MSAT. Other involvements in the 1500 MHz band are the development of ICAO equipment and system standards for the aeronautical mobile satellite service and development of proof-of-concept satellite radios for the Ontario air-ambulance service.

We will support various aspects of the department's initiative to develop the technology and use of Ka-band (30/20 GHz) for satellite communications. Currently we are conducting tests with the European Space Agency's Olympus satellite to evaluate a prototype group demodulator. Our plans include a personal communications terminal and an aircraft terminal. Field trials of the latter may be carried out using NASA's Advanced Communications Technology Satellite, to be launched in 1993.

We have been very successful in marketing our services and attracting interesting and useful work from DOC/Spectrum Engineering, Transport Canada, National Search and Rescue Secretariat, DND, the CSA and the Province of Ontario. We expect this to continue, with increased cooperation with the Canadian Space Agency being an obvious goal, due to our complementary mandate.

We carry out satellite communications R&D under these topics:

- Advanced Satellite Communications
- Modulation, Coding and Multiple Access
- Mobile Satellite Terminal Development
- Military Satellite Communications
- Satcom Engineering and Networks

Advanced Satellite Communications

We conduct research and development into system concepts and technologies suitable for future generations of communications satellites. Current priorities are the study of satellite onboard signal processing, the development of personal communications satellite technology

and the conduct of experiments using the Olympus Ka-band repeater. On behalf of the National Search and Rescue Secretariat/DND, we evaluate satellite position location systems and continue development of satellite systems and technology to support search and rescue. We also participate in CCIR NSG-4. We have developed an enviable reputation in all these areas.

Future work will be achieved through a combination of in-house projects, R&D contracts and collaborative activities with industries and universities. This will be supported by funding from the CRC A-base, Spectrum Engineering and other government departments. Planned programs include on-board signal processing studies, satellite-based personal communications terminal development, an experimental program using the Olympus satellite and continued development of technology to support search and rescue applications.

Modulation, Coding and Multiple Access

Our emphasis is to utilize signal processing techniques and technologies in order to achieve reliable, efficient, and economical communications for a broad range of mobile and portable applications. This objective is exemplified by the following project areas: aeronautical-satellite data communications (for Transport Canada), narrowband VHF tactical radio for secure voice and data transmission (for DND), studies on modulation, coding, and multiple access for mobile communications (for DOC/Spectrum Engineering), digital implementation of radio, and MSAT support.

We anticipate that the aeronautical-satellite and the MSAT support areas will be reduced in effort, with the resources being redirected towards other areas such as intelligent vehicle-highway systems. The modulation, coding, and multiple access studies, along with a project for the digital implementation of radio, will position us well for supporting new initiatives in the expanding areas of mobile and personal communications. All of the projects have a significant in-house component but efforts will be made to leverage the activity as much as possible by external collaboration with universities, and industry.

Mobile Satellite Terminal Development

The plan for this group is to develop mobile satellite systems, equipment and techniques to enhance vehicle operations. Tremendous potential exists for the development of vehicle communication and location systems. We will continue developing mobile vehicle satcom terminals focussing on the development of low-cost antennas and RF processing subsystems. Such work will require extensive design, testing, and fabrication of experimental equipment.

We will expend significant effort on the development of proof-of-concept L-band aeronautical satcom terminals. Our plan is to solicit funding from a variety of provincial and federal clients and to pursue this work in such a fashion that commercial terminals are

available by the 1994 launch of MSAT. In parallel, we will pursue an EHF aeronautical satcom program. Every effort will be made to establish R&D client relationships with small high tech companies. R&D support will be provided to these companies, who will cooperate with us through MOU's, joint patents, contracts, and shared working arrangements.

