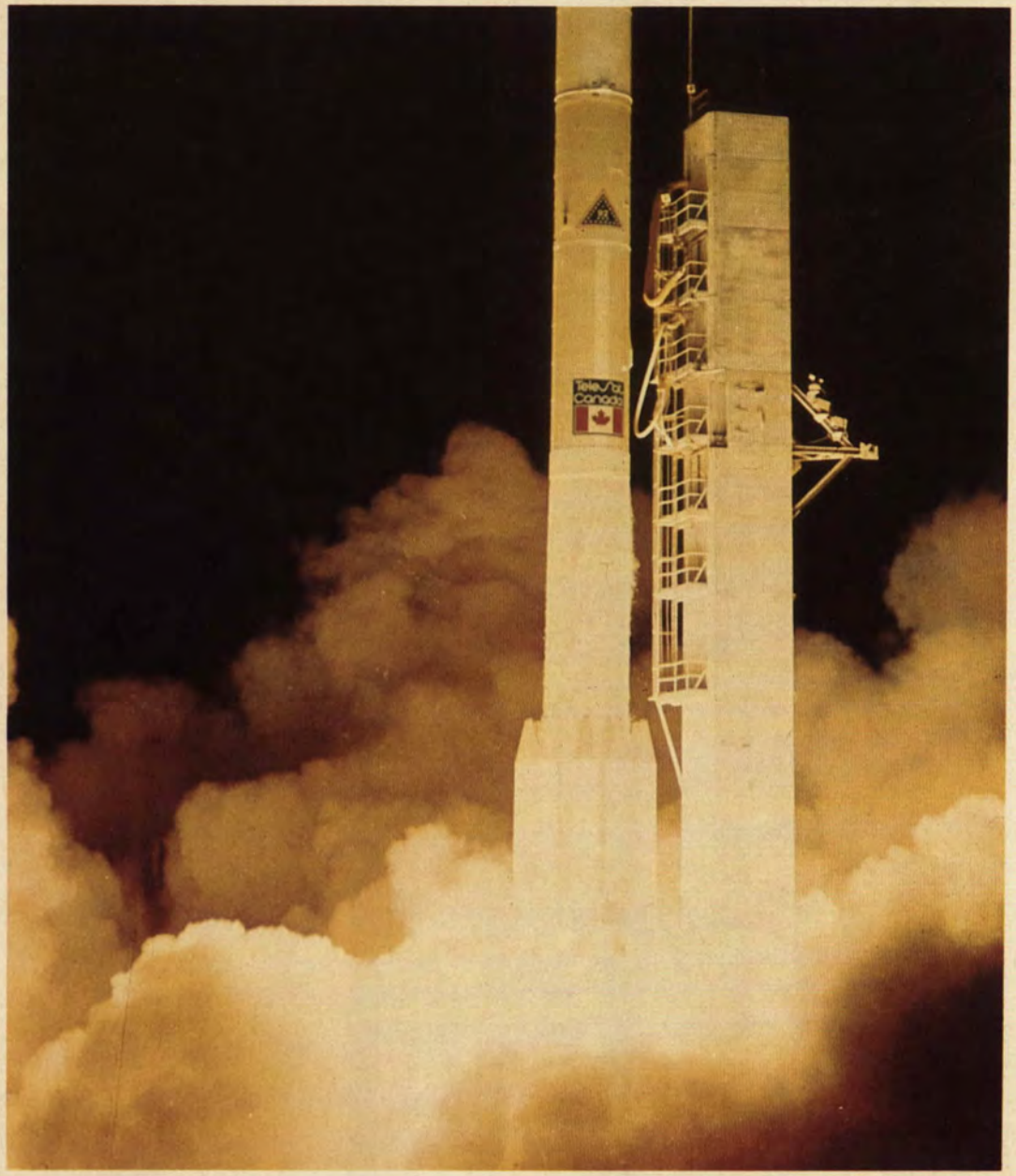
Canada in Space



Canada in Space

Government of Canada | Gouvernement du Canada

Published by the Interdepartmental
Committee on Space

Foreword

The remarkable progress of space technology in the past 20 years has translated the dreams of visionaries to everyday practicalities. While world attention has tended to focus on the more dramatic space achievements, developments in space technology have repeatedly proven the benefits and the potential of space to our daily lives.

This potential was recognized at an early date. Canada was the third nation in the world with a satellite in earth orbit and today, the most powerful telecommunication satellite in the world is Canadian. Through programs tailored to meet specific needs, Canada has built an enviable reputation in many areas of space technology and application.

Our space programs can best be described as pragmatic. We have concentrated our efforts on those programs which offer the most return in terms of benefiting the nation and its people. As a result, we are a world leader in the development and use of domestic satellite communications systems and in earth resources satellite receiving stations and data processing.

The development of space programs is generally initiated and supported by government. In Canada, a deliberate policy has centred technological design and manufacturing in the private industrial sector. Over the years, Canadian industry has acquired design expertise, development and manufacturing capability and international recognition in many areas of satellite and space systems technology.

Recognizing that many space programs require bilateral or multilateral co-operation, Canada participates actively in many international activities. Implications of developments in space have and will continue to occupy the attention of the world community. Canada, through activities in the appropriate international forums, is committed to promoting the peaceful applications of space technology.

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Introduction

Canada in Space

This brochure is designed to provide a perspective on current Canadian policy objectives and programs in space. A section describing the roles and objectives of the government departments and agencies closely associated with space is followed by an outline of major space programs in which Canada is presently involved and a section describing Canada's industrial space capability. Not every company that has a demonstrated capability in space work has been included in this brochure; rather, a sample was taken with the intention of expanding on it in future editions. The last section briefly outlines some of the space research being done in Canadian universities.

Scarcely 20 years ago, the first artificial satellite went into orbit, launching the world into the space age. Canada recognized at an early date the potential of space and became the third nation in the world to develop and orbit its own satellite. Since then, it has carried out an ambitious program of research, development and use of space technology.

Eight successful scientific and communications satellites have now earned this country's space scientists and engineers a reputation for performance and reliability respected around the world. In addition, Canada participates in a number of international space programs.

The country's first ventures into space were for research purposes. Four scientific satellites, beginning with ALOUETTE I, launched in 1962, have added immeasurably to man's knowledge of the ionosphere.

One of the most significant applications of space technology to Canada lies in the field of communications.

Canada has a greater area than any other country in the world, except the USSR. The vast extent of the country necessitates a quite extraordinary attention to the problems of providing transportation and communications services to as many Canadians as possible. The existence of two official languages further complicates the provision of communications services: about one million francophones are spread across the whole breadth of Canada outside Québec, while there are about one million anglophones living in Québec.

The rapid development of space technology has been of enormous importance to Canada, because it has provided solutions for some of the most intractable problems in telecommunications. In 1968, a federal White Paper* described the impact of satellite communications on Canadian broadcasting as follows:

> "A domestic satellite system of even a few channels would make television service in both French and English available to any point in Canada. It would do it sooner, and at a lower cost, than would any other known system of communication. In particular, it would facilitate the extension of television network service into many areas previously unserved because of the prohibitive cost of a terrestrial microwave feed."

Canada now has a domestic satellite communication system trying to fulfill that prediction and facilitate provision of telecommunications services throughout the country, not only in broadcasting but in every mode of acquiring and exchanging information over great distances. While Canadians enjoy a domestic satellite communication system, development of the technology continues. HERMES, a powerful new Canadian-built satellite, which has been described as a forerunner of the direct broadcast satellite, is the most recent success.

The future holds even greater promise in this field. Multiple access will provide two-way, point-to-point communications to isolated communities more economically, while direct broadcasting from satellites, satellite weather-forecasting, remote sensing, aeronautical and marine navigation applications are bound to play an important role in future development. For this reason, Canada is destined to become an even larger user of space systems.

* 'A Domestic Satellite Communications System for Canada', Government of Canada, March 28, 1968.

A Brief History

On September 29, 1962, with the successful launch by the National Aeronautics and Space Administration (NASA) of the Canadian-built scientific satellite, ALOUETTE I, Canada became the third nation to have a man-made object orbiting the earth. Today, there are eight Canadian satellites in orbit, and all but the first two are still operational.

In consequence of a deliberate policy of transferring satellite technology from government to industry, all but the first of the Canadian satellites have been built by industry. This policy has led to the establishment and maintenance of a joint government/industry capability for the design, manufacture and construction of space-applications systems and hardware.

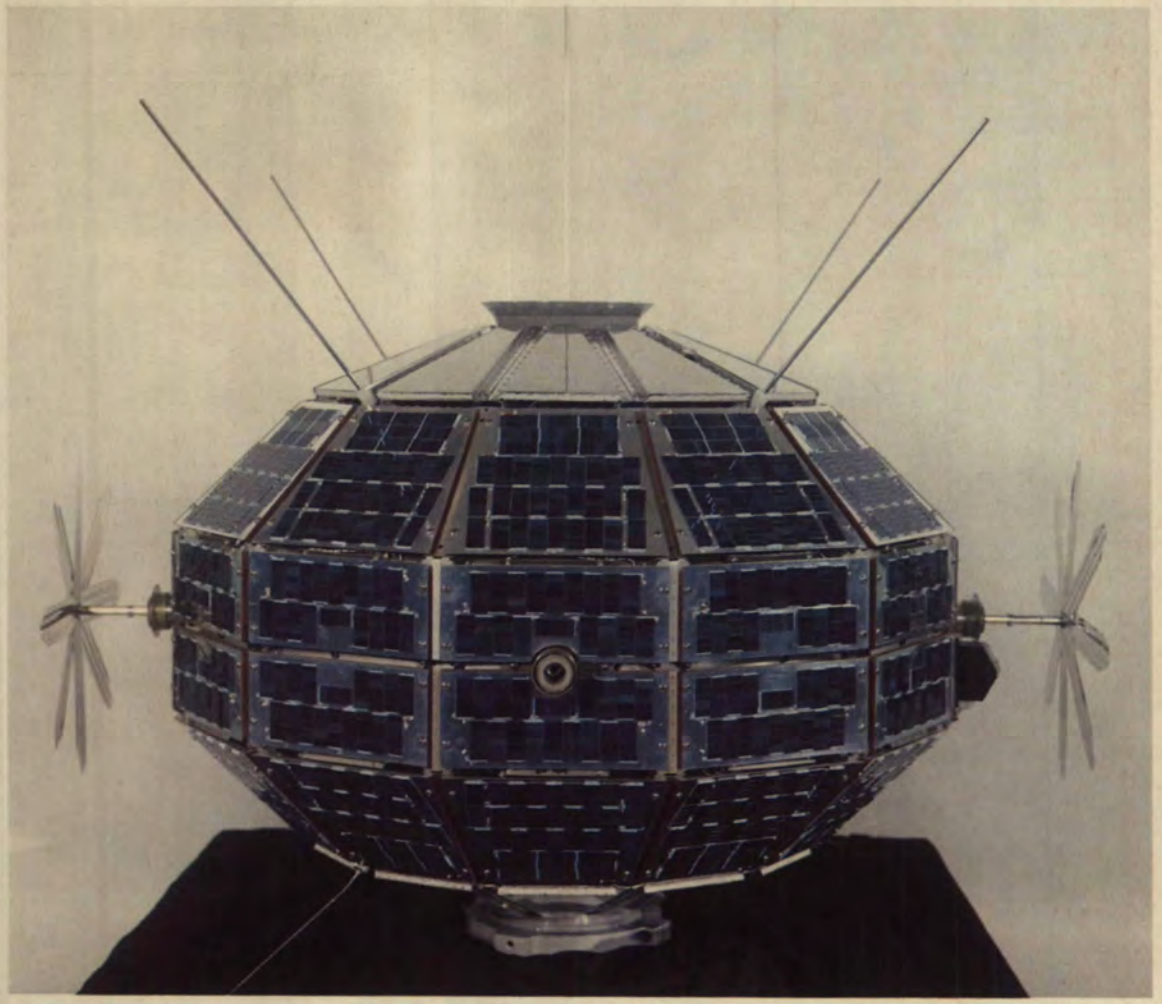
The exploration of space by satellites, which has been going on for less than 20 years, has been so dramatic that many earlier achievements tend to be forgotten. Canada was using balloons in the early 1920s to record temperature and pressures in the upper atmosphere to assist in weather prediction. During the next 20 years, the early meteorographs were gradually replaced by radiosondes, and the use of balloons was extended to cosmic ray studies. In the 1950s, a start was made on spectroscopic and photometric measurements. Balloons have continued to be used for scientific purposes to the present day. In 1976, Canada established its own mobile scientific-balloon launching facility which is described later.

Back in 1957, during the International Geophysical Year, the United States Armed Forces established a rocket range at Fort Churchill, Manitoba, and Canadian scientists began using sounding rockets to investigate the physics of the ionosphere to improve communications in the North. The development of Canadian telemetry components for rocket payloads began in 1960. Rocket flights are still extensively used for research in the upper atmosphere. With only a few exceptions, Canadian-built rockets have always been used at the Churchill Research Range. In 1970, Canada assumed the whole cost of the range. Its services are occasionally sold to the United States.

Balloon, just prior to being launched from one of the launching sites in Canada.

Research Satellites

The launch of the USSR SPUTNIK satellite in 1957 heightened the interest of Canadian scientists in developing a Canadian scientific satellite to investigate the upper side of the ionosphere. An agreement was reached under which the United States undertook to launch a satellite designed, developed and built in Canada. On September 29, 1962, ALOUETTE I was launched from NASA's Western Test Range. At that time, most satellites had a useful lifespan of only a few months. ALOUETTE I, however, was designed to operate for one year; the most optimistic prediction was for five years of declining usefulness. Remarkably, it transmitted useful data for more than 10 years.



Alouette II launched on November 29, 1965.

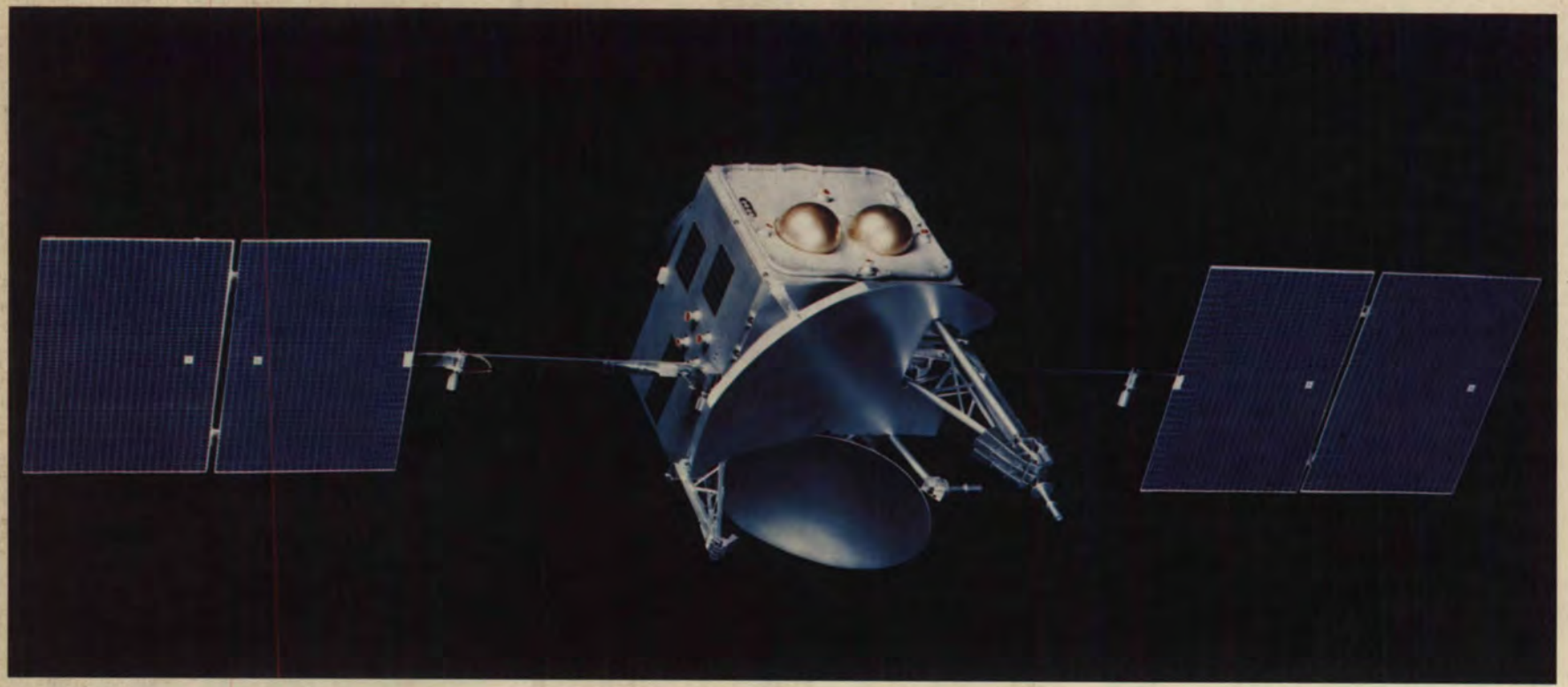
This success led to a new agreement for continuing ionospheric research, under which the United States undertook to launch, at its cost, up to four more satellites to be designed, developed and built in Canada at Canadian expense. This was the origin of the International Satellites for Ionospheric Studies, the ISIS program, which brought Canadian industry into advanced space technology. The stand-by for ALOUETTE I was modified, rebuilt and became the first of the ISIS series. Known as ALOUETTE II, this satellite was successfully launched on November 29, 1965, simultaneously with the United States EXPLORER XXXI, and remained operational for almost 10 years. The experience gained led to development of the more sophisticated ISIS I, launched on January 30, 1969, and still functioning satisfactorily today, and to ISIS II, carrying more sophisticated equipment and additional experiments, launched on March 31, 1971, and still fully operational.

