Department of Communications

Research and Development 1976-77

Government of Canada
Department of Communications

Gouvernement du Canada
Ministère des Communications

RESEARCH AND DEVELOPMENT

in the

RESEARCH AND SPACE SECTORS

of the

DEPARTMENT OF COMMUNICATIONS

CANADA

ANNUAL REVIEW, 1976/77

INTRODUCTION

With communications promising to play an ever increasing and vital role in maintaining and strengthening the social, cultural, political and economic fabric of Canada, Parliament created the Department of Communications in 1969.

The Minister of Communications must promote the establishment, development and efficiency of communications systems and facilities for all Canadians, in an environment of rapidly-changing technology. This responsibility entails determination of needs, formulation of plans and policies and co-ordination with the work of other departments and agencies, so that communications systems and services for Canadians are maintained and extended in the best possible ways.

It thus requires a significant research and development role for the department, which spends approximately one-third of its total budget on science and technology activities.

The Research Sector of DOC is engaged in a variety of scientific and technological programs of mission-oriented basic and applied research. It seeks to advance the state of the art in communications and computer/communications, provide input to departmental policy-making and planning, advise other government departments and support Canadian industrial expansion.

The department's Space Sector reflects the growing importance of satellite communications to Canada. Created in 1974, its in-house activities emphasize such areas as assessment of the suitability and likely performance of new technology for space applications, definition of the probable nature of future satellite requirements, identification of critical technical problems affecting

satellite communications systems, component or system feasibility studies and demonstrations in speculative or difficult areas, often with resultant technology being transferred to industry.

The department's principal research and development facility (and the key public sector repository for communications and space-oriented scientific and professional expertise) is the Communications Research Centre, just west of Ottawa.

This review, covering principal R & D activities of the Research and Space Sectors of DOC during the fiscal year 1976/77, is intended to inform agencies and organizations with which the department interacts professionally, as well as a broader public, of the background, extent, accomplishments and purposes of DOC research and development.

It is hoped it will facilitate better and more informed contact.

Those wishing further information should get in touch with the directors, program or project leaders listed at the end of the report.

CANADA

DEPARTMENT OF COMMUNICATIONS

RESEARCH AND SPACE SECTOR R & D ACTIVITIES

1976/77

H I G H L I G H T S

--Successful operation and commencement of applications experiments with Canada's HERMES, world's most powerful communications satellite and forerunner of a new breed of high-powered broadcasting satellites operating in the 12 and 14 GHz bands.....

--Demonstration of high-quality color TV reception, direct from a communications satellite, using new earth terminals as small as 0.6 metres in diameter.....

--Installation, for trial and refinement purposes in a Northern Quebec Inuit community, of a novel, hybrid VHF-HF repeater system for trail and remote camp radio communications for Inuit and other native peoples in remote regions of Canada.....

--Launching of a major program aimed at helping to improve communications facilities and service capabilities in rural areas of Canada.....

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--Another year of successful research activity on behalf of the Canadian Forces, including a proof-of-concept demonstration for a proposed satellite aided search and rescue system (SARSAT) and development of a new, inexpensive HF communications antenna that is both highly-directive and broadband

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Two new directors-general joined the department's Communications Research Centre in 1976/77: Dr. Bert C. Blevis, Director-General, Space Technology and Applications, from the department's international branch, and Dr. Martin Fournier, Director-General, Radio and Radar Research, from Laval University.

R E S E A R C H S E C T O R

RADIO AND RADAR RESEARCH BRANCH:

RADIO PROPAGATION LABORATORY

Microwave Propagation Studies for Space and Terrestrial Paths

Our ever growing requirements for more communications have resulted in a continual shift towards the upper end of the radio frequency spectrum, where bandwidths necessary for expanding services may be found. Digital communications, short and long-haul radio relay, cable television trunk circuits, radar and satellite communications are all competing for new microwave allocations.

The situation calls for long-range policy decisions. But optimum planning and design of communications systems must be based on sound understanding of the manner in which such radio waves propagate. Propagation effects of greatest importance are attenuation and depolarization, due to precipitation, and multi-path effects arising from the refractive structure of the troposphere. This project, which includes several different studies, investigates these effects at UHF and microwave frequencies.

At 11 and 16 GHz, transmission links have been set up so various combinations of polarization may be transmitted and received. They are intended to provide detailed information on the cross-polar discrimination which can be maintained during rainstorms. In addition, one of the links has been instrumented with a high-speed digital transmission system, capable of measuring digital errors during periods of multi-path fading.

At 13 GHz, a study of precipitation attenuation of sky noise, based on radiometer measurements at seven locations across the country, has been going on for several years. Data are being converted to statistics of precipitation attenuation which would have occurred on earth-space communication links and will be compared with predictions based on a rain attenuation atlas.

At 4 and 30 GHz, a 10-day experiment was conducted using beacon transmissions from the U.S. ATS-6 satellite, under conditions of near-horizon propagation.

Directly-related work was also supported through research contracts at three universities: the University of Western Ontario developed equipment to measure multi-path delay times and angle of arrival; Carleton University began work on a 37 GHz wideband digital propagation experiment and basic propagation

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studies at 70 GHz were continued at the University of British Columbia.

Shared Programs

This program involves three projects being carried out with various forms of assistance and participation from other agencies.

Two climatological factors--radio refractivity and rainfall attenuation--are of prime concern to many communication services in Canada. The need for a country-wide assessment of these factors, to benefit all users, was agreed to following representations from the Canadian Radio Technical Planning Board (CRTPB). This led to the initiation of a research project to evaluate available data for all regions of the country and develop atlases of refractivity and attenuation. Meteorological data covering a number of years at several locations were obtained from the Department of the Environment and processed in a lengthy study, under way for the past several years. All refractivity data have been processed and a first draft of an atlas prepared. Statistics of rain rates have also been derived. The next stage will see conversion of rain rate data into radio wave attenuation statistics. The end product of these studies will be two sets of atlases, which will indicate the magnitude of the two parameters for different regions of the country and for different frequency ranges.

The successful launch of Canada's experimental HERMES satellite, in early 1976, provided a unique opportunity to study rain attenuation and depolarization on a satellite-to-earth path at 11.7 GHz. Work was carried out in cooperation with Bell-Northern Research.

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The required equipment was built and installed at CRC and initial measurements during several thunderstorms were obtained during the summer of 1976. (A more extensive series of measurements were being planned for the summer of 1977.) Considerable success has been achieved in deriving a theoretical model that accurately predicts the relation between rain-induced attenuation and depolarization of microwave signals.

Because rainfall is usually fairly localized, one possible way of minimizing microwave attenuation on communications circuits is through site diversity. A two-year study into such possible benefits, involving locations near Toronto and Montreal, was undertaken on behalf of Teleglobe Canada.

A pair of radiometers, spaced a few kilometers apart, were operated at each location, in simulation of a satellite-to-earth circuit with site diversity reception. The results of measurements made during the summer of 1976 were similar to those made the previous year, indicating that the site diversity improvement for the Quebec sites was substantial. The Ontario locations experienced no appreciable improvement. Further work in this area is under discussion.

Support for International Commitments

The Canadian space program has built upon the success of Alouette-I, the CRC-built spacecraft launched in the early 1960s to study the topside of the ionosphere. It was followed by three additional Canadian-built satellites, in a comprehensive International Satellites for Ionospheric Studies (ISIS) program that involved 11 countries in a coordinated program of data gathering and analysis. Many scientists in other countries are still participating in

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collaborative studies.

The program remains active, with two of the satellites, ISIS I and ISIS II, still operating. It is coordinated by an international working group, whose chairman is at CRC, where satellite operations are scheduled and controlled. The department provides processed data to members of the experimenter group and participates in several joint investigations. Several dozen specific ionospheric studies are underway, with CRC participating to a limited extent on problems associated with ionospheric communications.