Military Satellite Communications

Through our research and development, we aim to improve the technology of survivable and enduring satellite communications for military applications. As a result of many years' experience working on DND programs, we have expertise in the specialized areas of electronic counter-counter-measure techniques, coding and diversity combining, synchronization techniques, spacecraft signal processing, optical signal processing and free-space optical communications. We are well positioned to conduct research on defence-related satellite communications topics. We also participate in TTCP STP-6 and in NATO/AGARD satcom working groups.

Our DND program of Tasking (application-specific research) and Technology Base (long-term, generic research) will include continued support for DND's EHF satcom program, optical technology development for multi-beam and phased-array antennas and further work on inter-satellite optical links. This latter program has also been supported by the Canadian Space Agency, and may receive further funding under the Long-Term Space Plan.

Satcom Engineering and Networks

We provide project management and system evaluation for the development of future satellite systems. We have developed considerable experience in the management of new satcom projects through many years' involvement with the MSAT project. Other areas of competence include the study of networks and access techniques and the use of satellites in non-geostationary orbits. We provide support to CCIR NSG-8 and its International Working Parties.

Our clients are industry and the user community. To satisfy their demands we will generate new technologies and system concepts. This will be done by carrying out a number of generic research programs within the institute and by working with the Canadian Space Agency in accordance with the Long Term Space Plan. Specific future program developments arising from the above activities will be coordinated with other groups within DOC, established to manage new major Crown projects arising from this work.

MSAT

MSAT is a commercial mobile satellite system which will provide mobile communications for voice and data to rural and remote areas of Canada. By so doing, it will provide complementary mobile communications to those in the major urban areas of the country. Together with its counterpart U.S. system, MSAT will comprise the first comprehensive regional mobile satellite service in the world serving land, marine and aeronautical terminals. MSAT, owned and operated by Telesat Mobile Incorporated, is presently in the implementation stage with an in-service date of mid 1994.

We conceived the idea of a fully integrated national mobile satellite system as early as 1979, in order to offer reliable and state-of-the-art communications to those parts of the country where terrestrial alternatives could not be made available at a reasonable cost. By offering such communications, MSAT would be the tool for the fulfilment of a number of major national aims such as industrial and regional development and sovereignty. We have played the leading role in the development of the enabling technologies both for the satellite and terrestrial components of the system, and together with the MSAT Program Office, demonstrated the commercial viability and the large socio-economic benefits of the venture; initiated and supported national and international activities aimed at ensuring adequate spectrum availability and Canada-U.S. cooperation amongst others; and defined and implemented the strategies and government support programs required in order to transfer the project to the private sector as a viable commercial venture. Although this commercial venture is now nearing its successful introduction through the availability of the system in 1994, a number of technical, institutional and strategic goals associated with the project still require close cooperation with and support of Telesat Mobile Inc. MSAT's ability to continue to offer improved services will depend on the implementation of follow-on systems using state-of-the-art technologies which we are presently developing.

Since 1979, the federal government has provided support to the establishment of a commercial MSAT system and services through the adoption of a favourable regulatory environment, technology and product development in industry, lease of commercial service for federal users and stimulation of the market through a Communications Trials Program. The federal MSAT program will promote the successful introduction of a wide variety of new services and applications by 1994. The program enables us to ensure the maximum industrial, regional and user benefits consistent with government aims set at the outset of the program, develop the technologies necessary for follow-on MSAT systems, and participate in national and international activities aimed at ensuring the continuing success and expansion of the services offered.

MSAT Application-specific Services

CRC continues to play a role in developing MSAT application-specific services for users' various market niches. These applications are also referred to as third party integration where hardware and software development are necessary to integrate the MSAT services with the particular requirements of a user. The users are primarily Federal and Provincial government departments and agencies.

These application-specific services encompass the mobile land, aeronautical, marine and also fixed remote data collection platforms. One example of such a market niche is the integration of the land mobile data terminals with corporate data bases for law enforcement agencies and government highway inspectors for vehicle inquires. Another market niche is the flight-following of aircraft via the MSAT position location system. This application has attracted considerable interest among aviation companies. Another large potential market niche for MSAT terminals is in the area of fixed Supervisory Control and Data Acquisition (SCADA) platforms. The SCADA market is diverse and numerous requiring that application-specific interfaces be developed and trialed to insure the integrity of each system before commercialization.