Communications Satellites

In 1964, Canada was a signatory to an agreement concerning a global commercial communications satellite, which was superseded by the INTELSAT Agreement in 1973. Canada is represented on the INTELSAT Board of Governors by Teleglobe Canada (formerly the Canadian Overseas Telecommunications Corporation), which owns and operates the three INTELSAT earth stations in Canada. By the end of 1976, approximately half of the more than 750 telephone and 450 telegraph circuits from Canada to overseas were routed via INTELSAT satellites.

In 1969, Telesat Canada was incorporated to operate a domestic satellite communications system. The system's first satellite, ANIK I, was launched on November 9, 1972, into geostationary orbit at about Long. 114 degrees W., and came into service about six weeks later, thus inaugurating the world's first domestic geostationary satellite communications system. A second satellite, ANIK II, was launched on April 20, 1973, and was followed by ANIK III on May 7, 1975. ANIK B, a dual-purpose satellite, incorporating advanced communications experiments as well as commercial radio and television links, is scheduled for launch in 1978.

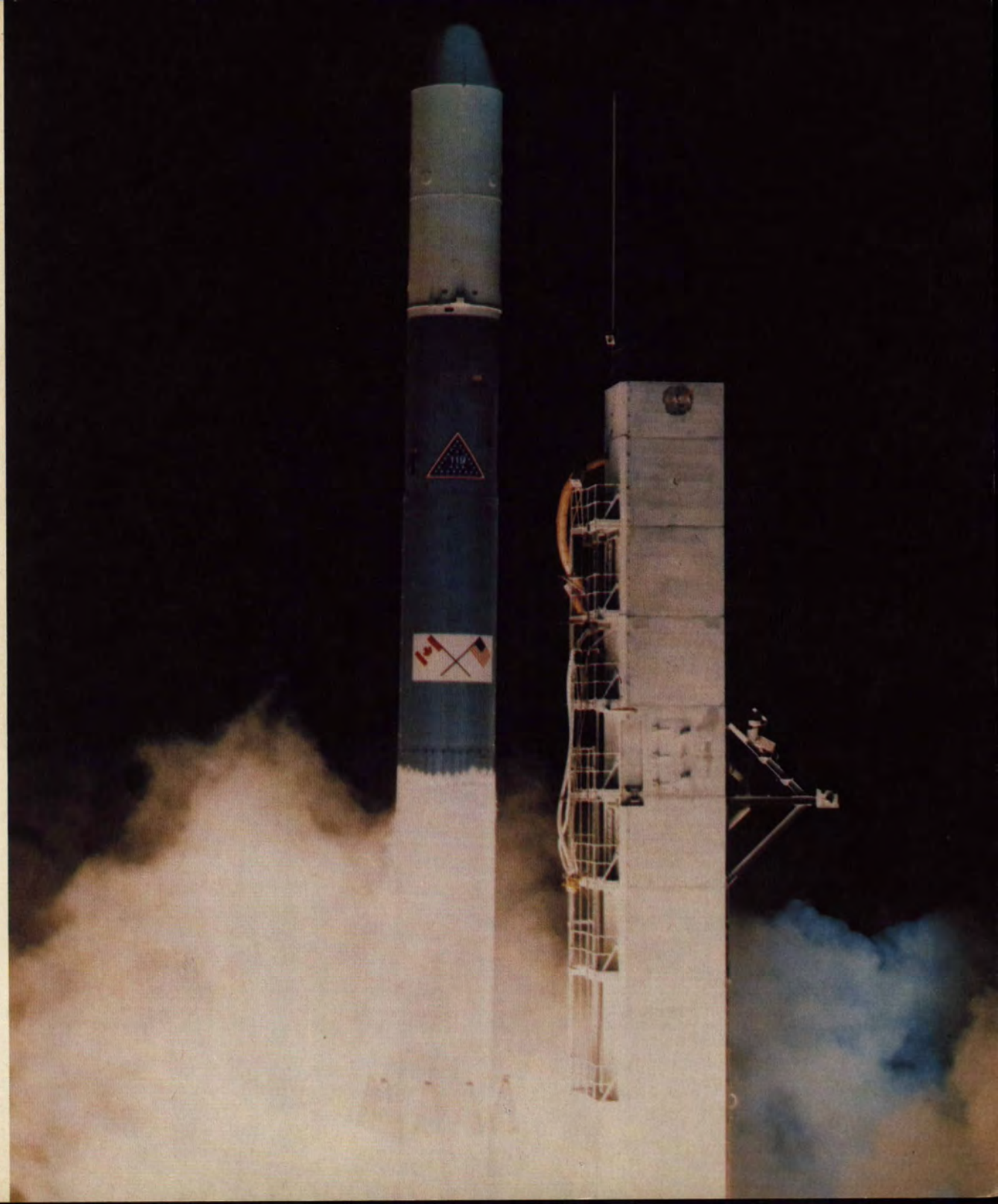
Telesat Canada's first satellite, ANIK I was launched on November 9, 1972 from Kennedy Space Center.

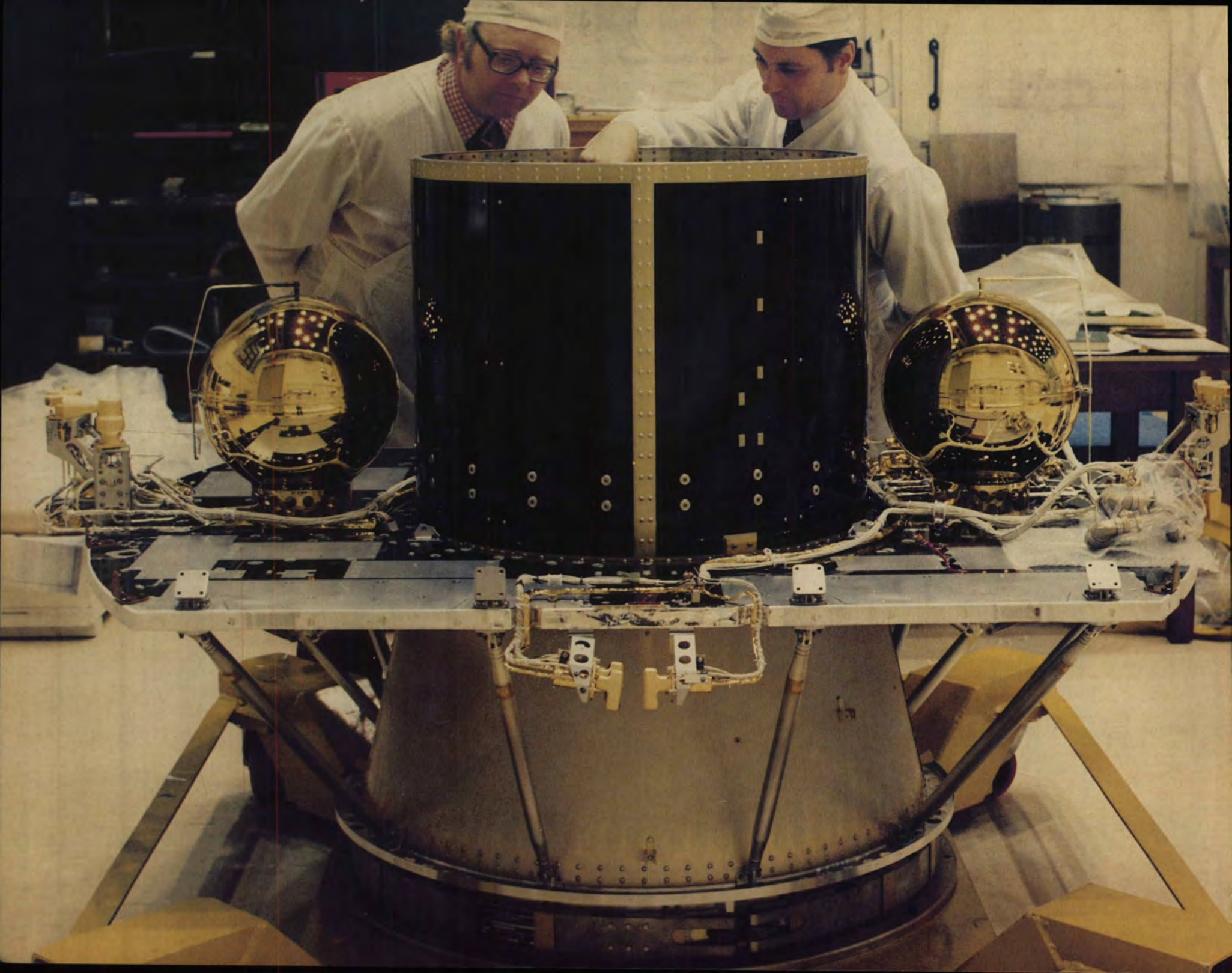


The need for large and expensive earth stations is a serious hindrance to effective communications in remote northern communities. However, this problem might be solved by the development of inexpensive earth stations and the use of more powerful satellites. To test this concept, Canada and the United States embarked on a joint program to develop and launch the powerful experimental communications technology satellite, later named HERMES, and conduct experiments using small ground stations of various types and complexity. The outcome was the launch of the Canadian-built satellite HERMES on January 17, 1976. Since then, an experimental program using the satellite has tested its application in telemedicine, tele-education, inter-community communications, television transmission from remote and even temporary locations and others.

Artist's conception showing the ANIK B spacecraft scheduled for launch in November 1978.

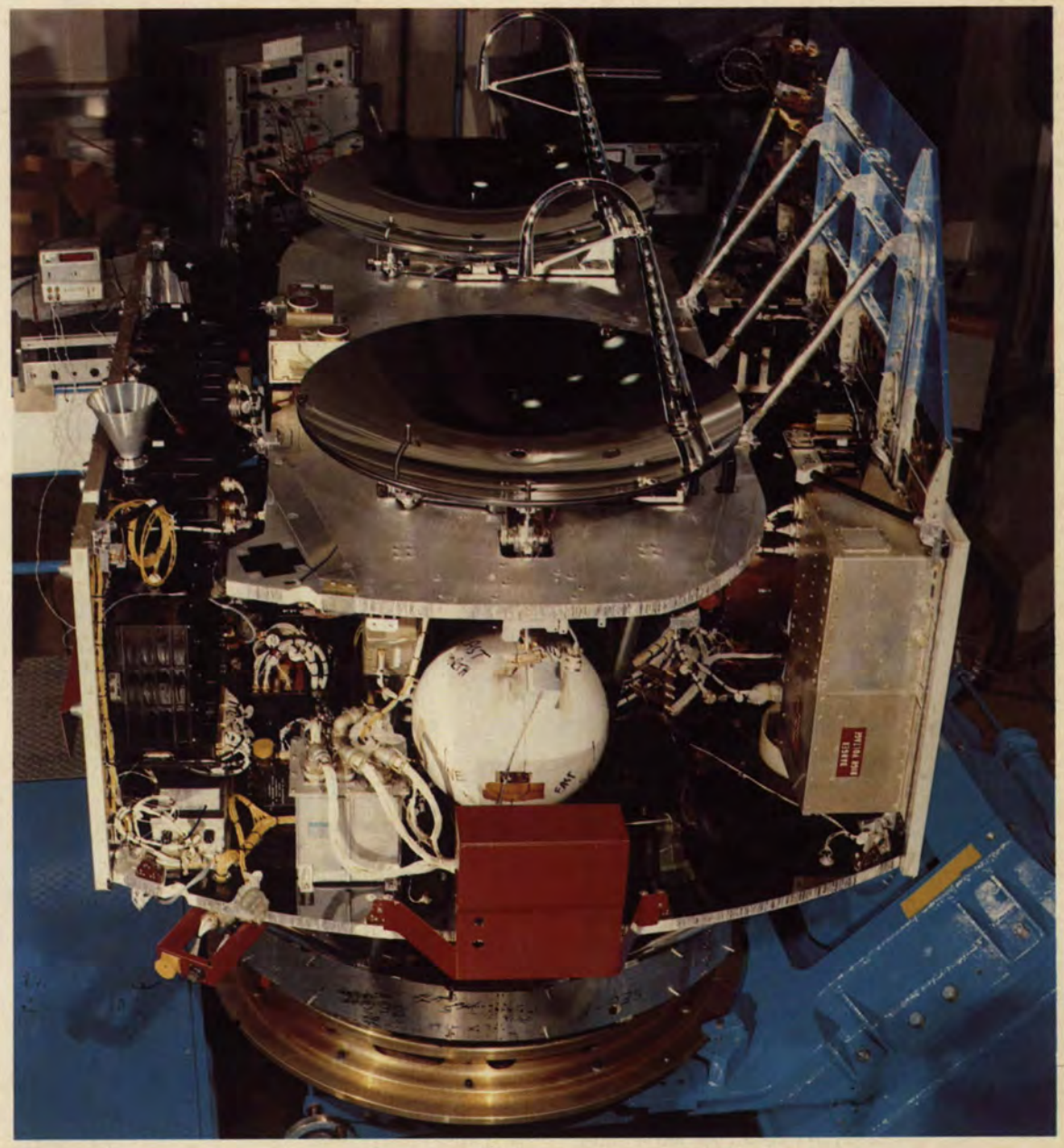
Kennedy Space Center, 18:24 hrs, January 17, 1976, HERMES lifts off in a Delta 2914.

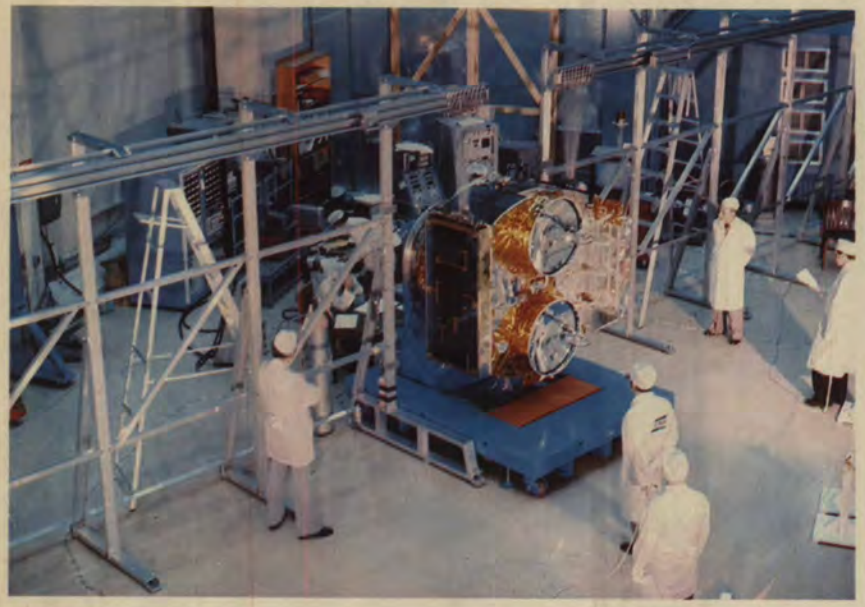


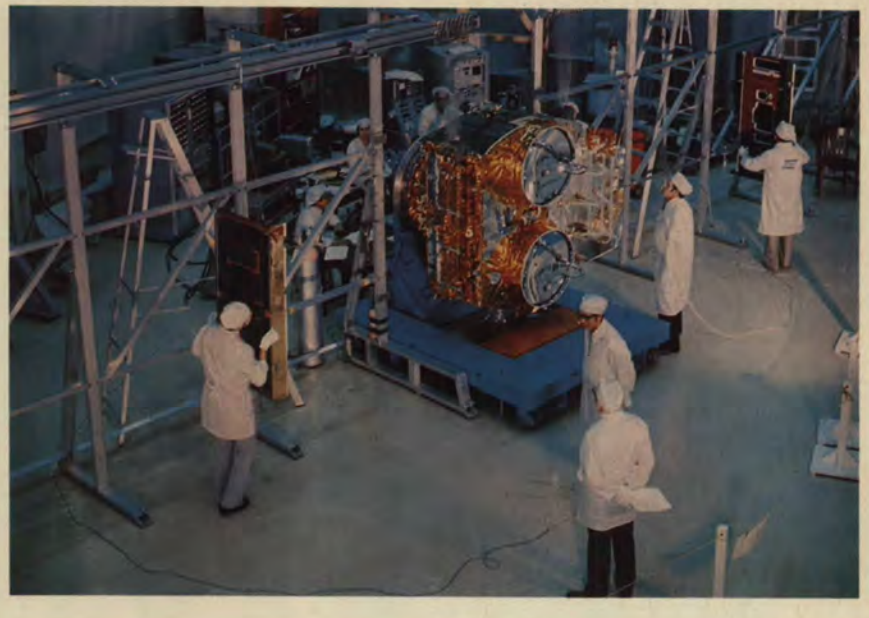


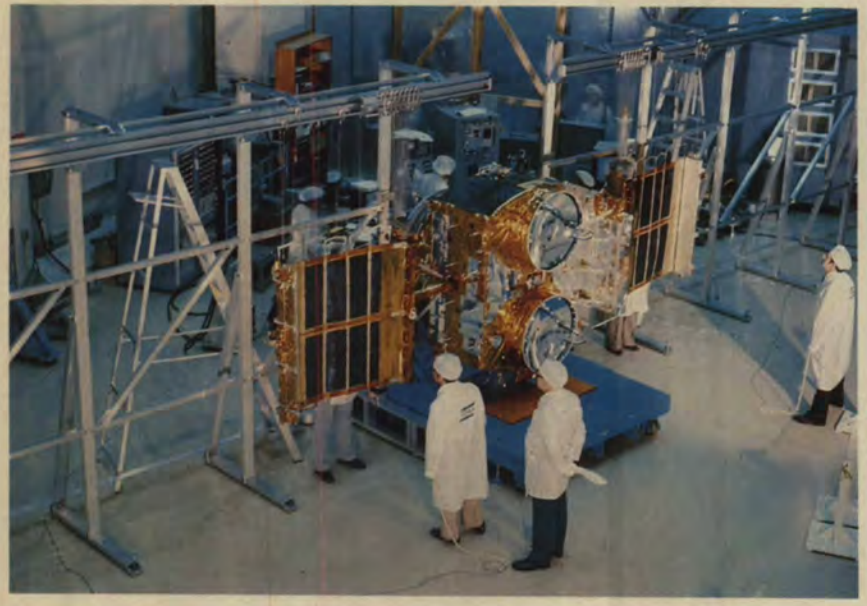
A side interior view of the engineering model of Canada's HERMES satellite.