The past year's activity included frequency of occurrence studies of ionized ducts in the magnetosphere, inter-satellite transmissions between the two ISIS spacecraft, work on 200-700 kHz noise bands observed over the poles, and a look at effects of the ionosphere on the doppler frequency of emergency beacon signals for a possible search-and-rescue satellite application.

DOC scientists participated in the UHF propagation study group of The Technical Cooperation Program's (TTCP) panel on space communications. The group is modelling the trans-ionospheric UHF propagation environment. CRC has contributed models of mid and high-latitude propagation during disturbance conditions that included fading on low elevation paths and enhanced natural radio noise levels.

CRC also participated actively in development of Canadian positions for three World Administrative Radio Conferences (WARC) to be held in Geneva under the auspices of the International Telecommunications Union (ITU). Information on tropospheric effects on radio propagation was provided to the subcommittee for the 1977 Satellite Broadcasting WARC. The accuracy of interference range contours used to determine frequency sharing between aeronautical stations was

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investigated for the 1978 Aeronautical Mobile WARC. The department has also been active on committees concerned with rearrangement of the radio regulations and with frequency allocations and technical regulations for the 1979 General Radio Conference.

An interim working party (IWP) of the International Radio Consultative Committee (CCIR) has been concerned with sky-wave propagation at frequencies below 150 kHz. The party's work is being coordinated by its CRC chairman. As one contribution to the study, signal strength measurements of transmissions from Ottawa on six frequencies between 20 and 90 kHz were made over a period of years at several points in Canada. Resultant data are being prepared for inclusion in the final IWP report.

VHF-UHF Propagation

The ability to predict accurately the signal strength, at any location, that would result from existing or proposed transmitters is vital to the planning and management of the VHF/UHF region of the radio spectrum. A project to develop a computer based VHF/UHF propagation model relevant to the Canadian environment was undertaken in 1975. The accuracy of this model was to be checked against the results of field measurements. First stages of the project, involving parts of Southern Canada, were completed in 1976. A start was also made on extending the validity range of the model to include Canada's Arctic regions.

The initial computer model included both statistical and detailed models for the calculation of path loss, as well as a topographic data base encompassing some 14,000 square kilometers of terrain in the Ottawa area. The

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data base enables propagation path profiles to be generated automatically. Field measurements of the path loss of television transmitters in the Ottawa area were made. These measurements were intercompared with predictions from the model, which was then modified, as appropriate. To extend the model's validity, measurements were taken at Resolute Bay and at Inuvik, N.W.T., during summer conditions, with further minor adjustments to the prediction program following.

The next phase will involve a series of measurements at those same locations under winter conditions, to be followed by a longer-term measurement program in the Great Lakes area. Results from the latter program will allow tropospheric effects on long paths in these areas to be modelled with a higher degree of confidence than has been possible in the past.

RADIO COMMUNICATIONS LABORATORY

The Inuit Trail Radio Project

The economic base of Canada's northern native people is largely dependent on land resources. Members of communities must frequently leave settlements to hunt, fish or trap. As a result, they need communications from settlements to and from trail parties and remote camps, as far as 200 miles from home. In response to a request from the Northern Quebec Inuit Association, an experimental project was undertaken in 1975 to explore various means of providing reliable trail communications and, with the participation of the Inuit, to demonstrate a suitable prototype system.

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The concept adopted is based on VHF and HF portable transceivers, in combination with a repeater base station. A limited number of fixed VHF transceivers, located throughout the community, would ensure, around-the-clock availability of at least one operator for emergency messages. The system is intended to operate like a party line, with all users throughout the community being potential operators. The project is now well-advanced.

Koartak, a Quebec Inuit community of 125 persons about 200 miles north of Fort Chimo, is the village selected for the pilot project to demonstrate concept feasibility and ascertain if native needs can be met. Equipment installation is being made there in several stages. During 1976, a VHF-FM repeater was installed, along with a fixed HF transceiver. The units have been in use by the Koartakmiut for some time. Early in 1977, tone-signalling and interface units were added. Later in 1977, the installation is to be completed, following which the equipment would be left with the Inuit for trial operations. The active participation of the native people has been required at all times.

Work has involved collaboration and discussions with industry and Bell Canada. Further equipment development would be required to provide permanent installations for additional native communities and permit interface with other communications systems.

Ionospheric Modification

Initial work on ionsopheric modification was carried out several years ago in the U.S. It showed that very powerful HF transmissions could modify portions of the ionosphere, causing them to scatter or reflect VHF/UHF signals,

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which otherwise would pass unaffected through the ionosphere. American work also showed that such scattered signals could be used for communication purposes. Because both the ionosphere and the orientation of the geomagnetic field at Canadian latitudes differ from the American situation, the U.S. results are not expected to apply in Canada.

To explore just what might occur when, by design or accident, ionospheric modification does occur at our latitudes, a modest project was mounted to investigate the scattering properties and their communications potential. An existing HF transmitting facility at CRC is being revamped to serve as the ionospheric "modifier". Calculations have indicated it should be capable of causing a scatter effect sufficient to support long distance UHF communications. A UHF bistatic radar equipment to assess scattering properties is also being developed. It is expected initial experimental observations will be made in mid-1977.

Spectrum Surveillance

The major responsibility of the Department of Communications is management of the radio spectrum.

Much of that function is in the process of being automated, with the initial phase involving the busy land mobile service and a computerization program called Spectrum Management System (SMS). CRC is providing assistance, including advice based on interference and environmental monitoring studies, and is undertaking a research project to produce criteria and obtain statistics on spectrum occupancy.

Because of the scope of the SMS program and its tight schedules, the CRC

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project has had to be closely integrated with it. Commercial spectrum surveillance equipment has been acquired and data on current utilization and occupancy in the land mobile band are being obtained in several communities.

To satisfy a more general monitoring requirement, and as a basis for continued input to the spectrum management process, CRC is developing an independent environmental monitoring system to cover the HF, VHF and UHF bands.

Radio Noise and Interference Measurements

Radio noise and interference are forms of pollution that adversely affect rational and effective use of the spectrum for communications. Research can help assess and evaluate these effects and recommend mitigating or preventive measures.

Some of the major noise sources are corona and spark discharges on extra-high-voltage power lines, automobile ignition systems and lightning. CRC is active in the measurement and characterization of noise from such sources and in relating measurements of noise intensity and amplitude probability distribution to the performance of communications systems subjected to noise contamination.

In the HF spectrum, such measurements have been under way for some time. Recently, interest has concentrated on emissions from power lines. Considerable effort has been devoted to measurement standards and equipment- independent parameters, so results can be intercompared with those obtained elsewhere and interpreted in terms of their effects on communications systems. Studies are now being extended upwards in frequency to 1,000 MHz, to cover the TV and land mobile bands. Urban environment measurements of man-made noise at 500 MHz were

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also begun in 1976.

A study of effects of ignition noise on error rates on communications circuits was begun. The technique is to subject the system to measured amounts of man-made noise, compute the error rate from theory, then confirm the computations by actual measurement. Performance theory for various types of man-made noise on different communications systems can be tested in this way.

RADAR

Airborne Radar and Remote Sensing

As a consequence of extensive experience with airborne radar systems for military applications, CRC is able to contribute to the planning of airborne and satellite-borne remote sensing systems.

Substantial technical support is being provided to the interdepartmental task force on surveillance satellites and in detailed program planning for proposed Canadian participation in the American SEASAT-A experimental satellite program. CRC provided the bulk of the information used by the task force for assessment of current and projected technical capabilities of space-borne radar imaging systems and for the proposed satellite surveillance system.