Part III: Services

An essential but sometimes under recognized part of a research establishment is the various services which are necessary for the overall functioning of the laboratories and which are normally provided to individual researchers. In the case of CRC, these services go beyond the normal "research" services to include the management of the overall site at Shirleys Bay, and several remote sites.

Site Services

The Shirleys Bay site is a shared research campus occupied by the Department of Communications (CRC), the Department of National Defence (Defence Research Establishment Ottawa) and the Canadian Space Agency. The site covers an area of almost 600 hectares and comprises 72 buildings and 13 km of roads. A major responsibility of CRC is the management of the site including the performance of all those functions normally provided by Public Works Canada to its clientele. The Site Services operation is divided into four major areas:

Plant Engineering Services

Plant Engineering Services is responsible for provision of all maintenance, repairs, minor and major construction, and central utility services for the entire site.

Facilities Management Services

Facilities Management Services is responsible for the provision of telecommunications, for the management of cleaning and waste disposal contracts, and for providing general facilities services such as office/laboratory design and accommodation planning.

Materiel Management Services

Materiel Management Services provides procurement services and assets management. It operates Technical Stores and Plant Engineering stores, and is responsible for the operation and management of a fleet of forty-seven vehicles.

Security Services

Security Services is responsible for fire prevention and physical security of the site. A resident nurse, from Health and Welfare, provides occupational health services to site occupants.

Records Management Services

Records Management Services provides central registry services, including storage, retrieval, scheduling and systems implementation, as well as mail operations.

Research Services

In addition to the site services required to support the campus, the various research programs require a number of specialized services in order to carry out their work. These services are provided mainly to CRC employees, but are also made available to the other site occupants through special arrangements. Research Services operation consists of four areas:

Prototype Development Services

Prototype Development Services carries out a wide variety of mechanical and electro-mechanical design, development and construction to provide researchers with specialized mechanical instruments and devices which are necessary for their research projects.

Creative Visual Services

Creative Visual Services creates artwork for journals, reports, brochures, manuals and slides and provides a wide range of photographic services, including camera coverage, film processing and printing.

Instrument Services

Instrument Services carries out maintenance and calibration of electronic instruments to internationally traceable levels, including the certification of standards. This group has the capability to carry out precision electronic measurements.

Prototype Design Services

Prototype Design Services is responsible for the creation of schematic and circuit drawings and printed circuit board layouts. In addition, the group has facilities for chemical milling and etching, plating of precious and non-precious metals and the production of prototype printed circuit boards.

Corporate Services

Corporate Services is a new function at CRC, reporting directly to the President. Once staffed and operational, it will provide financial and personnel services, as well as liaison with other sectors of the department.

Corporate Development

Corporate Development is also a new division at CRC. Its mandate is to provide business development, information services, and the management of intellectual property, including licensing, brokering and information on CRC technologies. Corporate Development is also responsible for the management of research programs conducted on behalf of major clients. It consists of four groups.

The Technology Transfer Office

The Technology Transfer Office provides intellectual property management services and promotes and licenses CRC's technologies to clients. It also provides project management services for IRAP projects and advice and support services to other government departments.

The Business Development Office

The Business Development Office is principally responsible for actively marketing the expertise of CRC and its unique facilities to major government organizations and to industry. It assists in the preparation of collaborative agreements and contracts for specialized services.

Library and Information Services

The CRC Library maintains a highly specialized collection of documents, publications and books. It also offers access to more than 350 scientific and technical databases, and an interlibrary loan service. Other library services include controlled access to classified documents and an inventory of CRC publications. Plans are being developed to provide network access to the collection and to some CD-ROM databases.