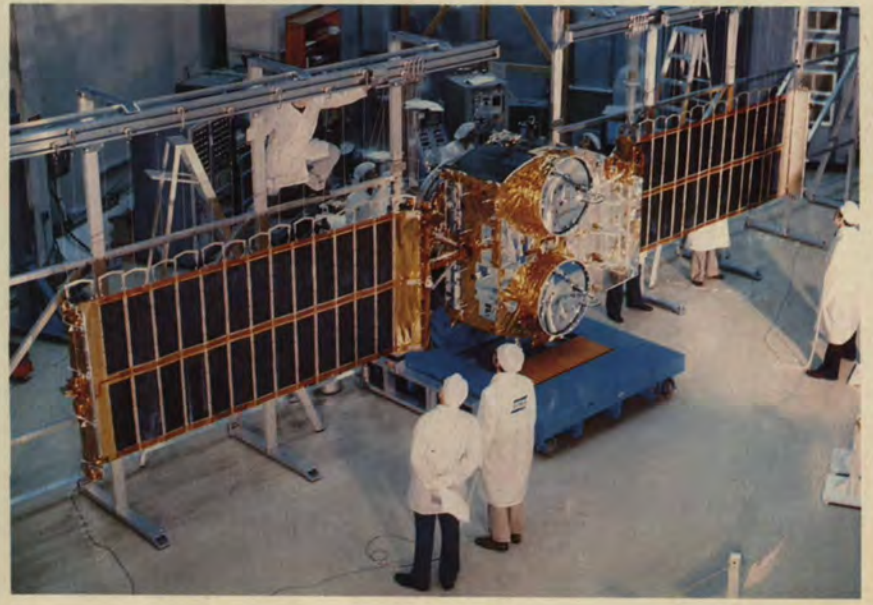
The two hydrazine ($N_2 H_4$) reservoirs used on the HERMES communications telecommunications satellite are of gold-plated titanium and carry a total of 23kg of fuel.











Satellite Remote Sensing

In May 1971, the United States and Canada began to co-operate in a remote sensing program using aircraft and satellites to acquire data. The first United States earth resources technology satellite, now called LANDSAT I, was launched on July 23, 1972. Three days later, on July 26, 1972, the first imagery of Canada was received at the Prince Albert receiving station in Saskatchewan. That station is now supplemented by a second at Shoe Cove, Newfoundland, to provide complete coverage of Canada.

Silt deposits around Akimiski Island, James Bay. Photo taken October 13, 1973.

The HERMES flight-model spacecraft during full-scale solar array deployment test in the high-bay of the David Florida Laboratory.

Remote Manipulators for Space

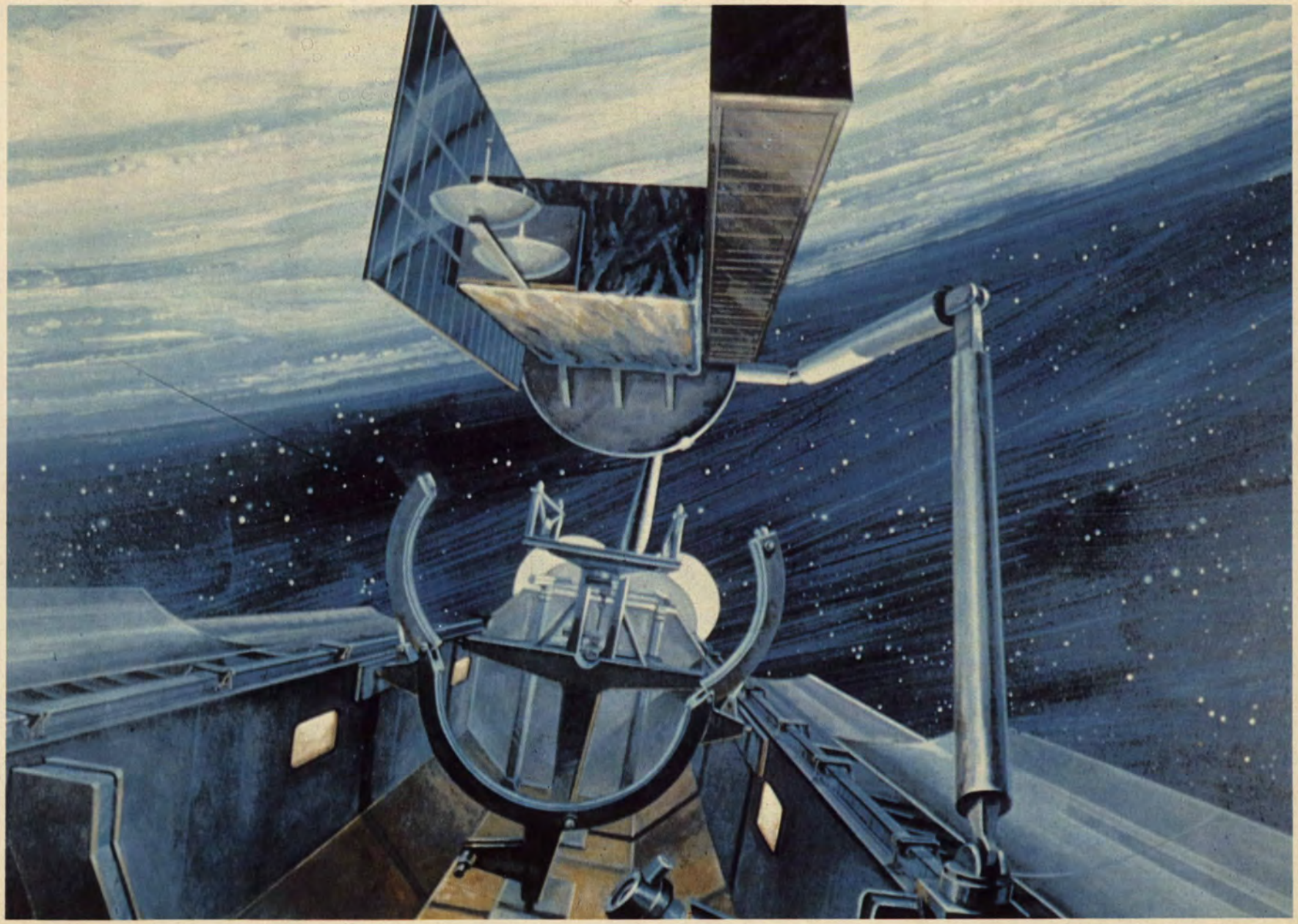
The latest step in the development of Canadian space capabilities under an agreement with the United States provides for the development and construction in Canada of the first flight unit of the remote manipulator system of the Space Shuttle Orbiter. In support of the program, Canada has also designed, built and put into operation a simulation facility for modelling remote manipulator systems.

International Co-operation

A remarkable feature in the history of space programs is that many countries have engendered an unprecedented spirit of co-operation, not only in development and implementation but, even more importantly, in establishing a legal and technological environment in which space activities can contribute to the well-being of all mankind. Canada was one of the pioneers in this movement, and since the early 1960s, has continued to be active in the promotion of international co-operation in space.

Artist's conception of the U.S. Space Shuttle Orbiter.

Facing Page: Artist's conception showing Remote Manipulator System which was designed and built in Canada.



Canadian Space Policy and International Relations

Canada's approach to space is pragmatic: activities are aimed toward applications that promote national goals. The particulars of government policy on the development and application of space systems were set forth by the Minister of State for Science and Technology in April 1974.

First, the policy recognizes that wise exploitation of space technology depends on the accumulation and maintenance of an up-to-date national reservoir of scientific knowledge. To provide the knowledge and skills needed to implement space applications, the government supports basic space research. As scientific research matures, it can be consolidated into applications programs for proof-of-concept, demonstration and, ultimately, fully operational systems. All such programs call for the production or acquisition of sophisticated systems hardware. Government policy prescribes that Canada's space systems will, to the fullest extent possible, be designed, developed and constructed by Canadian industry and under Canadian management, while purchasing policies are designed to promote the research, development and manufacturing capability of Canadian industry.

Although the hardware for Canadian space applications is procured through Canadian industry, launchings must be arranged through the facilities of other countries. So far, all Canadian satellites have been launched in the United States under arrangements with NASA.

Canada requires partners for its space program, as it cannot afford the costs of carrying programs alone and stands to benefit from the mutual sharing of technology. Co-operation with other countries enables Canada to participate in and benefit from a diversity of space projects. The USA has been Canada's main partner since the beginning of the space age and is expected to remain so because of its geographic proximity and technological supremacy and because of the substantial community of interests between the two countries.

The European Space Agency (ESA) has evolved into a promising additional partner for future Canadian space projects. Canada was granted observer status in ESA in June 1975 and is presently examining the possibility of updating its membership in the agency.

Possibilities are also being explored for increased co-operation in the space field with Japan.

The sharing of space among many nations necessitates international agreements on standards for orbital station-keeping, allocation of frequencies and similar practical matters. Canada's interests are promoted through membership in the International Telecommunication Union (ITU) and the Commonwealth Telecommunications Organization (CTO). Canada is also a member of the global satellite communications organization, INTELSAT.

The international aspects of Canadian space policy reach much further, however, than the pragmatic desire to assure access to key technologies or to have a say in setting international standards. Canada believes that space technology can serve to promote international goodwill, and hence to preserve peace in the world. Moreover, space technology has an important role in worldwide social and economic development.

Canada has been a member of the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS) since its creation in 1959 and is represented on its two subcommittees, the scientific and technical subcommittee and the legal subcommittee, which have stimulated international space co-operation and regulation of space activities.

In collaboration with Sweden, Canada has taken the lead in pressing for the development of principles to govern the relationship of space technology to international law, particularly concerning the use by states of satellites for direct television broadcasting. Canada is also active in the discussions concerning the legal implications of remote sensing satellites; it is hoped that these discussions will facilitate international co-operation in such areas as environmental protection and early warning of natural disasters.

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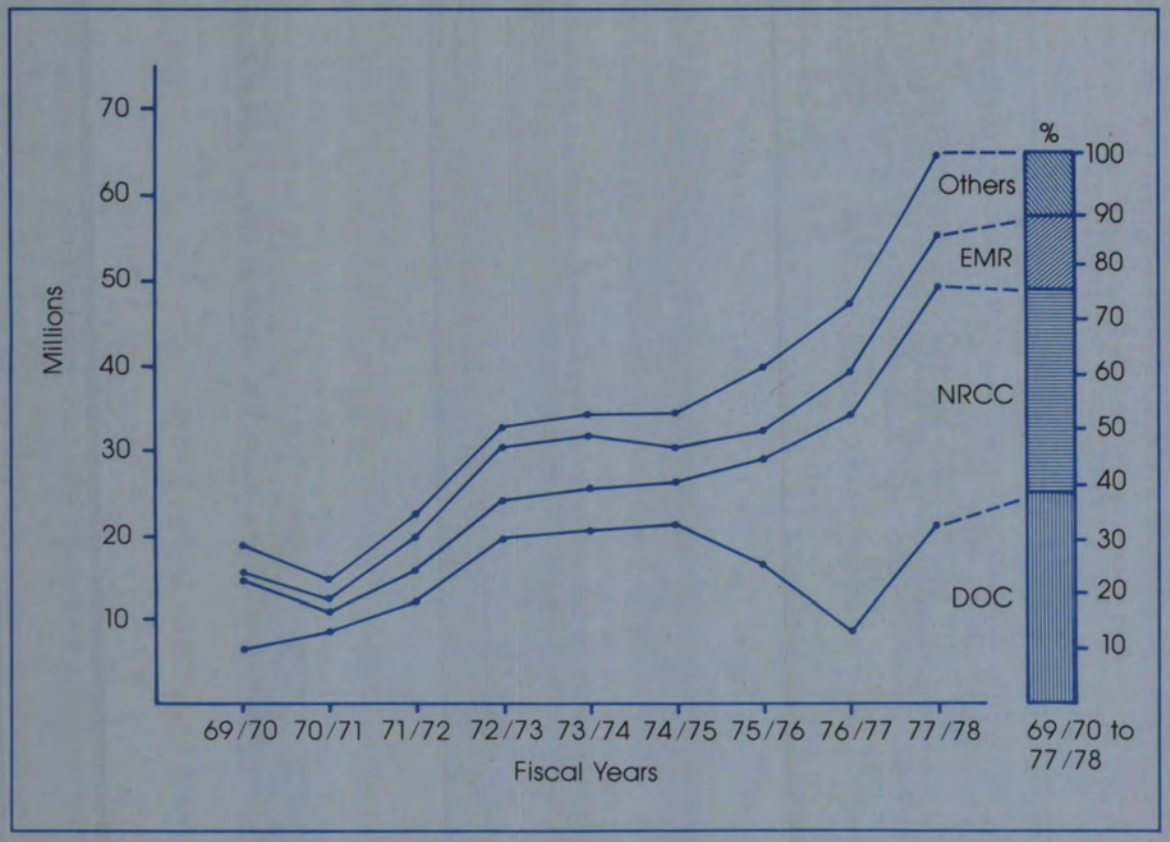
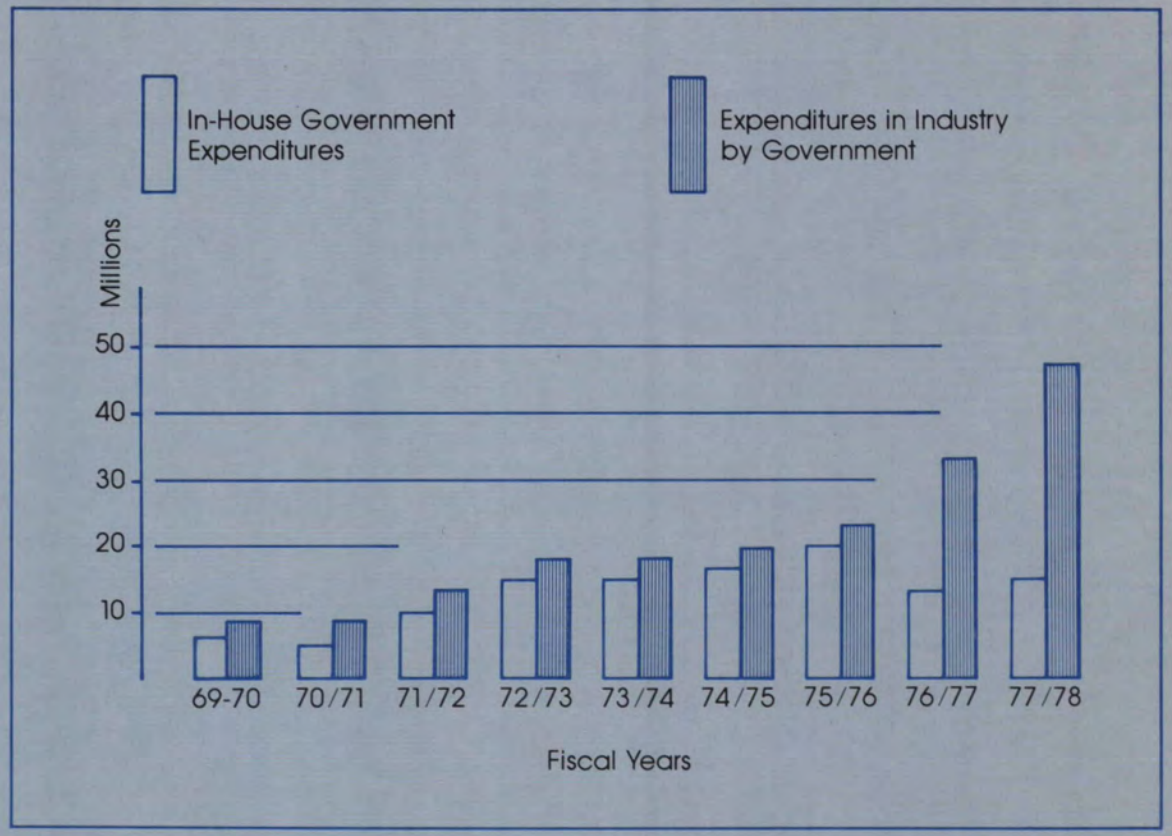
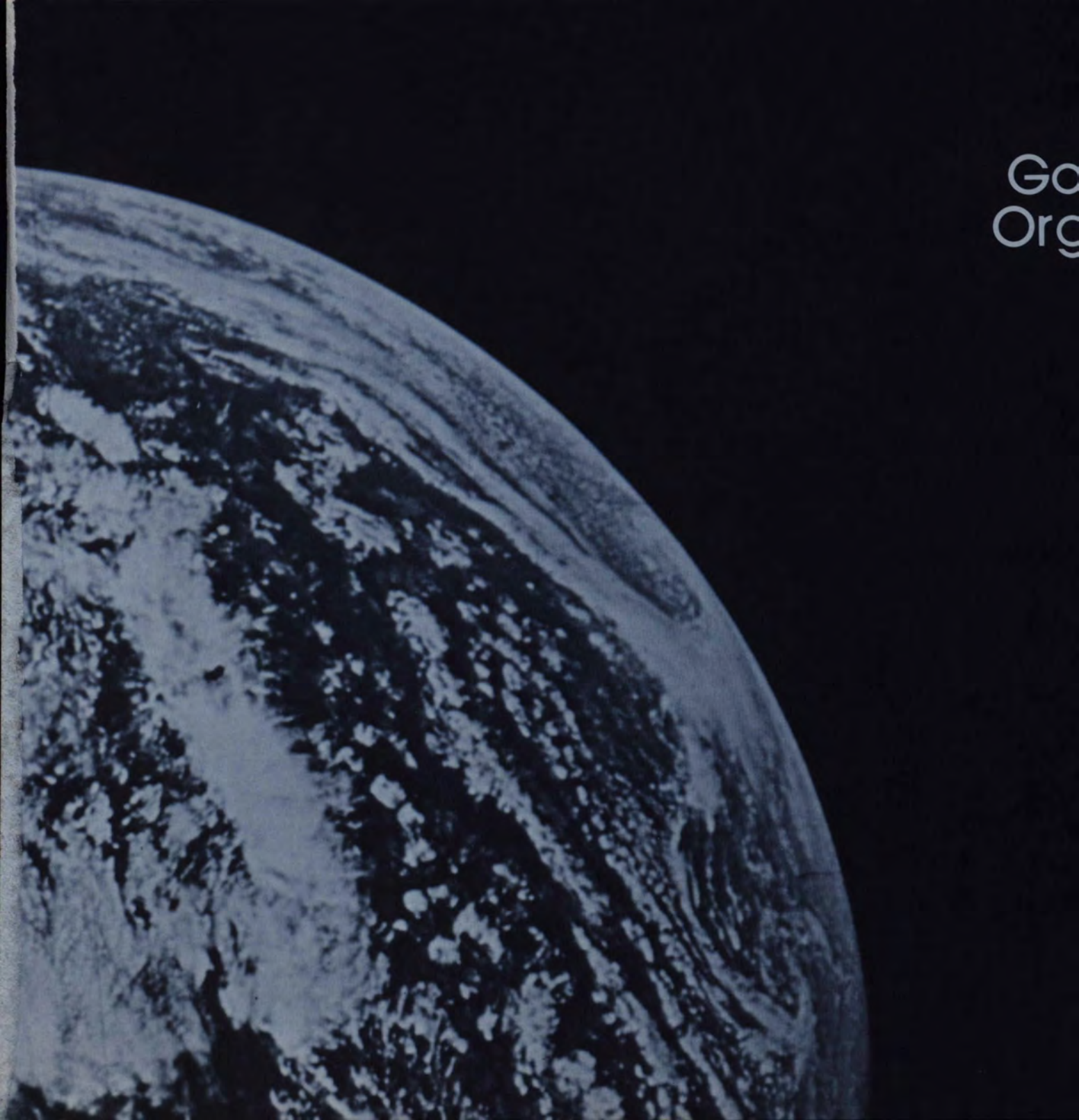
Government Space Expenditures by Department 1969/70 to 1977/78