This work has been crucial to a number of decisions concerning the data processing system for Canadian involvement with the SEASAT-A experiment and post-SEASAT-A digital processing of radar imagery. A number of fundamental questions concerning the feasibility of digital processing of satellite imagery remain to be answered: for instance, what effects might the ionosphere and sea

surface backscatter have on the ability of a satellite-borne radar to image ships and other specific targets and surface features?

Adaptive Radar Research Facility

Technological advances of the past few years have opened up a number of possibilities for major new developments in radar systems. To explore such possibilities, adaptive radar techniques which could have applications for air traffic control, surveillance of Canadian air space, and ship-borne radars are being evaluated.

The focus for the project, sponsored jointly by the departments of Communications and National Defence, is the development of a flexible adaptive radar facility. It incorporates an electronically-scanned phased antenna array, a coherent transmitter/receiver with a high degree of adaptivity and a complex, computer-based digital signal processing system. The phased array antenna was loaned to CRC by the Royal Signals and Radar Establishment, as part of a Canada-UK technical exchange.

During the past year, a rooftop laboratory was completed and the antenna installed, along with an advanced digital beam control subsystem, designed at CRC and built by Canadian industry.

Present efforts are directed towards implementing a medium-power, coherent transmitter/receiver facility, together with the digital processing subsystem. When completed, the facility will allow research into a variety of adaptive radar techniques, such as electronic (rather than mechanical) antenna beam steering.

TECHNOLOGY AND SYSTEMS BRANCH:

COMMUNICATIONS SYSTEMS RESEARCH AND DEVELOPMENT

Mobile Radio Data Systems Project

Following recommendations of the Computer/Communications Task Force that computer/communications be recognized as a key area of industrial and social activity, studies of industrial capabilities, standards and protocols for data terminals, and needs and markets were initiated.

Among the many terminal opportunities examined, mobile radio data systems appeared to be a likely viable market opportunity for Canadian industry.

In particular, Canadian police forces were identified as potential lead users in the area of computer-aided dispatch and data retrieval. Subsequently, DOC initiated discussions with the RCMP. The result was an agreement to design and build a mobile radio data system, combined with a computer-aided dispatch (CAD) capability, for installation and trial with a Canadian police force.

The first phase of the project consisted of two major contracts to develop an overall system design, determine the state of the art in digital transmission via radio and seek ways to improve on it. This phase, which produced a new mobile radio data system MODEM (for which a patent application is in process) was completed in 1976.

The second phase involved computer-aided dispatch requirements and the choice of the Vancouver Police Department as the co-operating force for initial installation and trial of an operational mobile radio data system.

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Cost-sharing arrangements were worked out with the City of Vancouver and work is proceeding through a contract with MacDonald, Dettwiler and Associates, of Vancouver. A further phase, designed to provide research and development support for creation of new Canadian products, will follow. Of particular interest is work on in-car terminals---a subject with considerable scope for creative design---and on the communications controller, where the present concept of a mini-computer can probably be replaced with a more cost-effective micro-computer.

Needs Research in Computer/Communications

As a follow-up to the Computer/Communications Task Force, work on understanding and quantifying current and projected needs of Canadian users of computer/communications has been in progress for several years. During the current year, a significant step was an extensive and intensive survey of a large number of sophisticated, high-volume users. Data were collected on corporate background, computer communications networks and equipment, traffic applications and expenditures. More qualitative questions, such as user satisfaction with carrier services, were also explored.

Quantitative results have been included in a computerized data base, which also contains historical information derived from annual surveys by the Canadian Information Processing Society, Dunn & Bradstreet and other sources. This data base is being used for development of descriptive models of traffic patterns and the Canadian computer/communications industry, as well as in other studies in support of federal policy development.

Urban System Studies

Studies of the technology associated with delivery of new communications services to individual homes were begun in 1976.

The work is a prelude to policy formulation and consideration of regulatory questions within the department. Its importance is dictated by the complexity of the issues raised by the prospect of such systems and services.

The first study involved examination of the possible implications for Canada of VIEWDATA and TELETEXT services in the United Kingdom. (VIEWDATA was developed by the British Post Office and TELETEXT by the British Broadcasting Corporation and the Independent Broadcasting Authority.)

The British systems offer a wide variety of services to the television subscriber, including news, education, weather, travel and hobby information. DOC studies suggest they are unlikely to be directly applicable to the Canadian scene. Differences in population density, demand and other factors would likely require major conceptual changes.

A second study is assessing functional characteristics required for terminals and cable systems for future home services. An associated review of developments in network technology is also under way, and the effect of potential new offerings on consumer spending on entertainment and information services is being evaluated.

Integrated Remote Communications System

Until recently, most telecommunications to and from small, remote communities in Canada's Northland were via HF radio.

But several factors combine to render this relatively inexpensive mode of

communications somewhat unreliable. And, in the light of inferior service quality, current utilisation of available HF technology is generally considered unacceptable.

Satellite communications are favoured as a better alternative. High reliability can be provided with facilities now becoming available to an increasing number of northern communities. But satellite terminals are still relatively expensive. For smaller communities, exploration parties and off-shore shipping, it is desirable to consider more cost-effective communications.

The aim of the Integrated Remote Communications System program is to develop such a solution. The approach is to integrate modern high frequency radio, voice-processing, telephone switching and satellite technologies into a common, automatic dial-up system. A fully-automatic HF radio telephone can be used to link small communities with larger ones equipped with satellite terminals.

The improved radio telephone would look after inter- community communications, while the satellite system would provide north-south communications. Use of small, local switchboards would permit community distribution and links to portable trail radios.

Intelligibility of the radio link would be improved through use of new voice processing techniques being developed by CRC to reduce the effects of a "noisy" channel. This integrated remote system is being developed through the combined expertise of CRC personnel and various Canadian companies. Plans call for a pilot system to be deployed for evaluation in 1979.

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Optical Communications Research

Because of the potential of optical technology as a supplement to (or an alternative for) radio in communications of the future, CRC conducts applied research into the theory, techniques, materials, components and performance of optical-fibre telecommunications systems. An evaluation of the technological feasibility of using optical-fibre transmission lines for the distribution of telephone and broadcasting services in rural regions of Canada is also under way.

During the past year, significant advances in the study of sources and detectors for the analog transmission of TV signals through fibres were made and high-performance fibre-optic star and "T" couplers were developed. System studies have shown use of such components in fibre-optic networks reduces the quantity of fibre required to deliver telecommunications services to subscribers, with concomitant cost reduction over other distribution schemes.

The study of nonlinearities inherent in optical fibres led to the first demonstration of continuous wave Raman and Brillouin oscillation. The Raman oscillator is a new, highly-efficient source of tunable radiation, with many areas of application---for example, as a unique source of tunable radiation in the infra-red, where optical fibres exhibit their lowest loss and lowest dispersion.

The Brillouin oscillator has attracted considerable interest for use as a precision navigation gyroscope. A separate study is now in progress to determine the validity of this application.

A new method for fabricating low-loss glass for possible use in optical fibre manufacture was conceived and demonstrated.

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Other activities of the group have been concentrated on second generation optical communication technology, the study of corrugated planar waveguide devices for use as filters and wavelength multiplexers and demultiplexers.

The group has also been active in light wave communication systems, in anticipation of involvement in a proposed field trial of fibre-optic technology for delivery of broadband communications services in rural regions of Canada. Several studies of modulation methods and system configurations have been carried out in-house, to determine the most efficient ways to use fibre optics in communications networks.

A fibre-optic system test-bed facility for evaluation of components and subsystems, (including fibres, sources, detectors, and digital and analog repeaters) has been implemented. This facility will be invaluable for monitoring rapidly developing fibre-optic technology.