Major Client Program Office

The Major Client Program Office is responsible for the management, coordination and implementation of agreements concerning research programs conducted on behalf of, or in collaboration with major clients such as DND.

Part IV: Corporate Plans

Business Plan Overview

The intent of the CRC Business Plan is to identify a detailed strategy to meet the following objectives:

- To increase the number of major CRC clients to better serve federal needs in communications R&D.
- To lever corresponding expenditures of funds by CRC's clients in collaborative R&D at CRC and joint projects to reach defined targets within five years.
- To increase the level of exploitation of CRC's technologies by marketing and transfering technologies to Canadian companies.
- To make available specialized services such as technology transfer services, technical advice services, data base services, and use of unique facilities.
- To increase staff interaction and interchange with client organizations.

The plan will address each of the above objectives separately, developing for each objective both short term and long term strategies. The short term strategy will outline steps that can be taken in the immediate future to meet the objectives. The long term strategy will identify areas where time is required to address political, organizational, financial,resource or other issues. For example, for the first two objectives, the plan will identify problems and opportunities related to each potential client and define a longer term strategy for improving client relationships and increasing the client and resource base.

The business plan will ensure appropriate linkages to CRC's Operational Plan and Strategic Research Plan. All research divisions will have the opportunity to take part in developing the strategy and implementing the plan. It will also include a corporate communications plan which links all the objectives through a promotional and publicity strategy to increase client awareness of CRC, its technologies and its capabilities.

The business plan will be dynamic in that it will be reviewed by the CRC management team on a quarterly basis and will be modified as new opportunities or changes in conditions occur. These quarterly reviews will also be used to determine the progress being made against the intended results.

Resource Overview

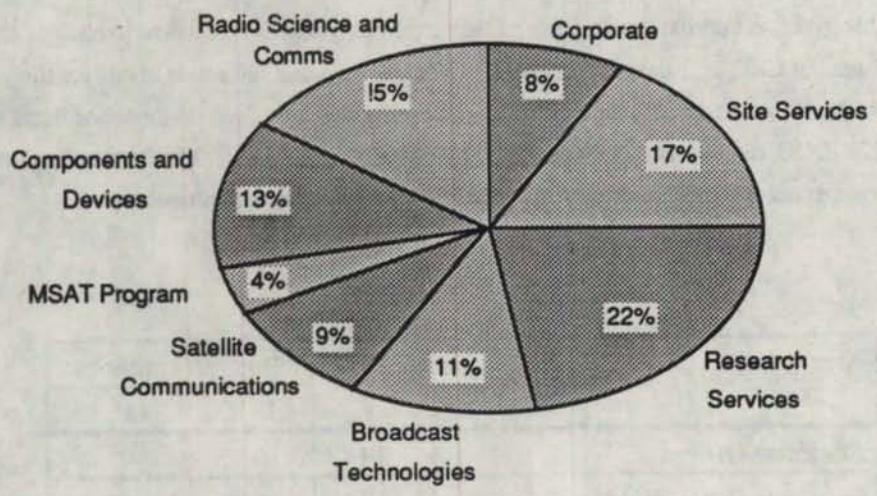
The table gives an approximate picture of the resources that will be applied to each of the major areas of CRC in fiscal year 1992/93. Since the financial reference levels for the year have not been finalized at the time of writing, these figures are based on those for fiscal year 1991/92. 'DOC' represents money allocated by the department, and 'Other' represents money from sources outside the department, usually other government departments.