Government Space Expenditures, In-house and in Industry 1969/70 to 1977/78

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Interdepartmental Committee on Space

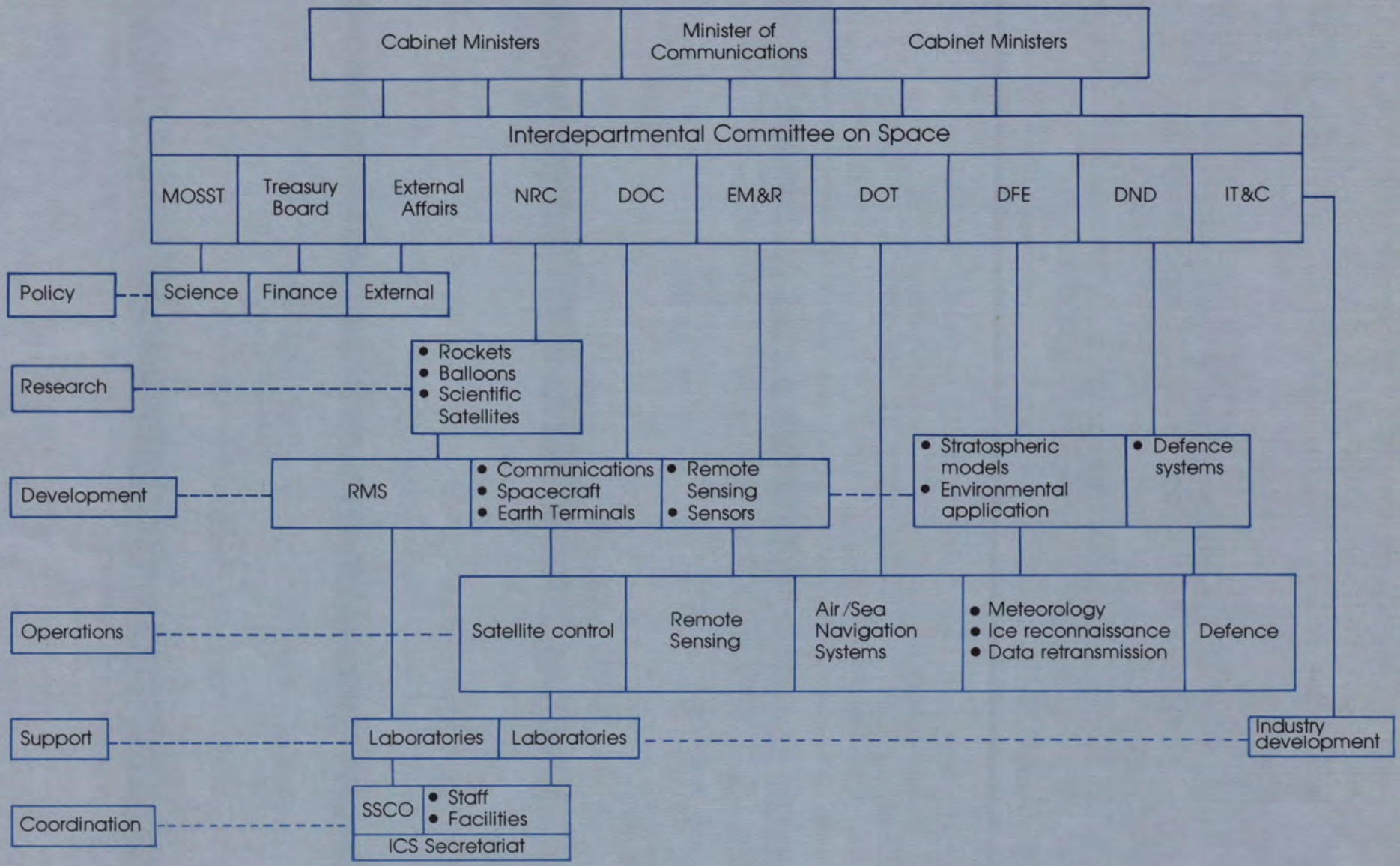
The Canadian space program is totally decentralized. No single agency has prime responsibility for all space and space-related activities. Rather, space applications are used by several departments in the pursuit of their objectives. Each government department or agency is responsible for the formulation and implementation of its own programs, whether or not these involve the development or utilization of space hardware.

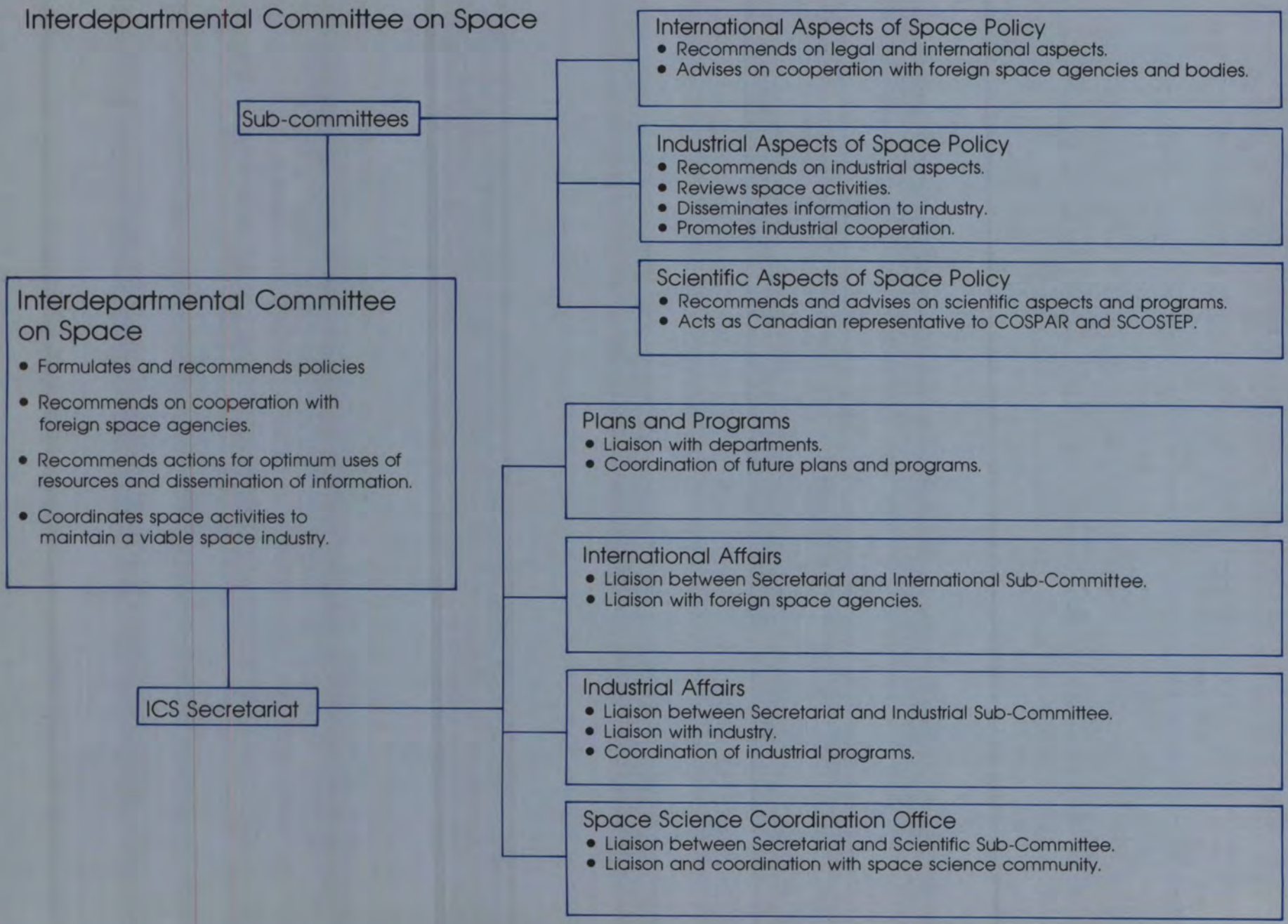
Over the years, each department that became involved in space activities developed certain areas of expertise. This led to the present situation in which a number of departments or agencies may each be regarded as the lead agency in particular areas of space application or research. For instance, the Department of Communications is the lead agency in spacecraft development, testing and assembly, and communication satellite research and development, while the Department of Energy, Mines and Resources is the lead agency in remote sensing technology, applications and operations.

Research on the space environment is supported by the National Research Council of Canada (NRCC) at many universities across Canada. In addition, the Department of Communications awards a small number of research and development contracts to universities in support of its space program.

The co-ordination of the space activities of government departments and agencies is achieved through the Interdepartmental Committee on Space (ICS), which was set up in 1969 and is responsible to the Minister of Communications. The membership comprises senior officials representing the National Research Council of Canada; the Department of Communications; the Department of Energy, Mines and Resources; the Department of Transport; the Department of Fisheries and the Environment; the Department of National Defence; the Department of Industry, Trade and Commerce; the Department of External Affairs; and the Ministry of State for Science and Technology. Observer status is also accorded to a representative of the Treasury Board Secretariat.

Interdepartmental Committee on Space – Organization




Interdepartmental Committee on Space
Sub-committees
Interdepartmental Committee on Space
• Formulates and recommends policies
• Recommends on cooperation with foreign space agencies.
• Recommends actions for optimum uses of resources and dissemination of information.
• Coordinates space activities to maintain a viable space industry.
ICS Secretariat
International Aspects of Space Policy
• Recommends on legal and international aspects.
• Advises on cooperation with foreign space agencies and bodies.
Industrial Aspects of Space Policy
• Recommends on industrial aspects.
• Reviews space activities.
• Disseminates information to industry.
• Promotes industrial cooperation.
Scientific Aspects of Space Policy
• Recommends and advises on scientific aspects and programs.
• Acts as Canadian representative to COSPAR and SCOSTEP.
Plans and Programs
• Liaison with departments.
• Coordination of future plans and programs.
International Affairs
• Liaison between Secretariat and International Sub-Committee.
• Liaison with foreign space agencies.
Industrial Affairs
• Liaison between Secretariat and Industrial Sub-Committee.
• Liaison with industry.
• Coordination of industrial programs.
Space Science Coordination Office
• Liaison between Secretariat and Scientific Sub-Committee.
• Liaison and coordination with space science community.

Since early in 1976, the ICS has been supported by a full-time Secretariat, administratively lodged in the Department of Communications (DOC), to ensure co-ordination and liaison between the departments and agencies concerned and with the various international space organizations and the Canadian space industry. Similarly, the recently formed Space Science Co-ordination Office (SSCO) of the National Research Council of Canada (NRCC) is functionally responsible to the ICS for maintaining liaison between the ICS and the space-science community at home and abroad. Three working-level subcommittees, which deal with the industrial, international and scientific aspects of space policy, also report to the ICS. The members of those subcommittees come primarily from government departments and agencies and, in the case of the scientific subcommittee, from the ranks of Canadian universities and industries as well.

Responsibilities of Departments and Agencies

The National Research Council of Canada (NRCC)

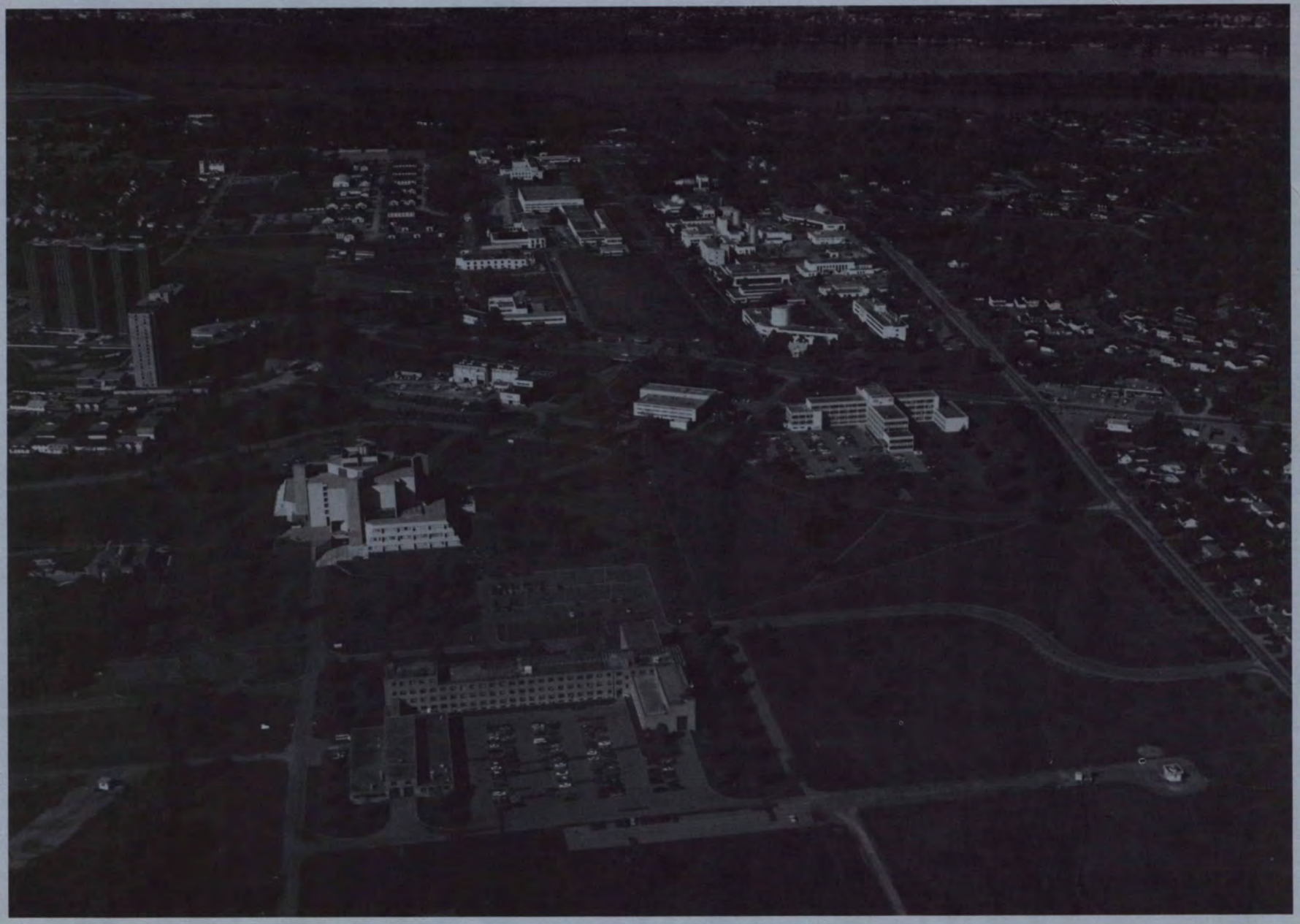
The NRCC undertakes and sponsors scientific and technological research in a broad range of disciplines, including aeronautics, astrophysics, biology, building, chemistry, mechanical engineering, physics and electrical engineering. In addition to extensive laboratories and other facilities, the NRCC has its own computation centre and manages the Canada Institute for Scientific and Technical Information (CISTI). The NRCC also administers research grants to universities and industry and for scholarships to post-graduate students.