A demonstration asymmetric, switched, integrated fibre-optic delivery system for voice and television delivery has been designed and built. Solid state switches are used for program selection in a central office, which serves to distribute selected programs to a limited number of subscribers.

THE RURAL COMMUNICATIONS PROGRAM

In 1976, the Department of Communications, concerned about the need for improved communications in most parts of rural Canada, initiated a major research program.

It is aimed at assessing communications services in rural areas,

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identifying ways in which they could be improved, identification of equipment development required and determination of types and levels of possible future services.

The program commenced with a preliminary assessment of rural communications---Present Status of Rural Communications in Canada (July, 1976). A number of additional studies have since been undertaken, or are contemplated for the near future. Most will be carried out by contract.

The studies fall into three main categories: those aimed at a better appreciation of current rural telecommunications services, both as to quality and economics, those concerned with a better insight into the impact of communications services on actual or forecast needs in rural areas and those assessing relationships between improvements in rural communications services and investment in new technologies.

These studies, particularly the latter category, are expected to help stimulate Canadian industry to appropriate action, where marketable products are identified. (The department regards this aspect of the program as of considerable importance.) Unit costs of delivering services to rural areas can likely be substantially reduced through more effective use of present technology, introduction of new technology, and identification of a broader market.

The program should also provide better insight into the nature of the rural population, possible patterns of future change, and cross impacts between telecommunications and socio-economic activity. It should identify new technology suitable for improving rural communications and related industrial and marketing opportunities.

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Institutional changes needed for implementation of certain solutions and advantages and disadvantages of various financial schemes associated with upgraded communications services will also be considered.

The past year was essentially the problem definition phase of the program, though good starts were made on a number of studies. Surveys of available hardware for telephony and CATV were completed. Demographic studies covering the 10 provinces are all but complete. Technical studies aimed at increasing the cost-effectiveness of existing distribution systems, characterizing emissions from radiating cables and assessing the feasibility of a pole line microwave system for rural distribution were launched. A survey of television coverage across the country was also initiated.

These studies are being continued and expanded.

DATA SYSTEMS

Man/Machine Interaction

This project is concerned with experimental and social psychology.

It focuses on the human user as he faces terminal equipment and interacts with the telecommunications system, using his sensory, motor and information-processing capabilities. In particular, the project seeks to develop new research methods and apply them to evaluation of behaviour during interactive communication via the HERMES satellite.

For this purpose, it was necessary to develop a methodology for time analysis of vocal interaction. The method, general enough to be applied to any

vocal communication, allows automated analysis of temporal aspects of vocal interaction between persons or groups at different sites, communicating through the satellite.

Time analysis is used to measure frequency of interruption, amount of simultaneous speaking, average pause length and other parameters of behaviour which may be involved in a better understanding of attitudes towards a particular technology and its effect on human interaction. Results are expected to provide increased understanding of satisfaction or dissatisfaction with a particular communications system---in this case, voice communication via satellite. Specifically, the results should contribute to better understanding of the human effects of delays due to the finite propagation times to and from satellites.

Image Communications

Many images can be stored better electronically than on paper---especially if they change frequently.

Much of our access to such stored images will likely be through telecommunications, rather than physical movement. But new communications systems will be needed.

This project is investigating modular, interactive visual communications systems for use over narrow band lines. The research is a contribution to an understanding of where and how such image communications may be applied. There is considerable interaction with industry and substantial technology transfer (including advice on topics such as the evolution of TV receivers) is taking place.

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Major achievements to date include:

- development of programming languages to simplify development of interactive image communications and manipulation systems;
- Definition of an image display terminal and commands to address it (Graphical Task Instructions, GTI);
- Demonstration of interactive graphic communications via switched telephone lines;
- Development of a state-of-the-art colour TV raster graphics system, in conjunction with Norpak Ltd., and
- Demonstration of the feasibility of application of interactive graphics to Blissymbol communication for the handicapped.

New Data Services and Systems

This project looks at the impact of future new services and systems on telecommunications in Canada and tries to foster development of appropriate computer/communications systems by encouraging a favourable environment. Emphasis is on Canadian ownership and control, regional balances, and ease of user access to services and systems.

Principal activities during 1976/77 involved the study of message and transaction communications systems being planned in Canada for future commercial operations, evaluation of a proposed health information system for Prince Edward Island and development of a relational associative processor (RAP).

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Two specific types of message and transaction system are being studied: those related to the movement of goods and those involved in funds transfer.

In the first area, support is being provided to the Canadian Organization For The Simplification of Trade Procedures (COSTPRO), to define communications protocols for moving files among an anticipated 40,000 terminals and to formulate communications implications of new procedures for handling trade documents.

Electronic payment services provided by automated teller terminals, point-of-sale terminals and other such facilities range from cash dispensing, through credit card payments for goods and services, to preauthorized on-line electronic funds transfers from one account to another. Communications policy concerns arising from the evolution and spread of these systems are being investigated.

An economic and technical evaluation of a proposal from the Prince Edward Island Minister of Industry and Commerce for a health information system for the province was co-ordinated and completed. A number of government agencies at various levels were involved. Results were so encouraging that funding to implement the system was allocated by the Department of Regional Economic Expansion, provided that DOC and the Department of National Health & Welfare provide support on technical and health aspects.

As computer data bases grow ever larger, methods of accessing them become increasingly important.

Several approaches using key word index searches are in vogue today. A different approach is relational searching of data bases, with actual data always searched directly for relevant information. But relational processing

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depends on parallel associative searching. Until the advent of the microprocessor, it had been too expensive to implement.

Such a development now appears feasible. The University of Toronto has a contract for a hardware implementation of a relational associative processor. When completed, it will be possible to search data bases rapidly, even if they are spread out across the country. DOC is now examining the impact of this novel data processing method on distributed computer/communications networks, because it appears likely there is a large potential export market for the hardware system developed under the RAP project. In order to ensure Canadian participation, studies are now under way to assess the marketability of the product and the potential benefit it might have for Canada.

Data Networks Compatibility

To provide for development of reliable, effective, nation-wide data systems, it is necessary to examine compatibility criteria for the interworking of data networks and attendant computer systems. During the past several years, the department has been involved in experimental investigations of distributed switching data communication system concepts. The development, manufacture, installation and maintenance of a multi-node loop configuration was undertaken by contract with ENA Data Systems Inc. Evaluations of the long-haul and local loop systems will soon be complete.

Terminals using different protocols may eventually have to do a substantial amount of communication with each other. Future data networks will have to be interconnected more frequently. Incompatible protocols can result in tremendous terminal and network interconnection costs. The study of

protocols is accordingly very important to the department. But tools for design, evaluation and comparison of protocols are not yet well developed. Effort is being devoted to studies of these topics. Much work involves modelling of computer/communications systems. To date, problems, goals and consideration of the type of modelling that best meets DOC needs are questions that have been addressed and are being pursued.

S P A C E P R O G R A M S E C T O R

SPACE TECHNOLOGY AND APPLICATIONS BRANCH:

SPACE COMMUNICATIONS PROGRAM

HERMES

Spacecraft Operations and Communications Experiments

Canada's experimental communications technology satellite, HERMES, was launched from the Kennedy Space Centre in Florida, January 17, 1976. After being manoeuvered by NASA into geostationary position at 116° west longitude, it was handed over to the CRC spacecraft control centre nine days later.

HERMES was then re-oriented, its solar arrays deployed, stabilization

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system activated and SHF communications transponder and 200-watt transmitter experiment package turned on. A thorough check-out showed the spacecraft was functioning normally.

Checkout of SHF ground terminals and preparations for communications experiments began Feb. 17, 1976.