Approximate Resource Levels

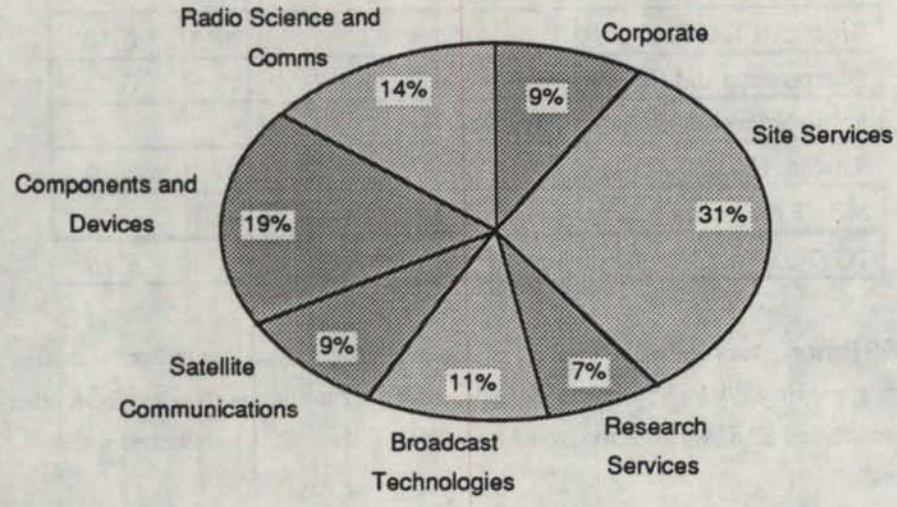
Area	PY	Budget ($million)	
		DOC	Other
Corporate Offices	14	0.15	
Corporate Development	17	1.74	
Site Services	68	6.62	
Research Services	88	1.49	
Broadcast Technologies	43	1.89	0.40
Components and Devices	52	1.41	0.52
Radio Science and Communications	62	1.63	2.45
Satellite Communications	37	1.30	1.79
MSAT Program	15	24.16	
TOTALS	396	40.39	5.16

The 396 Person Years represent a salary of about $18 million, so that the grand total of all costs is approximately $63.5 million. Of this about $5.2 million is received from other departments and $9.6 million is recovered from DND and the CSA for site and research services.

Number of Staff



Budget



Since DOC is a pilot department for the Single Operating Budget (SOB), Fiscal Year 1992-1993 will bring in major changes in financial management. There will no longer be a distinction between O&M and Capital budgets, and person-year controls will be relaxed by the ability to convert between salary and other budgets. In principle, it will be possible to hire new employees using operating budgets. Alternatively, managers will be responsible for ensuring their budgets are sufficient to meet salaries and other operating costs.

Part V: Collaborative Agreements/MOUs

The following is a list of collaborative agreements or MOUs which are in effect between the Communications Research Centre and various national and international laboratories and institutes, both private and public sector.

- Department of National Defence
  CRC provides R&D and site support services to DND in support of Chief, Research and Development/Defence Research Establishment Ottawa.

- Canadian International Development Agency
  CRC provides assistance to CIDA in fulfilling certain agreements under the Canada/ASEAN Technical Cooperation Agreement.

- TR Labs (formerly Alberta Telecommunications Research Centre)
  To develop gallium arsenide-based optoelectronic devices and circuits for broadband switching applications.

- Centre National des Études des Télécommunications (CNET)
  To carry out joint R&D on integrated array antennas for microwave and millimeter wave communications systems.

- ComDev Ltd.
  To co-operate on research into satellite onboard processors and high temperature superconductor microwave circuits for spacecraft.

- Hahn-Meitner-Institute (Germany)
  To co-operate in investigations of the effects of ionizing radiation on advanced GaAs components.

- Iotek Inc.
  To carry out joint R&D activities on GaAs high-speed digital and optoelectronic circuits for acoustic sonar detection systems.

- MPR Teltech (formerly MicroTel Pacific Research)
  Co-operative R&D in microwave integrated circuits and high speed digital multi-chip module design and application.

- Institut National d'Optiques
  To co-operate in research on and development of new technologies in the areas of optical communications and photonic and optoelectronic devices.

- Institute of Microstructural Sciences (National Research Council of Canada)
  To co-operate in research on and development of new technologies in the field of advanced semiconductor devices.