The space and space-related responsibilities of the NRCC can be divided into three main areas: research on the space environment, utilizing rockets, balloons, and scientific satellites; research from the space environment, such as remote sensing of the earth and observation of astronautical objects beyond the earth's environment; and research in the space environment including the development of equipment and instruments for use in the severe space environment.

In addition, because of its relationship with the scientific community as a whole, and more specifically with the space science community, the NRCC recently established the Space Science Co-ordination Office (SSCO) which, in addition to carrying out the NRCC leadership role in the area of space science, also acts as the liaison and co-ordination body for the Interdepartmental Committee on Space Secretariat.

Finally, the NRCC Associate Committee on Space Research (ACSR) advises on matters relating to space research. The ACSR also serves as the Canadian national committee on the Committee on Space Research (COSPAR) of the International Council of Scientific Unions (ICSU) and acts as the subcommittee on the ICS for the scientific aspects of space policy. Membership of the ACSR is drawn from the space science community at large, including universities, industry and government.

The National Research Council of Canada located on the eastern outskirts of Ottawa.



The Department of Communications (DOC)

The Minister of Communications has a statutory responsibility to promote the establishment, development and efficiency of communications systems and facilities for Canada and to take such action as may be necessary to secure, by international regulation or otherwise, the rights of Canada in communications matters.

As in most countries that now have a space capability, the newly emerging space technology was first applied in Canada to communications. With the launch of ALOUETTE I in 1962, Canada became the first country, other than the USSR and the USA, to have one of its satellites launched into orbit.

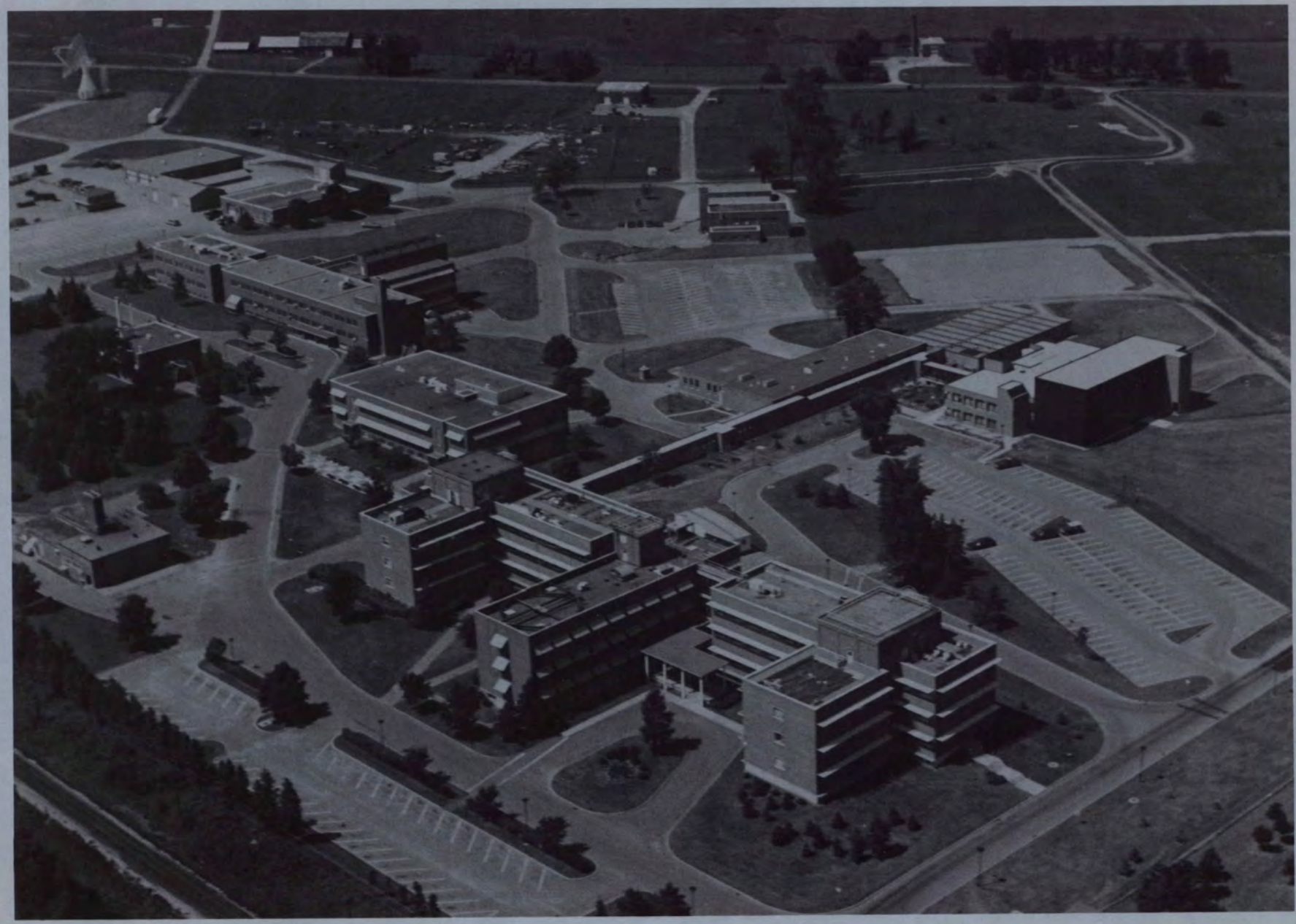
This satellite, and the remaining three satellites in the ALOUETTE-ISIS series launched between 1962 and 1971, made possible for the first time the study from above of the ionosphere and its effects on radiocommunications. The last of these satellites is still providing useful data to researchers.

These satellites, and more recently the high-powered HERMES communications satellite, were developed at the Communications Research Centre (CRC)[1] of the Department of Communications, from where the satellites are also controlled. The team of space system specialists involved in this activity at CRC also provides consultation and assistance to other Canadian government departments and agencies in the planning and implementation of their space programs.

DOC, because of its development of government satellite systems, is also concerned with ensuring that Canadian industry is able to take maximum advantage of government programs in establishing a competitive position to supply space-related products to both domestic and foreign markets. In addition to contracting its space projects to industry whenever possible, the department manages a multi-million dollar contract program specifically designed to prepare industry ahead of time to be ready to participate in planned programs. This contract program complements the larger and more general industry support programs of the Department of Industry, Trade and Commerce and of the National Research Council of Canada.

[1]CRC facilities are described on pages 44 to 49

The Communications Research Centre located on the western outskirts of Ottawa.



The Department of Energy, Mines and Resources (EM&R)

The Minister of Energy, Mines and Resources has the general responsibility of ensuring the effective use of the mineral and energy resources of Canada for the present and future benefit of the nation, through various programs such as energy development, mineral development, mining and metallurgical investigations and research, geological research and surveys, and the office of energy conservation. The minister also has the responsibility to contribute to the conservation and use of the resources of the earth for the present and future benefit of the nation through programs such as field and air surveys, mapping and aeronautical charting, geological research and surveys, research in geophysics, polar continental shelf studies, and remote sensing.

The primary involvement of EM&R in space is through the Canada Centre for Remote Sensing (CCRS). CCRS is responsible for the development of facilities and techniques for the production and use of remotely sensed data, using satellites and high-flying aircraft.[1]

The responsibilities of EM&R, and more specifically of CCRS, make the department the lead agency in the operating of the earth resources satellite program in Canada and also the lead agency for the development of remote-sensing platforms and sensors.

The Department of Fisheries and the Environment (DFE)

The Minister of Fisheries and the Environment is responsible, through programs of the Fisheries and Marine Service, for improving the management of the marine and aquatic renewable resources of Canada; and through programs of the Environmental Services, for protecting and enhancing the quality of the environment, for meteorological services, and for improving the management of the forest, wildlife and inland water resources of Canada.

DFE programs may use space-borne services for applications related to forestry, glaciology, oceanography, fisheries, inland waters, land use and meteorology. The department is primarily a user of services provided by space technology rather than being generally involved in sensor or spacecraft development. The most visible utilization of space-borne services by DFE is through the Atmospheric Environment Service[2], which operates three weather satellite ground receiving stations to acquire data from meteorological satellites. Also important is the acquisition of data via satellites from remote instrumented sites. The Environmental Management Service has facilities at the Prince Albert Satellite Station to decode, process, store and distribute data from the data collection systems of LANDSAT and GOES satellites.

DFE supports a program of experimental measurements of stratospheric trace constituents, with special reference to the kinetics of the ozone shield.

[1]The activities of CCRS are described on page 50.

[2]Atmospheric Environment Service, See page 87.

Scanning electron microscope with integral microprobe analyser used for reliability assessment and failure analysis of electronic materials and devices at the Communications Research Centre.

The Department of Transport (DOT)

The Minister of Transport is responsible for the formulation and implementation of federal policy for all forms of land, sea and air transport.

DOT operates air traffic control facilities for all international flights using the North Atlantic routes, and has similar responsibilities with regard to national and international shipping in Canadian coastal and inland waters. DOT is also responsible for fulfilling certain international responsibilities that have been assigned to Canada by the Intergovernmental Maritime Consultative Organization (IMCO) and the International Civil Aviation Organization (ICAO).

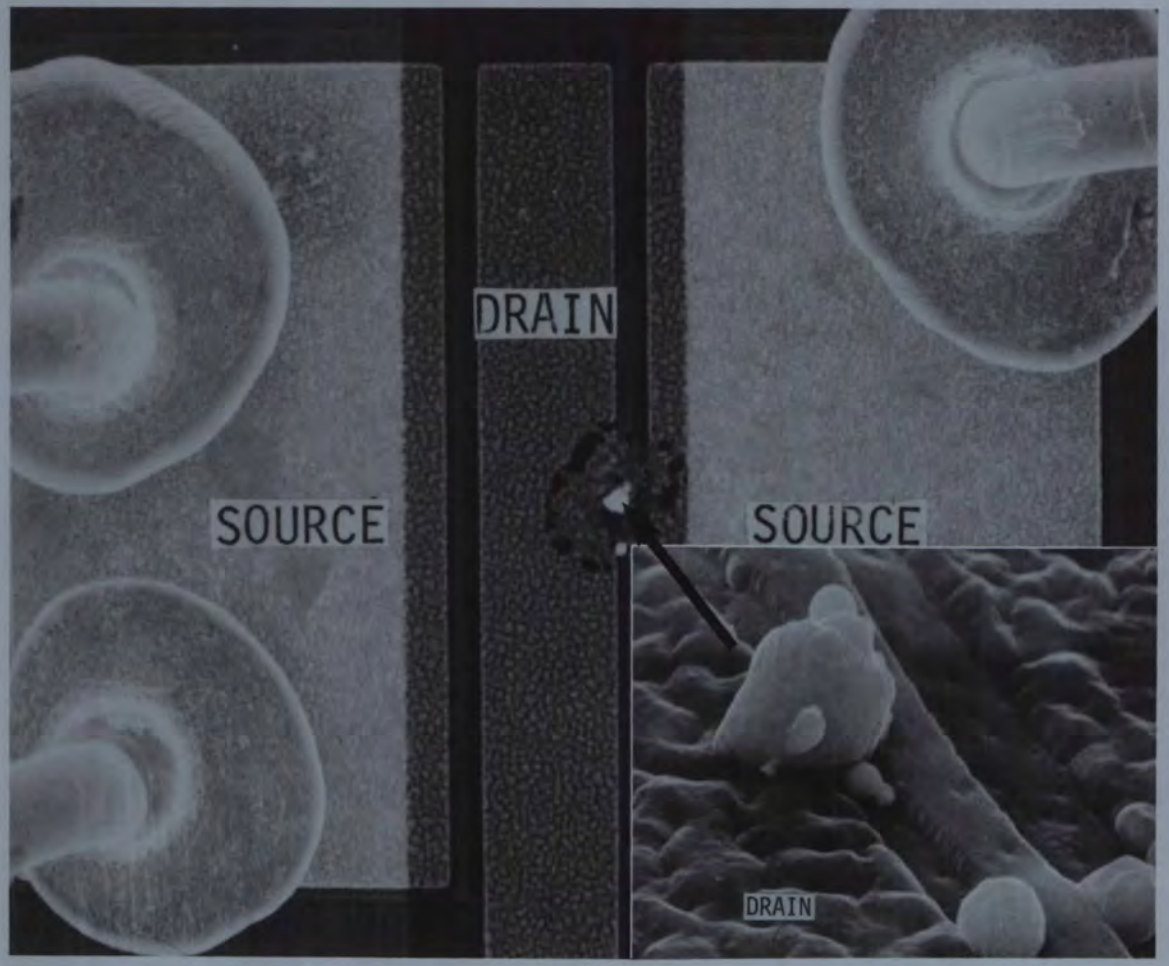
As a present and future customer of space services, DOT is participating in several space projects aimed at improving the safety and efficiency of air and marine operations. These include the international AEROSAT program, to be used in evaluating the use of satellites for air traffic control; the international INMARSAT preparatory committee concerned with improved maritime communications; the trials of a MARISAT terminal installed on one of its icebreakers; the study for the use of a Multi-purpose UHF Communications Satellite (MUSAT), which may provide communications to facilities located in remote areas of Canada, and to ships and aircraft operating in remote areas; and a Search and Rescue Satellite (SARSAT) which will quickly detect and locate aircraft and ships in distress. DOT is also monitoring the U.S. NAVSTAR program, which is a satellite system to be used for worldwide navigation.

The Department of National Defence (DND)

The Minister of National Defence is responsible for the formulation of defence policy and its implementation by the Canadian Armed Forces and for the management and operation of all Canadian military establishments and facilities.

The Defence Research Board, which reports to the Minister of National Defence, was responsible until recently for the Defence Research Telecommunications Establishment (DRTE) which was the lead agency for spacecraft design, development, construction and operation, and had been undertaking ionospheric and communications research for 15 years when ALOUETTE I, the first Canadian satellite was launched in 1962. DRTE had also been responsible for pioneering rocket and balloon programs. In 1969, it was transferred to DOC and renamed the Communications Research Centre (CRC).

DND policy is to keep up to date in its knowledge of space and space-related developments, and to take advantage of space systems that offer the most cost-effective way of meeting defence objectives. The department accordingly engages in studies of the feasibility and potential of space applications for defence purposes. Space-related research is done in a number of defence research establishments.



A catastrophic failure on a gallium Arsenide Field Effect Transistor, caused by static discharge. Photographed from the scanning electron microscope at the Communications Research Centre.

As part of the North American Air Defence (NORAD) Space Detection and Tracking System (SPADATS), DND operates ground stations at Cold Lake, Alberta, and St. Margarets, New Brunswick, using Baker-Nunn camera facilities to detect satellites and provide tracking information. In addition, at St. Margaret's, there is a unique space object identification (SOI) system, developed by the U.S. Air Force, providing optical signatures of space targets.

The Aerospace Engineering Test Establishment (AETE) of DND participates in an environmental sounding program at the Canadian Forces Base, Cold Lake. Since the program began, more than 900 rockets have been launched from the Primrose Lake Evaluation Range, providing temperature and wind data to altitudes of 50 kilometres or more. Combining the data from many stations and networks, the program provides a fund of research data, a climate record of upper atmospheric temperature and wind, and up-to-date reports approximating real time conditions in the upper atmosphere for immediate operational use.

The department also supports studies by CRC on military communications and, more recently, has been supporting CRC in the development of a search and rescue satellite system.

The Department of Industry, Trade and Commerce (IT&C)

The Minister of Industry, Trade and Commerce is responsible for the formulation and implementation of policies and programs to support and develop Canadian industrial capabilities and to promote and increase exports and international trade.

IT&C is intimately concerned with the implementation, in the space sector, of policies for the support and development of the Canadian space, electronics, and computer industries.

The Department of External Affairs (DEA)

The Secretary of State for External Affairs is responsible for the formulation and implementation of Canada's foreign policy and for the general supervision of all international relationships and activities. The department collaborates with DOC in the representation of Canada on space-related international organizations and is the negotiating agent for Canada in all international treaties and agreements.