On March 4, shortly after the start of the 1976 spring solar eclipse season, a relay malfunction damaged a module in the SHF communications power subsystem. To avoid the possibility of a similar malfunction, which could damage the backup power module during any relay operations in the eclipse interval, the SHF communications subsystem was placed in a standby condition. At the end of the six-week eclipse season, the redundant power subsystem was activated and the SHF communications subsystem turned back on.

Communications experiments were officially inaugurated by the Minister of Communications, May 20, 1976, (when the spacecraft was officially named "Hermes"). The ceremony signalled the start of 26 Canadian experiments, to be carried out by 20 different organizations. Experiments are broadly subdivided into two groups: 14 with a "social" emphasis and 12 predominantly "technological." Social experiments encompass tele-education, tele-medicine, community interaction, and administrative services.

Typical educational experiments include communications among the widely-separated campuses of the University of Quebec, exchange and sharing of University courses between Ottawa's Carleton University and Stanford University in California, and communications to and among native communities (an experiment of the Alberta Native Communications Society).

HERMES provided a linkup between University Hospital in London, Ontario

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and isolated northern medical care facilities at Moose Factory, and Kashechewan, Ont. Satellite-aided medical examinations, consultations and decision-making were carried out. Electrocardiograms, X-rays, ultrasonic imagery and other forms of medical data were transmitted during the experiment, enabling base hospital doctors to obtain the advice of specialists at the Southern hospital.

Technical experiments encompass propagation studies, modulation trials, system demonstration and testing and terminal evaluation. HERMES is the world's first satellite with an operational 12/14 GHz transponder and the most powerful communications satellite in orbit. It provides a unique opportunity to experiment with many new services.

By April, 1977, 11 experiments had been completed, nine were in progress, and plans were being made for six more. During a typical operating day, experiments begin at 6.30 a.m. and continue, in blocks of one to three hours, until 1 o'clock the following morning. Every completed experiment has been rated a success by both the experimenter and DOC. Interest in the results is high.

Although some problems have been experienced with several subsystems of the spacecraft itself, none have been serious enough to disrupt any of the planned experiments.

The performance of the primary telemetry transmitter that provides data about onboard functions has been degrading. The backup transmitter was switched in, but failed totally, September 15, 1976. Much of the time, the surviving primary transmitter operates in a low-power mode. This weaker signal can be received by several big NASA tracking stations, which provide invaluable backup

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for extended periods. Procedures have been developed for operation with no telemetry, in the event of complete failure of this sytem.

A short circuit occurred on one solar array on June 8, 1976. It resulted in a loss of 15% of the array power capability----not sufficient to hamper experimentation.

Nominal operation of the key communications system, attitude and reaction control subsystems, and thermal control and command subsystems has continued. Low on-board requirements for attitude control fuel, following a highly nominal launch sequence, have resulted in a large fuel reserve. Consideration is therefore being given to using some of the fuel for north-south station-keeping in order to hold the orbit inclination below 0.2^{o}. (A low inclination is desirable for better operation of low-cost ground terminals and in cases of poor telemetry.)

On August 3, 1976, NASA declared the HERMES mission a success. Canada did the same October 22. All primary Canadian objectives had been met and good progress was being made on secondary goals. In view of keen interest in HERMES and the satisfactory performance of the satellite in orbit, both countries are actively planning the extension of the operational life of the satellite until January, 1979.

Orbit/Frequency Utilization Simulation

The number of usable longitude spaces for communications satellites in geostationary orbit and the frequency spectrum available for the use of each such satellite are all strictly limited. Poorly-planned or poorly-coordinated use of satellite communications systems can result in interference. The design

of satellite networks and concomitant international negotiations must be based upon precise calculations.

The Orbit/Frequency Utilization Simulation (OFUS) was undertaken to provide a model of factors affecting efficient utilization of both frequency spectrum and geostationary orbit "parking spots".

Development of OFUS was accomplished through an industrial contract funded jointly by the department of supply and services, DOC's space program branch and the department's telecommunications regulatory service. The program development phase terminated in May, 1976. It was followed by another contract, for design and incorporation of additional antenna and ionospheric propagation models.

OFUS is complete and is being used operationally by a number of DOC branches.

SPACE SYSTEMS

HERMES Communications Technology Experiments

This project is concerned with investigating techniques for satellite communications.

It includes three experiments: Synchronization for Time- Division Multiple Access (TDMA), Demand Assigned Multiple Access (DAMA), and High-Speed Data. Each of these has used the facilities of HERMES and associated ground stations. The DAMA experiment is complete; the others are nearing completion.

A TDMA system using Centralized Synchronization And Ranging (CENSAR) was specified and built. It is a new concept and this experiment was its first trial. Precise ranging information about the satellite is obtained at the central station, in co-operation with only three other stations. Any other station is then able to synchronize accurately with the other four.

CENSAR is suitable for use with satellites having spot antenna beams. Successful trials were conducted in the summer of 1976. Results indicate accurate ranging and synchronization are possible with only 30 ns guard time.

The DAMA experiment tested a system for satellite communication operating in a single-channel-per-carrier FDMA (frequency-division multiple access) mode. Hardware items, incuding five remote controllers using microprocessors, were supplemented by extensive software to provide fully demand-assigned access of two-way voice, broadcast and conference calls. Pre-emption of ongoing calls by higher priority calls and automatic data log of call parameters were also featured. The system has been tested and further tests and demonstrations are planned.

The high-speed data experiment was designed to test the broadband capabilities of HERMES channels for digital signals. A new 62.5 Mbit/s modem was designed and constructed at CRC. Error rate tests and quality digital colour TV demonstrations have been conducted. Further tests are in preparation.

AEROSAT

On April 5, 1973, Cabinet approved Canada's participation in an

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international program to experiment with and evaluate an aeronautical satellite capability. This program, called AEROSAT, involves Canada, United States, the European Space Agency and the U.S. Federal Aviation Agency.

Canada will be both a user and a co-owner of a satellite communications system with two geostationary satellites, which will facilitate our air traffic control (ATC) responsibilities over the western North Atlantic.

The Department of Transport, responsible for ATC, requested CRC assistance in the implementation of the ground segment of the system and in system definition and evaluation.

CRC undertook technical activities required for procurement of the aeronautical services earth terminal. These included design, specification and contract action, studies of methods of access control and ranging, determination of requirements for electronic test sets and a satellite simulator, and participation in international working groups charged with system design and definition.

The basic design for the earth terminal has been completed. Issuance of the specification, a proposed method of access control, numerous studies into traffic loading and queuing, and a study of ranging techniques applicable to AEROSAT were also finished. Other work completed included evaluation of proposed spacecraft specifications, contractors' proposed designs techniques for forward error-correcting coding and data modulation, and possible methods for rapid acquisition of signals when operating in a polled mode.

(Editor's Note: The recent failure of the United States Congress to appropriate the necessary funds for U.S. participation has since resulted in curtailment of the AEROSAT program, as originally envisaged.)

Modulation Studies and Development

The purpose of this project is to support applied research and development

related to communications processing techniques for small terminal satellite communications systems. Potential applications and resulting benefits of such systems were determined in a previous program conducted by the planning branch of DOC. The intent is to meet future civilian and military requirements for low cost, reliable and compact earth terminals for thin route type voice and data traffic.

Techniques studied are applicable to a variety of systems, including ANIK, AEROSAT and military tactical satellites. In addition, non-satellite applications, such as mobile communications, are served by developments in this project.

Program outputs have included development of a multi-data-rate modem and a hybrid implementation of a delta decoder, both being marketed currently by industry. Future outputs will result from current development in the areas of digital modulation and source encoding techniques. Specifically, these will include a bandwidth-efficient, fast-frequency-shift-keyed (FFSK) modem and an all-digital delta codec.