- NovaTel Communications Ltd.
  To carry out joint R&D activities in the areas of GaAs high speed digital circuits and device modelling, integrated digital radio receivers, and UHF microwave ICs and antennas for cellular mobile radiotelephone and Global Positioning receiver systems.

- SPAR Aerospace
  To co-operate on research into phased array antennas and high temperature superconductor microwave circuits for spacecraft.

- Alberta Microelectronics Centre
  To collaborate in the design and fabrication of application specific integrated circuits based on silicon.

- Canstar
  To collaborate in the application of fibre-optic couplers to optical local area networks through technology transfer.

- University of Manitoba
  To collaborate in the research and development of phased array antenna technologies.

- Solid State Optoelectronics Consortium
  To collaborate in the research and development of optical wavelength selective devices for application to communications systems.

- National Research Council
  To carry out co-operative research and technology assessment in support of social, economic and technology development.

- Memotec Data Inc.
  To co-operate on selected areas of communications and information technology.

- Canadian Space Agency
  Agreement on joint participation in the international WG on inter-satellite optical links. Others TBD.

- German Aerospace Research Establishment (DLR)
  Scientific exchange on satellite communications technology.

- Memotec Data Inc. (Teleglobe)
  Cooperative research in selected areas of communications and information technologies.

- National Search and Rescue Secretariat
  Continuing support to new search and rescue initiatives.

- Queen's University and Com Dev Ltd.
  Agreement with respect to research on onboard processing for communications satellites.

- Telesat Mobile International
  Collaborative research on mobile satellite communications.

- Transport Canada
  Cooperation on aeronautical mobile satellite communications and standards.

- Advanced TV Test Centre (US) & Cable TV Labs (US)
  Memorandum of Agreement to perform collaborative research in the subjective evaluation of advanced television systems. DOC contribution to conduct ATV subjective assessments.

Part VI: Technology Licensing

The following CRC technologies are either available for licensing, or have already been licensed. The codes used are: 'XL' - an exclusive licence has been issued; 'L' - a sole licence has been issued, implying that another licence would be granted only in special circumstances; 'P' - pending.

Spectrum Shaping Microwave Digital Modulator
Optoelectronic Compound Switching Matrix
Optical Mixing/Demixing Device
Digital Colour Photographic Image Video Display System
Hybrid Monolithic Interconnection of Optoelectronic Devices
Reflex Optoelectronic Switching Matrix
MultiBit Error Correction of Digital Data
Compact Antenna Array for Interference Cancellation
Broadcast Telidon Encoder
Dual Polarization Electromagnetic Power Reception and Conversion
Microwave Powered Aircraft
Convolution Codec Software Package
Digital Transmultiplexer with Automatic Threshold Controller
Dual Polarization Microstrip Array Antenna
EPIRB Emergency Position Indicating Radio Beacon
Low Noise Dual Polarization Electromagnetic Power Reception Conversion System
Dual Polarization Dipole Array Antenna
TCMP Modem
RJ11/RS232 INTERFACE Tempest to industry fax
Dual Polarization Spatial Filter
Active Integrated Microstrip Antenna
Earth Magnetic Field Compass for Mobile Satellite Communications
Narrowband Communications System for the Mobile Radio Bands
Aviation LBand Satcomm Antenna
Low Cost Mechanically Steered LBand Antenna
Aperture Coupled Microstrip Magic T
Interactive Visual Communication System (CVS Net) (L)
Optical Fiber Coupler Technology (L)
Dual Slope Radiometer (L)
Small Automatic Radio Telephone System (L)
Analog Voice Privacy Device (L)
Spread Spectrum Modem for HF Channel (L)
VHF/UHF Computer Prediction Program & Terrain Data Base (L)
500 Metre Digital Terrain Data Base (L)
Miniature Linear Prediction Vocoder (L)
Small Adaptive Array Antenna (L)
4800 bps MultiPulse Excited Linear Predictive Vocoder (L)
Voice Detection Squelch (L)
HF Maxi Facsimile Terminal (L)
Automatic HF Radio Message Terminal (L)