The Ministry of State for Science and Technology (MOSST)

The Minister of State for Science and Technology is responsible for encouraging the development and use of science and technology in support of national goals. This is done primarily by developing policies for the support of science and technology in Canada; by developing policies and advising on the applications of scientific and technical resources to national issues; and by fostering the use of scientific and technological knowledge in the formulation and development of public policy.

In the highly technological and scientific world of space, the ministry has, therefore, the main responsibility for developing space policies for Canada, and for assuring that mechanisms for overview and management of space programs are kept up to date and responsive to changing conditions or new opportunities.

Government Space Facilities

The Communications Research Centre (CRC)

Since 1947, as the Radio Physics Laboratory, later renamed the Defence Research Telecommunications Establishment of the Defence Research Board, and under its present name, CRC[1] has been active in upper atmospheric research, space rocketry, satellite tracking, and the design, construction and operation of scientific satellites. It undertakes or sponsors a large part of Canadian space research, for which it is well equipped and retains responsibility for the ISIS scientific satellite program[2]. Research and development are conducted under three main headings: electronics, mechanics and applications.

The high-reliability laboratory is used for the development and application of techniques for assessing the reliability of electronic subsystems, components, devices, and materials for space communication systems. It develops non-destructive testing techniques, carries out failure analysis, assesses the reliability of fabrication techniques and systems, and establishes procurement procedures for spacecraft components and materials. The capability of the high reliability laboratory is illustrated in the accompanying photographs.

Space electronics activities include studies of the technology of earth terminals, RF attitude sensing, radio wave propagation and satellite-to-aircraft communication. A notable achievement has been the development of a 12 gigahertz Field Effect Transistor Amplifier (FETA). It is believed that this was the first FETA ever to be space-qualified and flown.

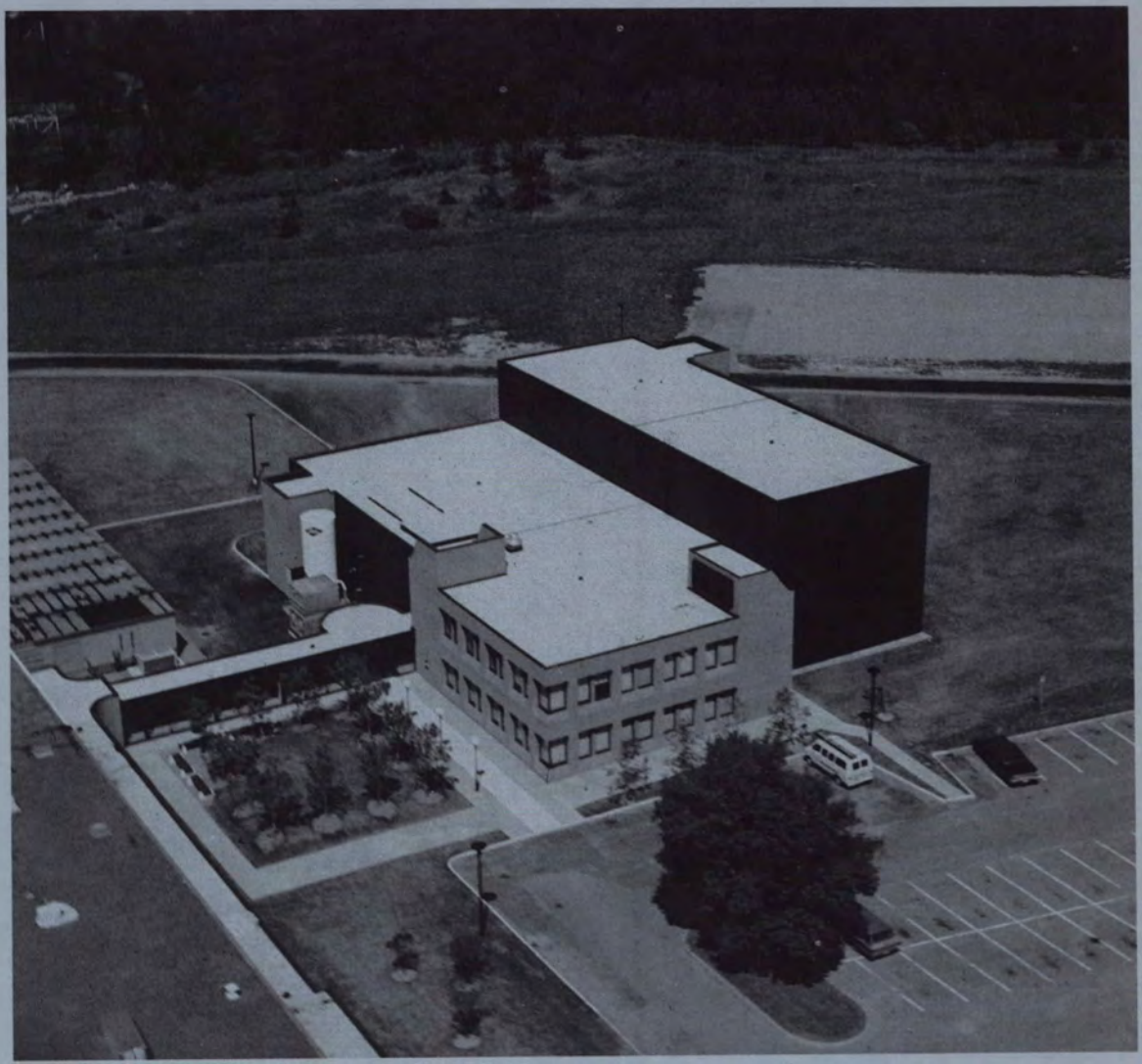
Space mechanics applied research and advanced development of critical spacecraft subsystems include work on structures, materials, control systems and dynamic modelling of flexible satellites or space assemblies. A hybrid computer facility is being used in the development of new satellite controls and in dynamics research.

The Space Communications Program Office (SCOPO) was established on April 1, 1976, to manage and control the operation of all DOC satellite missions, including the scheduling and control of all satellite functions; the deployment and maintenance of the associated Canadian ground terminals; and the coordination of all Canadian experiments making use of DOC spacecraft. SCOPO also assists in the planning of future satellite missions.

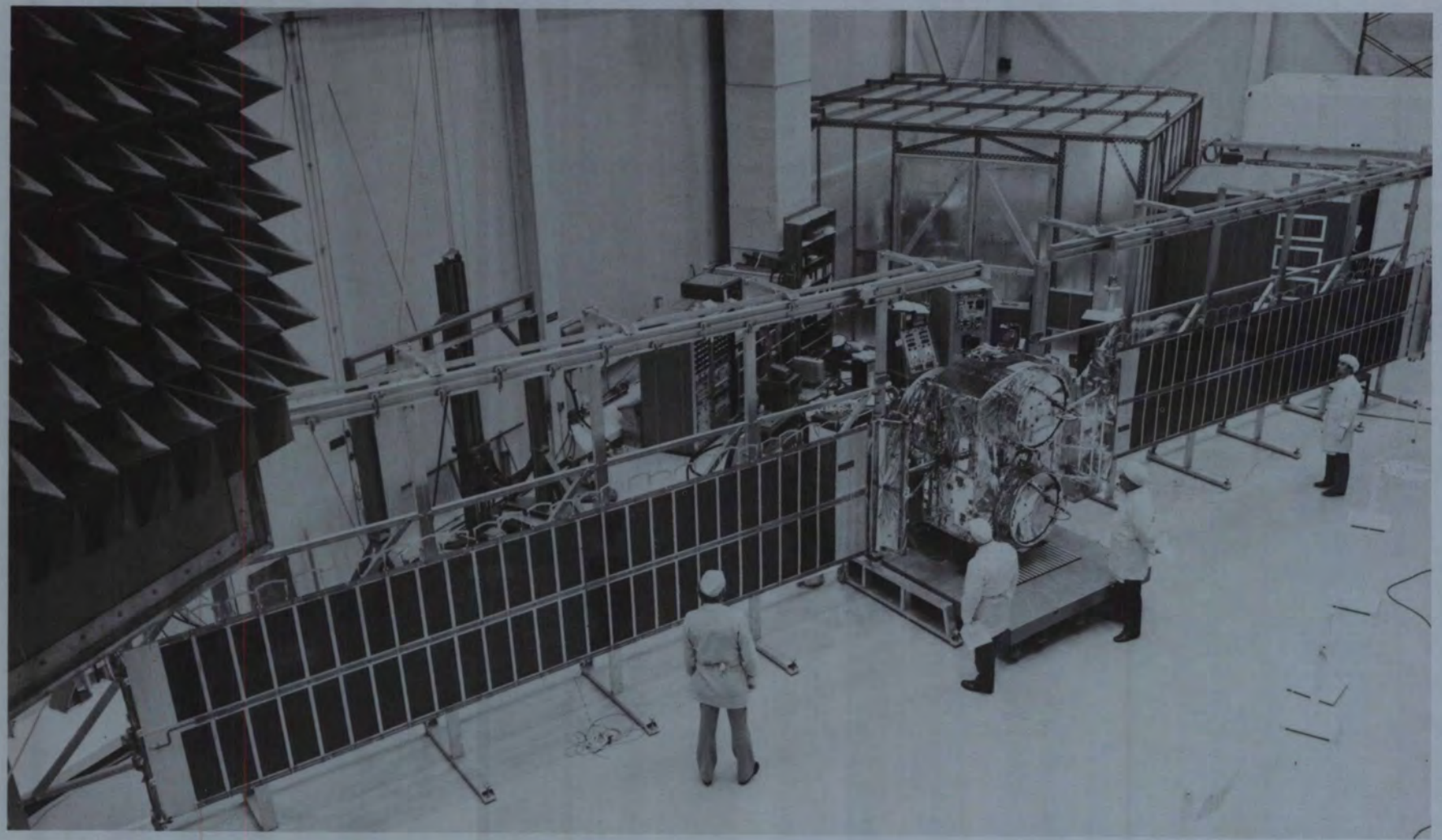
[1]The David Florida Laboratory, described on page 47 is a component of CRC.

[2]ISIS Program, see page 82.

The David Florida Laboratory (DFL)



The David Florida Laboratory located on the grounds of the Communications Research Centre.



The CTS flight-model spacecraft during full-scale solar array deployment test in the high-bay of the David Florida Laboratory. On the left is the corner of a door leading into the RF test facility

The David Florida[1] Laboratory at CRC, completed in 1972, provides services and technical support to industry, universities and government departments and agencies on a cost-reimbursement basis through its wide range of environmental and engineering facilities for building and testing spacecraft and aerospace systems.

The high bay measures 12×30 metres, and is nine metres high. Air filters maintain building cleanliness, while the integration area has horizontal laminar flow benches and a portable laminar flow filtration unit, filtering air to class 100.

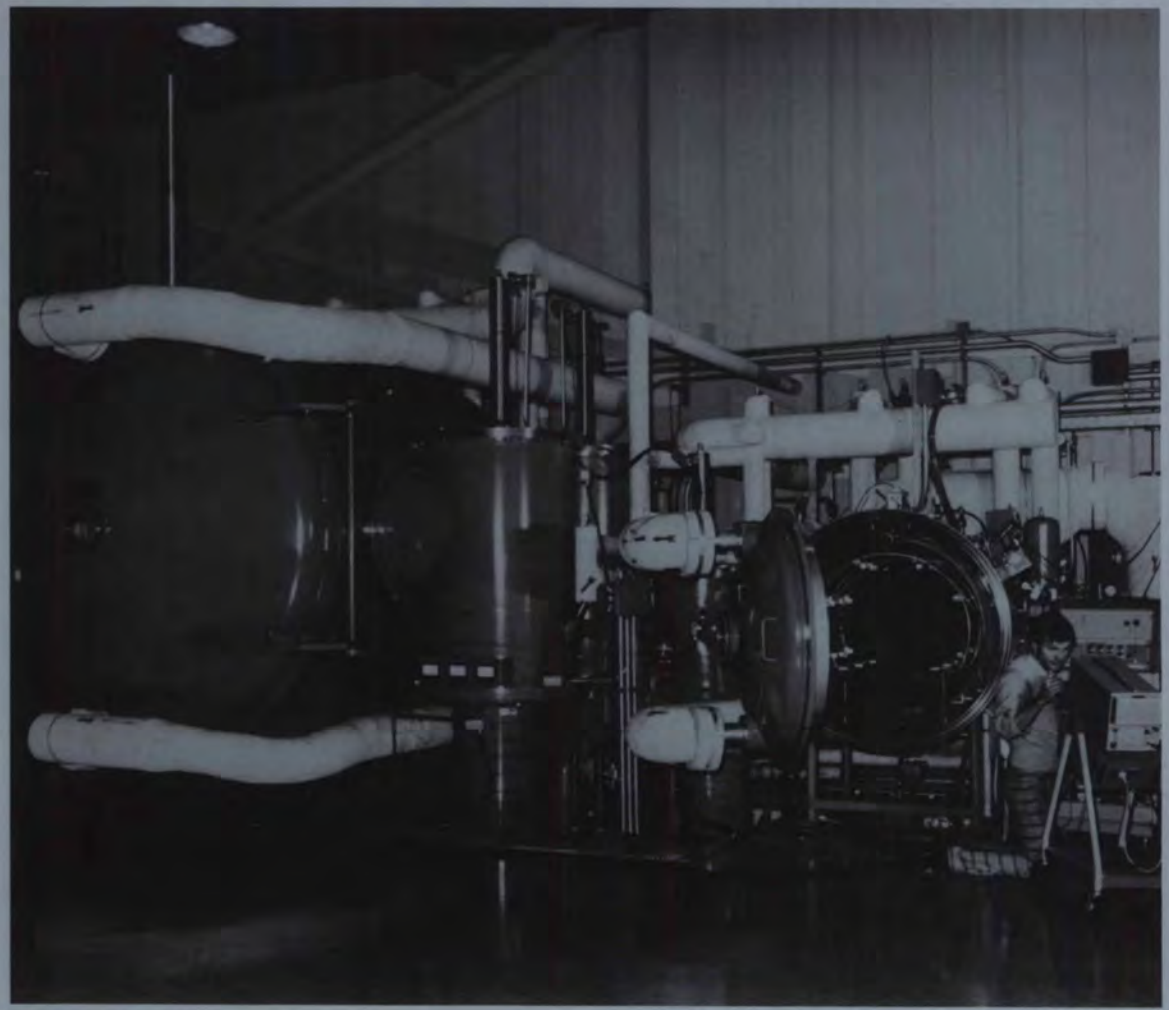
A seismically isolated floor area (125 square metres) is adjacent to component and test-intrumentation stores and is used for mechanical testing of spacecraft gyros, sensors and complete aerospace control systems.

The anechoic chamber measures 7m × 7m × 7m, exhibits an absorbtion coefficient of 30-50 db over the range 1-20 GHz.The remote controlled three-axis positioning table has an accuracy of 0.01°. A complete HERMES spacecraft has been tested on this table.

[1]C. David Florida was director of the National Space Telecommunications Laboratory and Manager of the ISIS program until his untimely death in 1971 at the age of 57. The laboratory was named to commemorate his unique contribution to Canadian space programs.

The RF test facility may be used either as one terminal of an antenna range, or as an RF anechoic chamber. The RF window faces a tower 150 metres away, which is used as the second terminal of the antenna range. An instrumentation and control room is adjacent. Standard test procedures have been fully developed, and there is a substantial library of data reduction software.

The environmental test laboratory contains vacuum chambers, vibration tables and other test facilities, allowing the environment to which aerospace and space components are subject during launch and flight to be simulated. The performance of electronic and mechanical subsystems and the integrity of associated structures are evaluated and recorded. Up to 160 test points can be monitored and the data recorded in full digital format for later reduction. Up to 20 test points may be displayed in real time. The temperature of the largest vacuum chamber (three metres in diameter and nine metres in length) is controlled by two removable cryogenic panels which can be cooled or heated either jointly or separately, thus permitting simulation of the strong thermal stresses encountered in space. All three chambers can follow a pre-programmed cycle of set thermal and vacuum levels.



Environmental Test Facility – 1m × 1m, 10^{-7} torr., –196°C to +150°C; 2.5m × 2.5m, 10^{-6} torr., –196°C to +150°C and in the far left, 3.0m × 9.0m, 10^{-6} torr., –196°C to +150°C.

There are several vibration tables available. The largest is mounted on a 68-ton seismically isolated mass and can provide up to 53 kilonewtons sinusoidal or up to 44.5 kilonewtons random. The test bed can be displaced up to 2.5 centimetres at frequencies from five to 3,000 hertz. Acceleration is applied in sine-wave, random, or mixed-wave forms. Maximum available acceleration depends on the combined weight of the article to be tested and the jig on which it is mounted; for example, a 550-kg test package could be subjected to a maximum acceleration of 10 G.

The location of the laboratory at CRC facilitates the exchange of specialized and engineering expertise and provides ready access to the complementary facilities at CRC.

DFL Vibration Facility Control Room. Acceleration and strain can be monitored at up to 42 points simultaneously. The console can also be preprogrammed to simulate tests and a safety system automatically shuts off vibration if the acceleration exceeds programmed test limits.