Both are to be fabricated with large scale integration techniques. New, potentially cost-effective technology, including surface acoustic wave (SAW) and charge-coupled devices (CCD), is being investigated with ultimate application in spread spectrum communications as a goal.

Mobile Satellite Communications Studies

Conventional satellite communications systems require use of large earth terminals, involving high-gain, steerable antennas. For mobile communications, such as to aircraft, ships and transportable stations, it is impractical to use

such antennas. Different communications techniques must be employed.

This project investigates these techniques, including the use of lower frequencies (in the UHF region), and modulation techniques capable of operating at lower signal-to-noise ratios.

For airborne use, L-Band frequencies were chosen (1550-1650 MHz). Early CRC activities concentrated on system specification, propagation measurements and ocean multi-path investigations. Later, an international experimental program, involving NASA, the European Space Agency, the U.S. Federal Aviation Agency and Canada, was set up to conduct a co-ordinated series of tests with NASA's ATS-5 and ATS-6 satellites.

This program is aimed at providing a basis for the design of more operationally-oriented programs, such as AEROSAT and MARISAT.

In collaboration with the department of transport, which provided a JetStar aircraft as a flying laboratory, and the department of national defence, which made a C-130 Hercules available, a series of experiments have been conducted. These included evaluation of various types of voice and data modems, detailed probing of ocean surface multi-path effects, and evaluation of a phased-array antenna developed under an industrial contract.

Experiments have also been conducted to study multi-path and propagation effects at frequencies from 130 MHz to 20 GHz (over the ocean) as the satellite rose above the horizon when being "drifted" to a new station. Similar experiments at L-band frequencies have been conducted over Arctic terrain.

These activities resulted in development and refinement of a model of ocean "multi-path," production of statistics of fading due to propagation effects, development of novel types of voice modem capable of operation at low

signal-to-noise ratios in the presence of multi-path, and development of data transmission and error correction techniques suitable for the aeronautical channel.

SPACE ELECTRONICS

SHF Technology

During the past year, several separate studies were undertaken into new circuit elements for space communications systems in the SHF band (3 to 30 GHz). Commercial equipment is not available for all parts of this band. In-house R&D work, together with industrial involvement, as appropriate, is being aimed at future utilization of these frequencies.

A major effort was devoted toward in-house development of a 12 GHz uncooled parametric amplifier in microwave integrated circuit (MIC) form. A number of designs were investigated. The most promising is a novel device that is still being studied. At the same time, a DOC-funded industrial development was undertaken. It also involved a prototype, uncooled 12 GHz parametric amplifier. Market prospects for this product appear good.

Speculative in-house development studies have enabled technical assistance to be provided to several Canadian companies concerned with state-of-the-art, low-noise amplifiers and oscillators which utilize the latest gallium arsenide FET devices.

One such CRC development has already been exploited by Canadian industry and is the basis of a COMSAT contract for a prototype spacecraft X-band source

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using Gallium-Arsenide field effect transistors (GaAs FETs). Other work is underway to determine the effects of radiation on GaAs FETs, a subject of some importance with increasing exploitation of these devices in new and future spacecraft.

Speculative theoretical and experimental studies have been made in a number of circuit concept areas involving MICs. This type of work is expected to continue at a modest level as an encouragement to industrial applications.

One such study has focused on optimum RF configurations and likely manufacturing costs of a 6 GHz data retransmission platform, for use in relaying data from a remote measuring station to some central processing location, via satellite. This appears to be an application of considerable future potential. In-house development work has been initiated to evaluate ideas and assess some of the technical problems involved.

Spacecraft Charging

The sudden failure in June, 1973, of a U.S. communications satellite was the first step in a realization of hazards associated with electrostatic charging on external surfaces of spacecraft in geostationary orbit.

By 1975, this realization had permeated the aerospace industry. As a consequence, studies were begun to determine how such charges could contribute to operational anomalies or malfunctions of the electronic circuitry of orbiting spacecraft and how to prevent such events. Unfortunately, it was not possible to make major additions to the HERMES satellite mission, then in its final development phase. Some minor changes, consisting mainly of additional grounding of surface materials and other measures, were made in an attempt to

prevent effects of surface charging and discharging.

Following the January, 1976, launch of HERMES, a spacecraft charging project was begun at CRC. Its objectives are to provide a better understanding of the physical processes involved, and to produce a set of specifications for protection from electromagnetic interference and for testing of both subsystems and the integrated spacecraft.

The project involves a simulation experiment, university contract work, and close liaison with the National Aeronautics and Space Administration, the United States Air Force, the European Space Technical Centre, and a number of U.S. aerospace companies and agencies.

During the past year, a simulation experiment chamber was assembled and initial tests on it completed. The facility will provide measurements of the RF energy associated with discharges on dielectric materials, and will permit experimental tests in materials modification.

A related experimental project, with a smaller simulation facility, is being operated under contract by the University of Toronto. The University of Saskatchewan, also under contract, is conducting a monitoring program of some magnetospheric parameters that may contribute to surface charging on the HERMES satellite in its orbital position. These activities are continuing.

Multipurpose UHF Satellite (MUSAT)

Work on definition of requirements, consideration of system options and assessment of the feasibility of a multi- purpose UHF satellite, intended to satisfy a wide range of government communications requirements, has continued during the past year.

Major effort is being devoted to assessment of the technical feasibility of the transponder and antenna system which would be required for MUSAT. UHF satellite transponders are susceptible to intermodulation products produced by various transmitted signals, which can seriously degrade receiver effectiveness.

The extent of such intermodulation problems and possible performance and reliability hazards are the principal subjects of this study. An evaluation of intermodulation characteristics of candidate antennas, diplexers, and associated components---along with the construction and testing of a "brassboard" model of the transponder---is included.

Fabrication of this model was initiated in August, 1976 at the conclusion of a systems engineering study which defined transponder and antenna requirements. Most of the transponder components are available commercially, but CRC development of the power amplifier to a pre-engineering model state was found to be necessary. This work is progressing satisfactorily and is expected to be completed in October, 1977.

A MUSAT system would require a highly portable earth terminal, suitable for use in remote locations. Initial cost and implementation studies pinpointed the difficulty of obtaining or developing an adequate antenna. There could be schedule problems, due to long development times associated with some components.

As a consequence, an advanced development phase is under way. It includes contract studies of possible antenna configurations and their portability, ease of erection and implementation. Battery pack options are also being studied. At the conclusion of present studies of earth terminal hardware, development of

selected terminal subsystems is expected to commence.

MUSAT systems engineering activities during the past year also involved frequency plan coordination, development of system models and performance prediction for the proposed system. Numerous short studies on topics such as frequency control, sensor data readout, propagation considerations, and possible modulation techniques have also been performed.

Small Earth Terminals

This project was established to develop and demonstrate the feasibility of low-cost terminals capable of direct television reception from 12 GHz satellites such as HERMES. A further goal was the establishment of a Canadian supplier of microwave components and subsystems for application in SHF satellite earth terminals.

In August, 1976, CRC completed development of a demonstration TV reception terminal, employing a 1.2 meter antenna. The performance of this terminal was comparable to that of several foreign terminals which were also being tested.

A unique feature of the CRC terminal was a double conversion receiver with a relatively high first intermediate frequency to simplify expansion to multi-channel operation and reduce stability requirements in the local oscillator. The small noise figure degradation inherent in this approach was offset by the decision to develop and use a high-efficiency Cassegrain antenna. A second terminal is currently under development. Notable features include high-efficiency, prime-focus-fed 0.6 meter and 0.2 meter antennas, microwave integrated circuit image-enhanced mixer and 1.2 GHz bipolar amplifier mounted at the antenna feed, stable SHF local oscillators and cost-effective processors

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using both conventional and surface acoustic wave (SAW) filters and demodulators. Areas receiving major attention include higher-stability local oscillators, lower-noise 1.2 GHz amplifiers, SAW/VHF signal processors, and low-cost, volume production fabrication techniques. The system tradeoffs required to allow use with future satellites are being evaluated.