CAPSSB MODEM Technology (L)
Microwave Polarizing Lens Structure (L)
Fabrication Technique for Fused Taper Directional Couplers (L)
Aviation BPSK Modem Software (L)
8000 bps Codebook Excited Linear Prediction Vocoder (L)
CHAT (Conversational Hypertext Access Technology) (L)
Authorizing Guide & Associated Software for CHAT (L)
Aeronautical Mobile Satellite Protocol Software (L)
Pattern Recognition Algorithm (L)
"Database for AM, FM, TV and NIRAD" (L)
Signal Processing Software Program For Characteristics of Broadcast Channels (L)
RF Synthesizer Hybrid Module (L)
Shortened Conical HeliArray (L)
Back Propagation Implementation (BPI) Neural Network Software (L)
Method of Creating an Index Grating in an Optical Fiber and a Mode Converter using the Index Grating (LP)
Discrete Electronic Mail System (DiSKeM) (LP)
CDMA Simulation Software (LP)
Startrack 200 Control System Software (XL)
VSAT Technology (XL)
Commercialization of a Microminiturized "Forward Error Correction Circuit" (XL)
Contacts 90 Software (XL)
NABTS Teletext/Videotext Systems & Implementation (XL)
Datacasting System Technology (XL)
Spacecraft OnBoard Modular Microcomputer (SOMM) (XLP)
Personal Locator Beacons (PLB) Technology (XLP)
Universal Banknote Reader Technology for the Blind (XLP)
Low Noise Amplifier (XLP)
GaAs Wafer Mapping and Analysis Software (XLP)

Part VII: Recent Research Publications

The following are research publications, published by the staff of CRC since January 1990.

Broadcast Technologies

M. Sablatash, "An error-correcting coding scheme for teletext and other transparent data broadcasting", *IEEE Trans. on Broadcasting*, vol. 36, p. 65, 1990.

B.C. Mortimer, M.J. Moore, and M. Sablatash, "Performance of a powerful error-correcting and -detecting coding scheme for the North American Basic Teletext System (NABTS) for random independent errors: methods, equations, calculations and results", *IEEE Trans. on Broadcasting*, vol. 36, p. 113, 1990.

M. Sablatash, S.T. Craig, and B.C. Mortimer, "Methods and formulas for computer simulation studies of the performance of error-correcting codes for the North American Basic Teletext System (NABTS)", *IEEE Trans. on Broadcasting*, vol. 36, p. 132, 1990.

T.E. Whalen and A.S. Patrick, "COMODA: a conversation model for database access", *Behaviour and Information Technology*, vol. 9, p. 93, 1990.

G. Chouinard, "HDTV satellite broadcasting", *Proc. of HDTV '90 Colloquium*, vol. 1, 1990.

S.J. Lupker and P.J. Hearty, "Quality judgements and purchase decisions: an evaluation of consumer reactions to HDTV", *Proc. of HDTV '90 Colloquium*, vol. 1, 1990.

M. Sablatash, "A communication-theoretic system model for examination and evolution of ATV principles and proposals and its applications", *Proc. of the 15th Biennial Symposium on Communications*, 1990.

P. Fannon, W. Sawchuk, P.J. Hearty and C. Rhodes, "Objective and subjective tests of ATV emission systems", *Proc. of HDTV '90 Colloquium*, vol. 1, 1990.

A. Vincent, A. Mainguy, M. Sablatash, B. Caron, G. Gagnon and J. Maheux, "Design principles for ATV systems", *Proc. of HDTV '90 Colloquium*, vol. 1, 1990.

S. Shlien, "Multiple binary decision tree classifier" *Pattern Recognition*, vol. 23, No. 7, 1990.

B. Caron, "Real-time video channel simulator for ATV", *International Conference on Consumer Electronics*, Digest of Technical Papers, 6-9 June 1990.