The Canada Centre for Remote Sensing (CCRS)

CCRS, operated by Energy, Mines and Resources under the guidance of the Inter-Agency Committee on Remote Sensing (IACRS) in conjunction with the working groups of the Canadian Advisory Committee on Remote Sensing (CACRS), serves federal and provincial departments and agencies, industry, universities and the general public. The activities of CCRS itself are concentrated on the satellite remote sensing program, the airborne remote sensing program and the applications program, but its facilities are made available to scientists and users of remote sensing data and techniques.

The Prince Albert Satellite Station, at Prince Albert, Saskatchewan, regularly tracks LANDSAT and NOAA satellites covering most of Canada, with a 26-metre antenna and is supplemented by a manual four metre antenna which gives good data reception from NOAA satellites when there are conflicts with LANDSAT data reception. In 1977, a system was introduced at Prince Albert to produce high resolution, high-quality, black-and-white imagery on a laser-beam recorder.

All the high resolution imagery from the LANDSAT spacecraft produced by CCRS has been done on these electron beam image recorders. Electrons write the images on 70mm film in these machines.

In order to complete coverage of the whole of Canada and an extension into the Atlantic, a second station, built by MacDonald, Dettwiler and Associates Ltd., of Vancouver was installed at Shoe Cove, near St. John's, Newfoundland, in early 1977. Except for the antenna, the receiving and processing equipment is housed in one trailer which could readily be moved elsewhere if required. The system is at present programmed to process LANDSAT and NOAA satellite data but could be reprogrammed to produce images, CCTs and computer-facsimile signals from any satellite MSS. The station will be modified to read out and process data from NASA's SEASAT A, scheduled for launch in April 1978.

The Prince Albert satellite station records multi-spectral scanner (MSS) data from LANDSAT and very high resolution radiometer (VHRR) data from NOAA satellites. A quick look display system produces real-time images for rapid distribution to users.

Extensive support facilities have been established in Ottawa. These comprise large-and medium-sized minicomputers and associated special purpose equipment.

The sheer volume of satellite data presents problems; for example, a single 185-square-kilometre LANDSAT image has about seven million data points. The Image-100 system was designed to deal as effectively as possible with this volume of data. Usage of this system includes classification of forests and range-lands, crop identification, analysis of damage caused by insects, disease, fire and flood analysis, assessment of pollution in lakes and a wide range of other problems needing analysis. A similar, but slower, interpretation system is part of the large PDP 10 computer system.

A large conventional computer, the DEC System 10, offers scientists throughout Canada remote or direct access to most of the powerful satellite data-processing facilities in Ottawa. A color display system and a scanning microdensitometer are special purpose peripherals on this system. An array processor will soon be added.

The PDP-10 time-sharing computer system in CCRS laboratories is used to preprocess LANDSAT data, to process digital airborne data and to digitally analyse and enhance MSS data.

CCRS facilities also include four aircraft equipped with the necessary sensors and navigation equipment.

A Dassault Falcon Fan Jet with an altitude capability of 11,000 metres is used for high-altitude sensing. A Convair 580 with a range of 4,000 kilometres is being outfitted for work in the Arctic and offshore. It will carry microwave sensors such as a synthetic aperture radar for studies related to the requirements for a future Canadian surveillance satellite. Two DC-3 aircraft are outfitted for low-level remote sensing, and for testing new sensors and sensing systems. These aircraft are operated on behalf of users all across Canada on a limited charge-recovery basis.

The Dassault Falcon Fan Jet provides CCRS with a high-altitude airborne sensor platform with the ability to reach distant areas quickly.

The National Research Council of Canada Space Facilities

The Space Research Facilities Branch (SRFB) of the NRCC supports Canadian space science by planning and conducting rocket and balloon launch campaigns and operating several research stations. The branch can support rocket and balloon launches from any location in any season in order to meet scientific objectives. Services are provided to non-Canadian organizations on a cost-recovery, time-available basis.

Engineering Section

The Engineering Section of SRFB implements sounding rocket programs by procuring rocket motors and monitoring the design and fabrication of instrumented rocket payloads by Canadian industry. In conjunction with the Operations Section and with the assistance of specialists from industry, the Engineering Section arranges for the launching and tracking of sounding rockets, acquisition and recording of telemetered data, recovery of rocket payloads and conversion of recorded data to forms appropriate for analysis. During 1976, four major sounding rockets were launched as part of the Canadian space science program. A Black Brant IVB, Black Brant VB, and a Black Brant VI were launched from the Churchill Research Range (CRR) and a Black Brant VB was launched from Woomera, Australia.

Balloon, just prior to being launched from one of the launching sites in Canada.

The successful inaugural test flight of the Nike-Black Brant V sounding rocket system in December 1975 led to the acceptance of this vehicle for scientific research. Three Nike-Black Brant rockets were launched during 1977.

Operations Section

The Operations Section of SRFB operates the Churchill Research Range, a permanent launch complex and ground-based instrument facility, the Great Whale Geophysical Station, a ground-based instrument facility and the NRCC balloon facility. The section also provides launch site services and range safety functions for all sounding rockets launched from Canadian territory. Semi-permanent, rocket-launching facilities are maintained at Resolute and Cape Parry, Northwest Territories. The section directs scientific balloon campaigns in Canada, providing ground and airborne command and telemetry electronics; launch and recovery equipment; and tracking, launch and recovery services (through contracts to industry). It procures balloons, helium, parachutes and other flight-related hardware.

Black Brant III vehicles ready for launch from a remote launch site in Nova Scotia to study a solar eclipse.

Black Brant III payloads being assembled by an NRCC technician.

Churchill Research Range

The CRR at Churchill, Manitoba, has been operated by the NRCC since 1965. In addition to the regular Canadian scientific rocket launching activities, CRR operates various ground-based instruments on a continuing basis, provides rocket launching service to foreign agencies, launches meteorological sounding rockets as part of the North American synoptic network and provides some services for Canadian balloon launches.

Great Whale Geophysical Station

SRFB operates a geophysical station at Poste de la Baleine, Québec. The instrumentation includes riometers, auroral radar, all-sky cameras, magnetometers and ULF micropulsation instruments.

Scientific Balloon-Launching Facility

In response to a need for scientific balloon facilities for Canadian scientists, SRFB, with co-operation and support from the Atmospheric Environment Service (AES) of DFE established a complete mobile facility, which became operational in 1976.

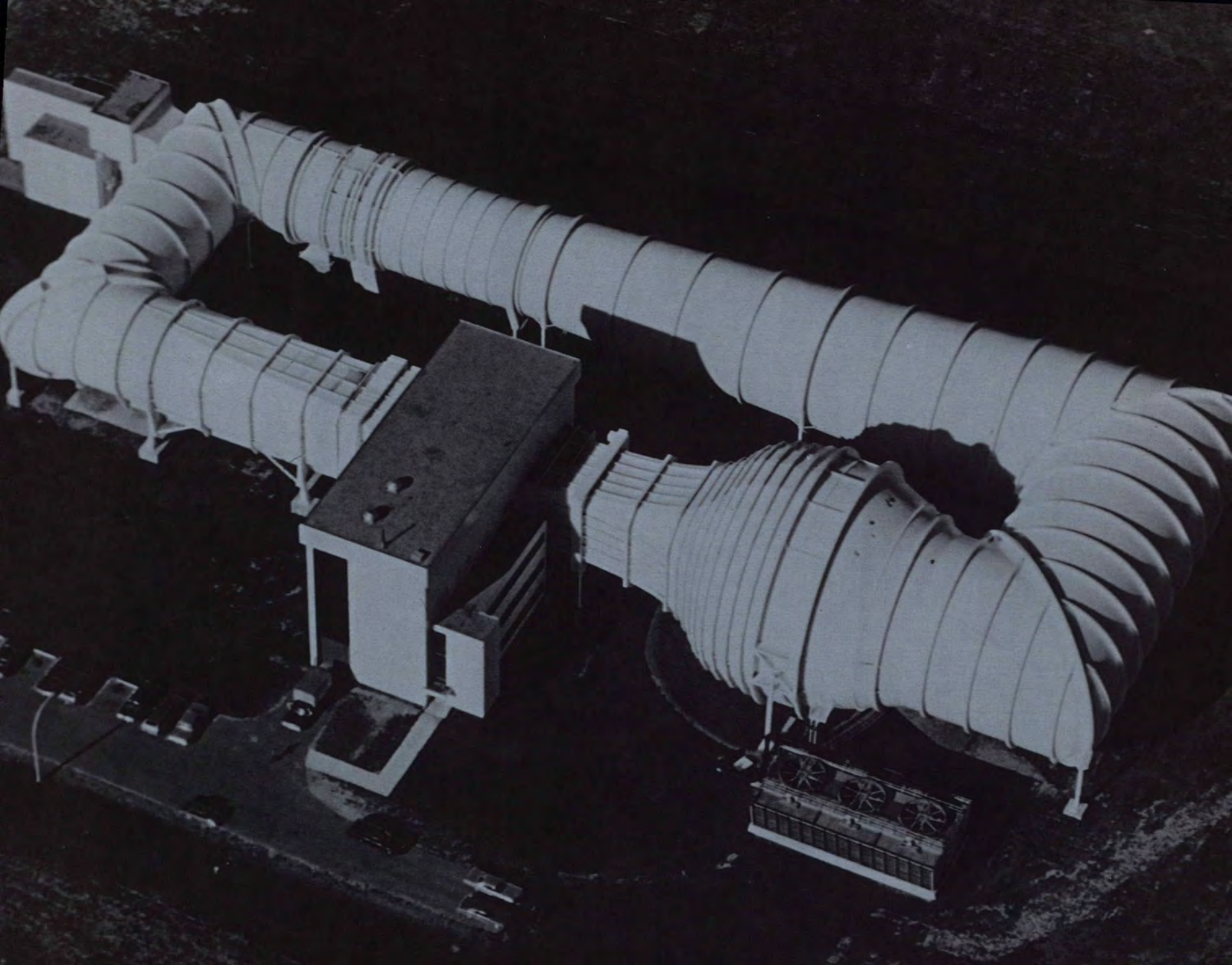
The inaugural flight from Churchill, in July 1976, carried a cosmic-ray telescope. A major campaign was carried out successfully from Yorkton, Saskatchewan, in August 1976. SRFB launched a balloon in February 1977, from Cold Lake, Alberta, which was the first winter attempt with a large balloon from Canadian territory.


Balloon and Rocket Launch Sites
R Resolute
R Cape Parry
Yukon Territory
Northwest Territories
British Columbia
Alberta
B Primrose Lake
Saskatchewan
R B Churchill
Manitoba
B Yorkton
Ontario
Labrador
B Poste-de-la baleine
Québec
Nfld.
P.E.I.
N.B.
N.S.
Legend:
B Balloon launch sites
R Rocket launch sites

The High-Speed Wind Tunnel

The National Aeronautical Establishment (NAE) of NRCC operates a large high-speed wind tunnel in Ottawa which is used extensively by scientists from several government departments and agencies, the Canadian aerospace industry, NASA and agencies of other foreign countries. The tunnel is of the blowdown type with a 1.5-metre-square working station and is built to withstand an internal pressure of more than 1700 kilopascals. A unique feature is the High Reynolds Number Two Dimensional Test Facility (the NAE2-D insert) – 38 centimetres × 1.5 metres – which is used to test airfoil characteristics in the transonic range at Reynolds numbers close to the full-scale values; the facility has also been used to investigate supercritical airfoil designs and jet-augmented airfoils. The tunnel has been used for the testing of rocket bodies and for dynamic stability studies of aerodynamic vehicles such as the Space Shuttle Orbiter.

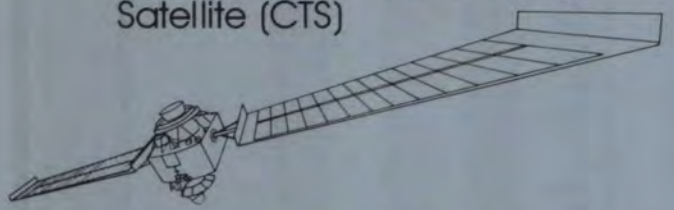
High-speed wind tunnel of NRCC located at Uplands Airport on the outskirts of Ottawa.



Government Space Activities

Satellite Communications Program

HERMES — The Canada/United States Communications Technology Satellite (CTS)



In April 1971, DOC and NASA formally agreed to undertake a joint communications technology satellite program. The objective was to place an advanced communications technology satellite in geostationary orbit at Long.116 degrees W. as a vehicle for technological and communications experiments in the 14/12 gigahertz frequency band. It is being shared equally by the United States and Canada.

The spacecraft, now officially named HERMES, was designed and built in Canada, under contracts with Canadian industry. NASA developed the high-power (200 watts) high-efficiency ()50%) Travelling Wave Tube (TWT), provided test support and undertook the launch. Under a separate agreement with Canada, the European Space Research Organization (now the European Space Agency) provided medium-power TWTs and parametric amplifiers and funded the development of the blankets for the flexible solar arrays.

HERMES was launched by NASA on January 17, 1976, from the Kennedy Space Center on a Thor Delta 2914 launch vehicle and became operational on February 1, 1976, thus becoming the first high-powered communications satellite operating in the 14/12 gigahertz band.

The Canadian objectives for HERMES were to establish and maintain a Canadian industrial capability in design and manufacture for space applications, to develop and test components applicable to future Canadian communications satellites and to conduct satellite communications systems experiments in the 14/12 gigahertz band.

Extensive flight performance data under normal operating conditions have been collected and are now being evaluated. In most respects, performance under normal operating conditions conforms to, or is an improvement on, specification and prediction. In addition, the study of behavior under abnormal conditions, which require excitation of spacecraft motions by a special jetpulse program, has been successfully performed.

The ANIK and HERMES satellites were used for demonstration of two-way radio transmission at the 2nd Symposium of Radio and the 80's in June 1976 in Ottawa. HERMES provided the Ottawa-Frobisher Bay link and ANIK rebroadcasted to other northern communities.


Satellites
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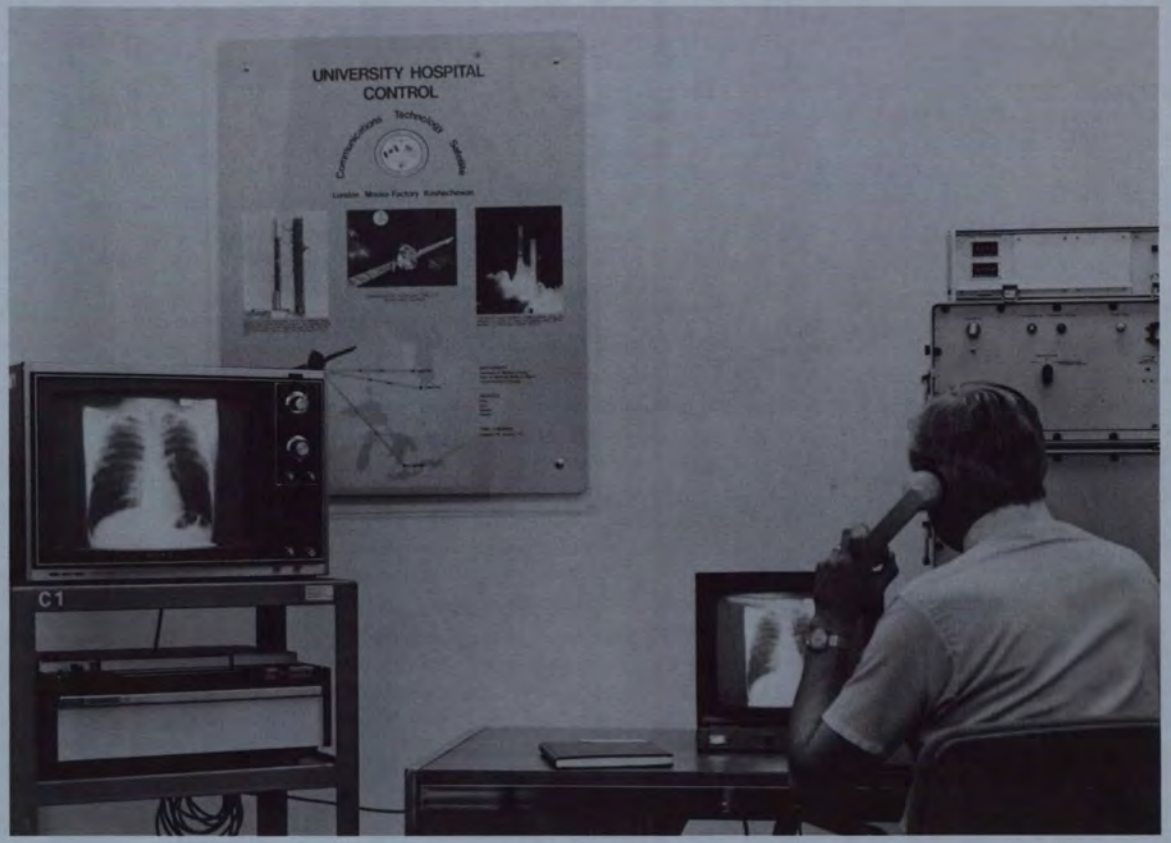
T. et ANIK

Communications experiments cover a broad range of disciplines and objectives. Several relate to communications technology, dealing with matters such as the performance of transportable earth terminals, the quality of signal reception in metropolitan areas, high-rate data transmissions and demand-assignment multiple-access experiments to investigate the efficiency of a few telephone channels being used by many callers. Many of the other experiments are addressed to social aspects of communications for community development, cultural exchanges and the provision of educational, health and medical services. Experiments are being conducted by federal and provincial government organizations, universities and cultural and other associations, each of which are responsible for its own planning and system design.