During the past year, largely as a result of a contract from DOC, SED Systems Ltd., of Saskatoon, Sask., has developed low-noise amplifiers at 40 GHz and a complete line of SHF mixers. The company is also developing a 12 GHz receiver using a field effect transistor front end, for use in Anik B and C ground terminals.

SPACE MECHANICS DIRECTORATE

Solar Array Development

In keeping with its lead responsibilities for Canadian space technology, DOC has a continuing need to maintain in-house expertise and try to foster an industrial capability in spacecraft mechanical systems. During the past year, the applied mechanics group has been active in thermal design (pipes for heat transfer and improved insulation techniques) and in components and materials work (advanced fibre composites and deployable antennas). In addition, there was major effort on development and testing of a weight-effective solar array, undertaken to meet power requirements, for future communications and other satellites, of between half and two kilowatts.

The development was undertaken through contract to Canadian industry. The

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main constraints and guidelines for the work were that: the array was to meet launch requirements of the NASA Delta rocket, the design concept had to satisfy both transfer and geostationary orbit power requirements, the maximum in-orbit power was to be 2 kw and the array mechanism was to be reliable, light and low-cost.

On the basis of a trade-off study, a design employing articulated rigid frames with tensioned flexible cell substrates was chosen. A development model of the array was fabricated. It is representative of the deployment mechanism, geometry and hold-down system of a flight model. The strength, stiffness and mass distributions were known, so test results could be extrapolated to the flight model.

The development model array was subjected to a series of representative sinusoidal vibration and acoustic exposure tests. One series of tests included the use of actual photovoltaic cells in regions identified as critical from earlier tests. These studies indicated that a viable design had been developed. It has the advantage that required structural properties can be obtained by judicious choice of materials, without changing the basic design concept.

The present array design concept is a candidate for Telesat Canada's Anik-C spacecraft and for the federal government's proposed multi- purpose UHF and surveillance satellites.

General Purpose Satellite Bus Study

NASA's reusable space transportation system (space shuttle) has prompted examination of the feasibility of a satellite bus that could satisfy potential

Canadian geostationary missions of the next decade. During the transition period from expendible to re-usable launch vehicles, it is necessary to consider a satellite bus capable of being launched by both types of vehicles. Identified missions were those of Telesat Canada, in the 4-6 GHz and 12-14 GHz frequency bands, and a possible government mission in the UHF band (MUSAT).

The study was carried out by means of an industrial contract. A constraint was that the basis for the general purpose bus design should be that of the flight-proven Hermes. The study was also to incorporate results of research and development on certain critical components that had already been performed, both in Canada and abroad.

The study established the feasibility of the general-purpose bus. It provided information on the technical implications of both launch vehicles, on the current state of related space technology, and on associated cost and schedule estimates to implement the project. In view of the expanded information base the study provides, it will enhance Canada's ability to plan and implement future space projects.

Satellite and Antenna Control and Pointing

Spacecraft and antenna orientation control work on the experimental HERMES satellite identified "strap-down technology" as a fruitful area for future space applications. Accordingly, the objective of establishing an effective aerospace control capability in Canadian industry through exploitation of the technology is being pursued. During the past year the project included effort on two separate phases.

First was an industrial contract to undertake a literature survey of the

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state of the art in this field (a survey of Canadian computer and sensor manufacturers) and an assessment of possible space applications. The second was a feasibility study of the use of strap-down technology for stability augmentation of the control for the NASA shuttle remote manipulator system (SRMS), which is being supplied by Canada.

A hybrid computer facility was set up to support the project. Identified as a "system 511," it is built around a large general purpose analog computer and is a dedicated, general purpose facility. It can be easily interfaced with any type of analog or digital hardware (such as sensors, transducers or displays) for on line control and decision making, real time hardware performance analysis or real time man-in-the-loop training. And it is highly suited to simulation studies, because it combines the high speed capability of analog computing with the high accuracy of digital computing.

Orbit-Attitude Determination Techniques

A major part of the development of satellite technology is the capability to determine and predict spacecraft orbits, position and attitude in space.

Until recently, DOC depended on the National Aeronautics and Space Administration (NASA) for most requirements of this nature, despite constraints dictated by NASA's particular programs and computers.

To provide for more flexibility and programs better-suited to Canadian requirements, both current and future, an orbit determination program was initiated. It will deliver more efficient computations. Effort is being directed into two areas--an orbit perturbation measurement experiment, using time division multiple access (TDMA) data from the HERMES satellite for

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determining position in orbit, and orbit/attitude determination based on HERMES tracking data. These activities are being carried out by contract.

In the first study, TDMA data are processed together with the known station locations, to produce satellite position results which are being compared with HERMES operational orbit determinations. Potential accuracies of less than a meter have been demonstrated.

For the second study, HERMES tracking data are being studied in detail and subjected to various data processes. To date, close accord has been demonstrated between simulated and actual flight data.

Shuttle Remote Manipulator System

Canada is developing a remote manipulator system (SRMS) for NASA's space shuttle program as a deliberate step toward building industrial capability in space systems for this country.

It is a National Research Council project, but certain aspects involve the Department of Communications, because it has experience in spacecraft systems and its David Florida Laboratory is a unique national facility of importance for certain phases of the development. Because much of the development program is being carried out by industrial contract, DOC support activity consists mainly of:

--Secondment of DOC personnel to NRC for specific functions,

--Consultant support to help with specifications, design review, contract monitoring and reliability analyses, and

--various ad hoc tasks, not covered by industrial contracts, for which DOC has a capability.

CTS (HERMES) Technology Experiments

This is a project in technology development, carried out with industrial support in accordance with basic systems concepts selected by CRC.

It was undertaken in conjunction with the HERMES satellite development and was addressed to the problem of predicting how flexible structures behave in space. Two particular aspects were considered, both unique to HERMES:

1. The design and flight-testing of a three-axis attitude stabilization system, capable of maintaining antenna pointing accuracy to within ± 0.05 degrees, for a spacecraft with flexible appendages and
2. The design and testing, in space, of a deployable solar power array of 1 kw initial capability.

Experimental aspects of the project have been satisfactorily completed. They included demonstration of:

--Agreement between theory and measurement (in space) of 3-axis attitude stabilization,

--Agreement between theory and measurement of the effect of structural flexibility on the stabilization system,

--Satisfactory electrical, thermal, mechanical and orientation performance of the solar array and

--Measurement of the solar and magnetic torque environment and their satisfactory correlation with theory.

In general, results of the various tests have confirmed predictions based on modelling techniques developed for this purpose. The models are capable of extension to larger structures of different design for future space systems.

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THE DOC/DND RESEARCH PROGRAM

Through both its Research and Space Sectors, DOC undertakes a significant amount of R&D work for other government departments.

Most is for the Department of National Defence, in accordance with an understanding reached when CRC, formerly known as the Defence Research Telecommunications Establishment (DRTE), was absorbed from DND by the new Department of Communications in 1969.

Its terms require DOC to continue to fund, on its own initiative, certain research of interest to the military and carry out an agreed R&D program under direct DND funding. It also commits DOC to support DND in international R&D activities and commitments and to provide general backup and advice in communications related areas.

The agreed program currently represents some 55 man-years of effort in direct support of DND research tasks, plus substantial indirect support and background research activities. Details of this program are negotiated through

formal channels each year. They involve a wide range of scientific and technical expertise. In a number of cases, the work has civilian as well as military communications applications.