C. Casserly, A. Patrick, and T. Whalen, "CHAT on job interviews: new software for career counselling", *Proc. of the International Association for Educational and Vocational Guidance - 14th World Congress*, Montreal, August 1990.

M. Sablatash, "The recent evolution of developments in error-correcting codes for applications in advanced television systems", *Proc. of the Canadian Conference on Electrical and Computer Engineering*, Ottawa, September 1990.

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Y-F Lum and W. Sawchuk, "The merging of communications, computers and broadcasting", *Proc. of Inter Comm 90*, Vancouver, October 1990.

C.T. Le Dinh, J. Maheux, and C. Tremblay, "Evolution of multi-dimensional filtering techniques for composite video applications", *Proc. of the 132nd SMPTE Technical Conference*, New York, October 1990.

M. Sablatash, "System design for HDTV transmission over B-ISDN photonic networks", *Proc. of the First International Workshop on Photonic Networks, Optoelectronics, Components and Applications*, Montebello, Quebec, October 1990.

M. Sablatash, "System design for transmission of HDTV over broadband ISDN photonic networks", *Proc. of the First International Workshop of Photonic Networks, Components and Applications*, Montebello, Quebec, Canada, October 1990.

D.A. Phillips, "Telematics and training for development", *Proc. of the 10th International Conference on Computer Communications*, New Delhi, India, November, 1990.

J.L. Harbluk, A.S. Patrick and S.J. Lupker, "On the fate of unrecalled items", Canadian Psychological Association Annual Meeting, 31 May - 2 June 1990. Abstract No. 6 in *Canadian Psychology*, 31 (2a).

L.B. Stelmach and P.J. Hearty, "Requirements for static and dynamic spatial resolution in advanced television systems: a psychophysical evaluation", *Journal of the Society of Motion Picture and Television Engineers*, vol. 100, January 1991.

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R. Voyer and F. Conway, "Digital audio broadcasting experimentation and planning in Canada", *EBU Technical Review*, April 1991.

G. Chouinard and F. Conway, "Broadcasting systems concepts for digital sound", *Proc. NAB '91*, Spring Convention, Las Vegas, April 1991.

M. Richer, P. Fannon, C. Tanner, and P. Hearty, "Status of testing of advanced television systems", *1991 HDTV World Conference Proceedings*, Las Vegas, April 1991.

R. Voyer, F. Conway, S. Edwards and D. Tyrie, "Initial experimentation with DAB in Canada", *Proc. NAB '91*, Spring Convention, Las Vegas, April 1991.

M. Sablatash, "Signal processing to decrease the effects of channel degradation in HDTV transmission", *Proc. 1991 International Conference on Acoustics, Speech and Signal Processing*, Toronto, May 1991.

L. Wang, M. Goldberg, S. Shlien, "Interleaved image adaptive vector quantization", *IEEE International Conference on Acoustics, Speech and Signal Processing*, Toronto, May 1991.

M. Sablatash and L.J. Mason, "The uncertainty principle and applications in advanced television", *Proc. 1991 International Conference on Acoustics, Speech and Signal Processing*, Toronto, May 1991.

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G. Gagnon, B. Caron, J. Maheux, A. Mainguy, M. Sablatash and A. Vincent, "Design principles for ATV systems", *HD World Review*, vol. 2, No. 3, 1991 (Reprinted from HDTV '90 Colloquium proceedings).

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T. Grusec and L. Thibault, "Musicam listening tests report", *CRC Report #CRC-RP-91.001*, October 1991.

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T.E. Whalen, "Accessing the magic of virtual worlds", in *Bioapparatus* (Book), p. 86, Banff Centre for the Arts, 1991.

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D.A. Phillips, "Value Added Services on Computer Communications Networks: Emerging Technologies and Social Issues", *Proceedings of INFOCOM'91*, Bombay, India, November 1991.

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