The recently-investigated problem of tropospheric fading of satellite signals in the high Arctic is an example. Data on fade duration, signal amplitudes, and rate of signal level change were studied to investigate possible methods of improvement. Based on these initial studies, experiments are being conducted to determine the seasonal dependence of low angle fading, the site diversity improvement, and wide band channel characteristics. Results will aid in design of more reliable satellite communications for the North.

SARSAT

Because of Canada's vast size and largely inhospitable terrain and climate, the task of locating a downed aircraft and rescuing survivors is often both lengthy and very costly. A proposal to replace or augment the existing all-aerial operation with a satellite-aided search and rescue system (SARSAT) has recently been put forward. The system would be able to establish a prompt crash alert and then pinpoint location of the wreck to within a few miles, within a matter of minutes. CRC tests of the system concept, using simulated "crash" signals and the Radio Amateur Satellite Corporation (AMSAT) satellite OSCAR-6, were made during the past year and clearly demonstrated its feasibility.

Radio Direction Finding

The program in radio direction finding consists of exploring techniques to improve measurement accuracy of bearing and elevation angles of incoming high frequency waves and improve the efficiency with which measurements are taken. An antenna array with an aperture of 2 km is being used, with properties of incoming waves recorded separately at a number of antennas within the array.

This complete record allows experimenters to perform studies and develop techniques to treat the data at their convenience. Since direction finding errors are primarily attributable to the ionosphere, measurements are being made over various paths and under different inonospheric conditions.

Beveridge Antenna

A new antenna to meet requirements for reliable, long range HF communications links has been developed. It's a long, terminated, horizontal wire stretched several feet above the ground. Because of its inherent simplicity, it is relatively inexpensive and easy to erect and maintain. With its low physical profile, it is broadband and highly directive. Now in operational use in British Columbia, it is comparable in performance to antennas 10 times more costly. Further applications are being explored.

Radar

The radar program includes research and development on ground, ship and airborne systems, as well as microwave remote sensing from the air and space. Principal areas of interest include signal processing with adaptive digital and optical techniques, electronically-scanned arrays and automatic target

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detection, association, and tracking. A large part of the research program is centred on an adaptive array facility incorporating an electronically-scanned array, a flexible beam control system, and an adaptive, coherent transmitter and receiver.

Work on automatic detection and tracking is directed toward maritime and ground-based surveillance requirements of the Canadian Forces. Problems of low-angle and multi-target tracking in maritime fire-control radars are under investigation and facilities are being developed to study possible solutions to these problems. Radar laboratory staff also provide advice to the Canadian Forces in selection of radars for ground-based surveillance, air traffic control, and the ship replacement program.

An experimental side-looking radar (SLAR) has been developed by modifying an existing radar. It was flown on an Argus aircraft. High-quality imagery was generated. It had resolution five times better than that achievable with the original equipment. An optical correlator for processing such signals has been developed cooperatively by the CRC radar and DND laboratories. A processor based on this facility is under study for use in handling signals from the experimental SEASAT-A satellite.

The project is part of the interdepartmental surveillance satellite program in which DND participates. Other work relating to this program includes development of a generalized mathematical model of synthetic-aperture radar signals, application of this model to a study of digital processing techniques and a study of the effect of the ionosphere on the performance of a satellite-borne radar.

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UNIVERSITY RESEARCH CONTRACT PROGRAM

DOC's university research contract program was established to provide access to special expertise and facilities in Canadian universities; for fundamental research in the technical, legal, economic and social areas of communications; to encourage participation of the universities in development of various aspects of communications; and to encourage the initiation and growth in the universities of expertise in new areas of communication of interest to the department.

Each year, the program's emphasis reflects DOC priorities and activities. Thus, in fiscal year 1976/77, a major portion of the university research contract budget was devoted to activities directly associated with HERMES satellite experiments. The program also included research contracts on economic, social and regulatory aspects of communications, spacecraft materials and structures, a futures study, radio propagation, computer activity,

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demography and rural communications studies.

Of total contract money awarded in 1976/77, 52% went to universities in Québec.

Ontario universities got 24%, 16% went to the Prairie Provinces, 4% to the Atlantic Region and 4% to British Columbia.

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SPECIAL FACILITIES

HIGH-RELIABILITY LABORATORY

Because of the impossibility of making repairs in-orbit, when a circuit component fails, any satellite system or satellite mission can be jeopardized by an unreliable electronic component. Space systems are vulnerable unless component manufacturers can build to a much-increased reliability standard.

DOC is taking a leading role in this field. Its High-Reliability Laboratory assesses selected new devices and circuits that have been developed in industry, develops standards and techniques to facilitate such assessments, and encourages Canadian industry to accept higher reliability standards for components and equipments being built for space applications.

Component reliability was recognized early as fundamental to successful Canadian space ventures. A rigorous in-house test and analysis program during the past several years has undoubtedly contributed materially to the success of

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the HERMES (and other) DOC satellite missions. During this period, the laboratory has built up extensive test facilities that include such diagnostic equipment as scanning electron microscopes and an X-ray microprobe, as well as procedures and standards for testing and fabrication. Last year, the laboratory acquired a scanning auger microprobe which will enable critical analyses of material surfaces and interfaces to be performed.

During the past fiscal year, the CRC high-reliability laboratory has been concerned principally with a detailed study of operational malfunctions that occurred on the HERMES satellite, reliability assessment of gallium arsenide devices (particularly field effect transistors) and spacecraft power sources, and with support to both other government departments and Canadian industries interested in reliability assessment of electronic devices and materials.

These endeavours are expected to continue, with particular attention being paid, where possible, to support of industrial efforts aimed at higher component reliability for space applications.

THE DAVID FLORIDA LABORATORY

The David Florida Laboratory (DFL) at the Communications Research Centre is operated by the Department of Communications as a national facility for environmental testing and integration of satellite and space hardware.

The laboratory has thermal/vacuum chambers, ranging in size from 3 x 3 feet to 10 x 30 feet. The thermal control capability allows temperature cycling at predetermined rates in the range from $-195^{o}C$ to $+150^{o}C$, with a

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vacuum capability of at least 10^{-7} torr in all chambers. Also available are vacuum measuring instrumentation, a mass spectrometer for outgassing analysis, and a capability of up to 300 thermocouple data channels. All temperature data can be stored in a digital format for ease in subsequent data reduction.

The DFL also has facilities for vibration testing of satellite and space components, including a 12,000 lb force sinusoidal system, a 10,000 lb force random vibration system, a 6,000 lb force sinusuoidal system and a 3,000 lb force random system. A recording capability of up to 56 direct channels of data is available. Both accelerometer and strain gauge data recording and reduction can be accommodated. Real time analysis of vibration data is also available.

A shielded enclosure and equipment to provide radio frequency interference or electromagnetic compatibility testing is available. There are two anechoic chambers---one, designed for X-band studies, measuring approximately 14 x 14 x 10 feet; the other, for a frequency range of 1 to 20 GHz, being 20 x 20 x 22 feet. This second chamber is completely shielded and provides access through an RF-transparent polystyrene window to a 500-foot antenna range. One side of the chamber also has a pyramidal horn with a 7 x 7 foot opening.

During the past fiscal year, DFL facilities have been used for environmental tests of the space shuttle remote manipulator system, ANIK-B transponder system and prototype rigid solar arrays. The laboratory's RF facilities have been involved in antenna studies for DOC, the Ministry of Transport and the Department of National Defence.

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Radar

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W.L. Hatton, Acting Director-General		596-9387

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W.L. Hatton, Director		596-9341
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J.R. Marchand, Director		596-6072

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Space Programs Branch

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