Communications Research Centre engineer checks out one of the ten 81cm diameter earth stations used in the communications technology satellite program. In the background is a nine-metre antenna, similar to those commonly used with conventional satellites.

The following examples are cited to give an indication of the varied nature of these experiments:

- The Memorial University, St. John's, Newfoundland, is supporting a medical education program, using one-way video and two-way voice communications between a central point in St. John's and four outlying hospitals at St. Anthony's, Stephenville, Labrador City and Goose Bay.
- The University of Western Ontario has experimented with the provision of remote-access medical consultation services, using one-way video and two-way voice communications between the hosptial at Moose Factory and the University Hospital in London, Ontario;
- The Government of Québec and the University of Saskatchewan have undertaken a cultural exchange experiment, using two-way video and voice communications, between Zenon Park, Saskatchewan, and Baie St. Paul, Québec;
- A community development program of the Alberta Native Communications Society plans to use HERMES for the transmission of video programs from Edmonton to three remote communities and for re-broadcast to other sites.



Typical telemedicine scene where a specialist in a large hospital in London, Ontario, is consulting with a base doctor and nurses in a small northern community hospital in Moose Factory, Ontario.

This low-cost ground terminal for voice communication was transported to the site by Otter aircraft and canoe. This photograph was taken during a geological experiment in the James Bay area of Québec.

ANIK B — A Dual-Band Satellite

The Canadian domestic satellite communications systems operated by Telesat Canada[1] has three spacecraft in orbit, ANIK I, II and III. A fourth spacecraft, ANIK B, is now being built, with launch scheduled for late 1978. The payload consists of a 12-channel 6/4 gigahertz transponder, to serve as a replacement for ANIK I and a four channel 14/12 gigahertz transponder for experimental use. The characteristics of the 14/12 gigahertz transponder channels are similar to those of the next series of satellites being planned by Telesat Canada to go into commerical operation in the Fixed Satellite Service in 1980 (ANIK C series). DOC has a contract for the use of this transponder to continue the exploration and development of new satellite communications services begun in the HERMES program.

Participation in the SYMPHONIE Satellite Program

Symphonie is an experimental satellite communications system jointly developed by France and the Federal Republic of Germany (FRG). Two satellites in geosynchronous orbit over Europe are visible in Ottawa at about 10° elevation. Signals were first received in January 1975 by a DOC mobile earth station, verifying predicted performance and confirming the feasibility of signal reception in Canada. In 1975, there were five technical and social experiments with France and, in April 1976, a teleconference via satellite with the FRG was arranged for the American Institute of Aeronautics and Astronautics (AIAA) Conference in Montreal. Further experiments continued through 1977.

10m all-aluminum dish used for the Symphonie experiments. The 18m trailer houses the complete electronic equipment package. The antenna can be erected without mechanical aids.

[1] Telesat Canada, see page 95.

Canadian Participation in INTELSAT

INTELSAT was formed in 1964 and operated under an interim agreement until 1973, when a new permanent agreement came into force. Canada has been a member of INTELSAT since its creation and is represented at the Assembly of Parties, which meets once every two years, by officials of the Department of Communications, supported by the Department of External Affairs. Canada, is also represented by Teleglobe Canada*, a Crown corporation which is the designated operating entity at the Meeting of Signatories and at the Board of Governors. Teleglobe has three fully commercial INTELSAT Standard A satellite communication earth stations making use of the INTELSAT IV and IV-A satellites.

As Canada's international carrier, Teleglobe was the first telecommunications entity in this country to participate in the adventure of communications through space. In fact, in 1964, Teleglobe was one of the eleven original signatories to the first INTELSAT agreement. INTELSAT is a consortium now numbering 96 countries, which was formed to own and operate a global, commercial satellite system.

For Teleglobe Canada, 1976 was marked by the satellite transmission of the Olympic Games to countries all over the world. Olympic activity began as early as February, when Teleglobe carried more than 60 hours of television coverage to Canada from the winter Olympics in Innsbruck, Austria. At the time, this represented the largest continuous period of television transmission that Canada's international telecommunications organization had ever carried for a single event.

That record held only until the summer Olympics in Montreal, the undoubted highlight of the year for the corporation. It was a project that meant four years of studies and planning, and one year in advanced provisioning of Telex and telephone facilities, expansion all across the Teleglobe network and the installation of a transportable earth station on Mount Royal in the centre of Montreal. This station was capable of sending two simultaneous video signals to Europe and the Atlantic Ocean area via the INTELSAT satellite stationed in orbit 36,000 km above the earth. A third video channel to Europe was provided by the earth station at Mill Village, Nova Scotia. One television channel, provided by the Lake Cowichan, British Columbia, earth station and the INTELSAT Pacific satellite met the requirements of the Pacific rim countries. These facilities were used to capacity as Teleglobe Canada transmitted 782 hours of television programming to Asia, Europe, Latin America and Africa, making record use of the INTELSAT system.

The corporation owns and operates three satellite earth stations: two at Mill Village and one at Lake Cowichan.

The facilities provided by the first Mill Village earth station enabled Canada to participate in the early development of the technological and commercial aspects of satellite communications via EARLY BIRD and its successors.

* Formerly the Canadian Overseas Telecommunications Corporation (COTC).

MUSAT - A Multi-Purpose UHF Satellite

Several government departments and agencies require improved communications with ships, aircraft and land mobile vehicles operating within Canada and off its coasts, particularly in the Arctic. Satellites and small, mobile earth stations operating in the UHF appear to meet this requirement. System definition studies by DOC have identified certain design problems in UHF satellite transponders and these will have to be resolved before the feasibility of a Canadian MUSAT system can be verified. Studies are proceeding.

Mill Village, N.S., site of two satellite earth stations owned by Teleglobe Canada. The radome in the background covering a 25m Cassegrain-type dish was built in 1965. The antenna in the foreground, with a 30m dish, was built in 1969.

Remote Sensing Program

The Canada Centre for Remote Sensing (CCRS) is the nucleus of a national program in remote sensing, introducing this new technology into the established resource management and environmental monitoring agencies in Canada. Under the guidance of the Inter-Agency Committee on Remote Sensing (IACRS) made up of representatives of various federal government departments, the centre serves federal and provincial agencies, universities, industries and the general public. It co-ordinates the national effort in conjunction with the working groups of the Canadian Advisory Committee on Remote Sensing (CACRS) made up of representatives of provincial and federal organizations, industry and universities. There are 13 working groups representing the disciplines that support or use remote sensing techniques.

The CACRS was established in 1972 to assist and advise the government in meeting the objectives of the national program on remote sensing of the surface environment, by diffusing remote sensing technology in Canada and by assisting in co-ordinating and evaluating programs to assure a high level of national benefits relative to the cost of remote sensing. It advises on remote sensing applications, remote sensing platforms, satellite systems, aircraft systems and balloon systems; on sensor development; on data processing; on cataloguing, reproduction and marketing of data; on regional development; and on research grants and contracts.

Changing ice conditions in the Gulf of St. Lawrence as seen from the U.S. NOAA 5 weather satellite. Photo on left taken March 13, 1977 shows westerly winds pressing ice against the west coast of Newfoundland. Pack ice is drifting and melting as it is driven through the Cabot Strait. Photo on right taken 6 days later shows the Gulf almost free of ice. Photos were received and reproduced by the Atmospheric Environment Service, Toronto.


NOAA5 ORBIT 2808-VIS 13MAR77 1340Z GULF ICE 13/155G


NOAA5 ORBIT 3266-VIS 19APR77 1335Z GULF ICE 14/175G

Remote Manipulator Systems (RMS)

The Shuttle Remote Manipulator System (SRMS)

Following consultation with Canadian industry and negotiations with NASA, the NRCC undertook, in July 1975, the design, development, flight qualification and manufacture of the first flight unit of the SRMS for the Space Shuttle Orbiter. The National Aeronautical Establishment (NAE) of NRCC is responsible for the program.

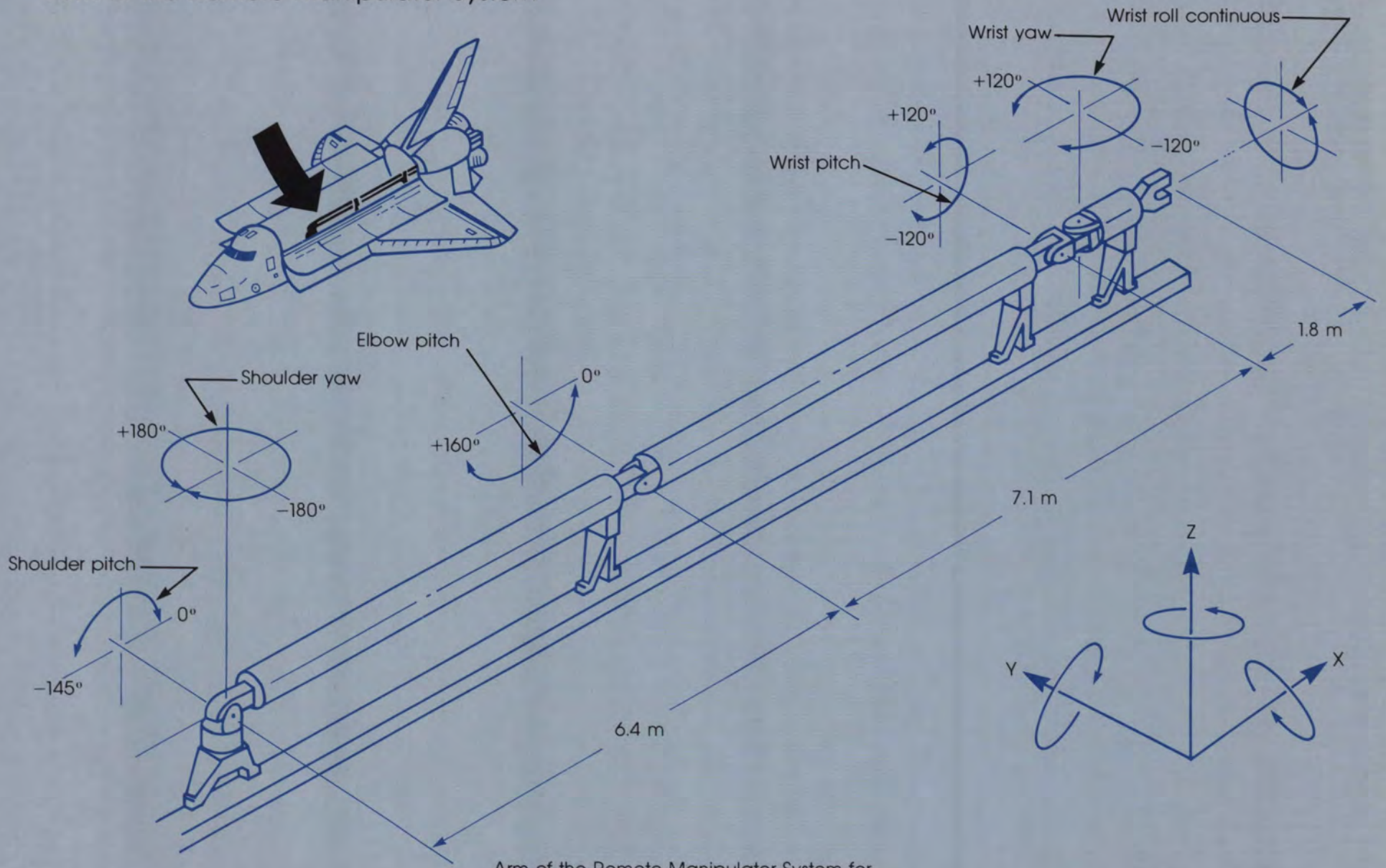
The program covers the design, development and construction, for delivery to NASA, of the first flight unit of the SRMS for the Advanced Space Transportation System (Space Shuttle), and the design and construction of an SRMS Simulation Facility (SIMFAC). The SRMS is an arm-like device which will be used to deploy payloads, satellites and other space devices from the cargo bay of the Space Shuttle Orbiter and also to retrieve recoverable payloads.

The design, development and construction of both the SRMS and the SIMFAC are being carried out by a Canadian industrial team. SPAR Aerospace Products Ltd. is the prime contractor responsible for over-all program management. CAE Electronics Ltd., Montréal, is responsible for the display and control subsystem. SPAR Technology Ltd. (STL), Montréal, is responsible for the electrical subsystem and Dilworth, Secord, Meagher and Associates, Toronto, are the engineering consultants responsible for the design of special test equipment.

The SRMS is a six-degree-of-freedom manipulator arm to be operated by a payload specialist located in the crew compartment of the Orbiter spacecraft. The arm is 15.2 m long and is in three segments with electromechanically driven joints. The joint at the shoulder, which is secured to the longeron of the Orbiter, has two degree-of-freedom shoulder pitch and yaw and is joined by a 6.4-m-arm segment to the elbow joint, which has motion in the elbow pitch plane only. A 7.1-m-arm segment terminates in a wrist joint which allows wrist motions in pitch and yaw. A further 1.8-m segment terminates in a joint providing continuous wrist roll motion with an end effector or hand to grapple the payload.

The current payloads envisaged for the Orbiter spacecraft include: a large space telescope, earth observation satellites, the NASA reusable tug, the Interim Upper-Stage tug, and the Long Duration Exposure Facility (LDEF), all of which will be manipulated by the SRMS. Over-all, the Space Shuttle System is to have the capability of placing payloads up to 18.3 metres long, 4.6 metres in diameter, and 30,000 kg mass in orbit.

Arm of the Remote Manipulator System

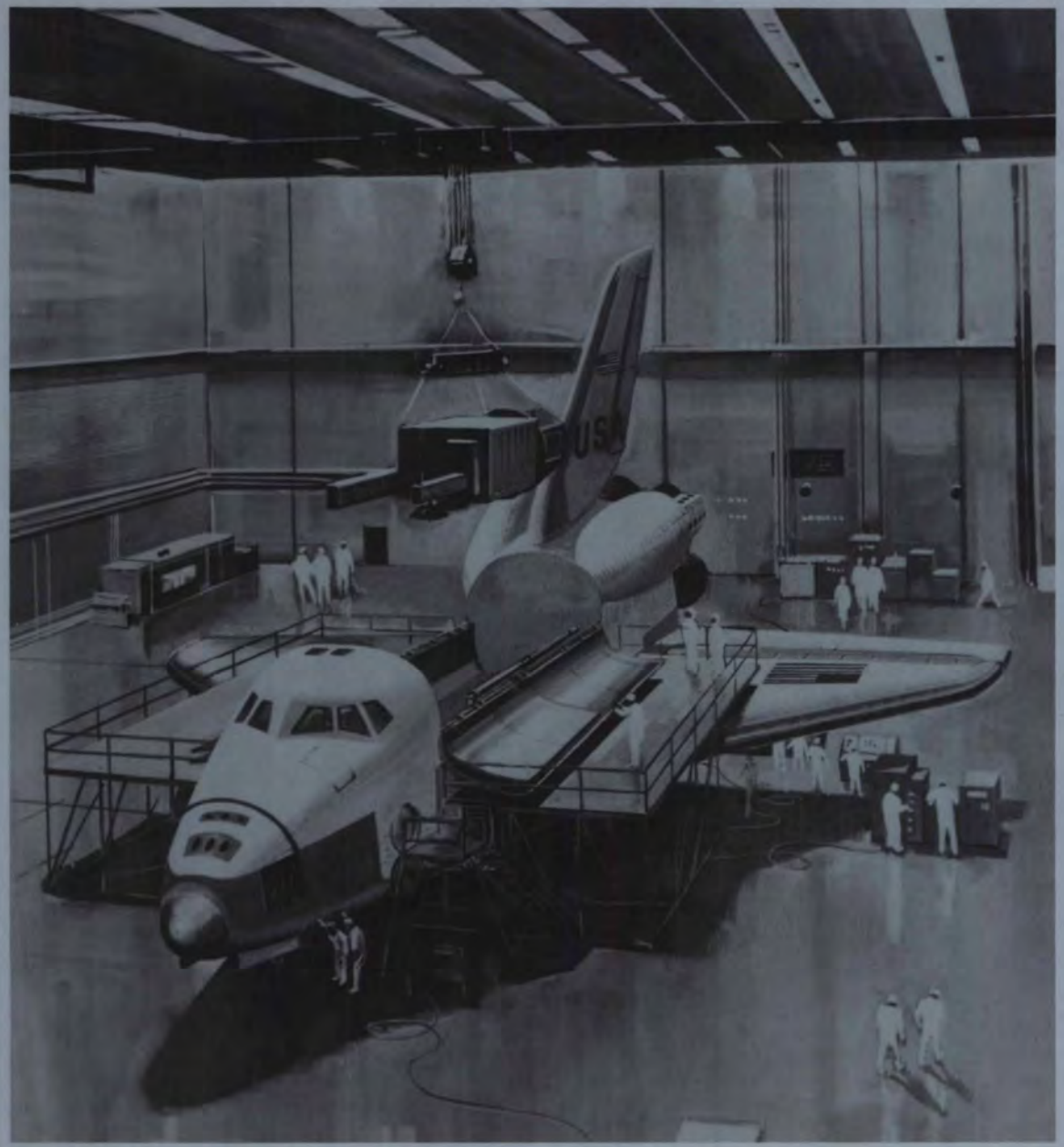


Arm of the Remote Manipulator System for the deployment and retrieval of satellites and other payloads in Space Shuttle operations.

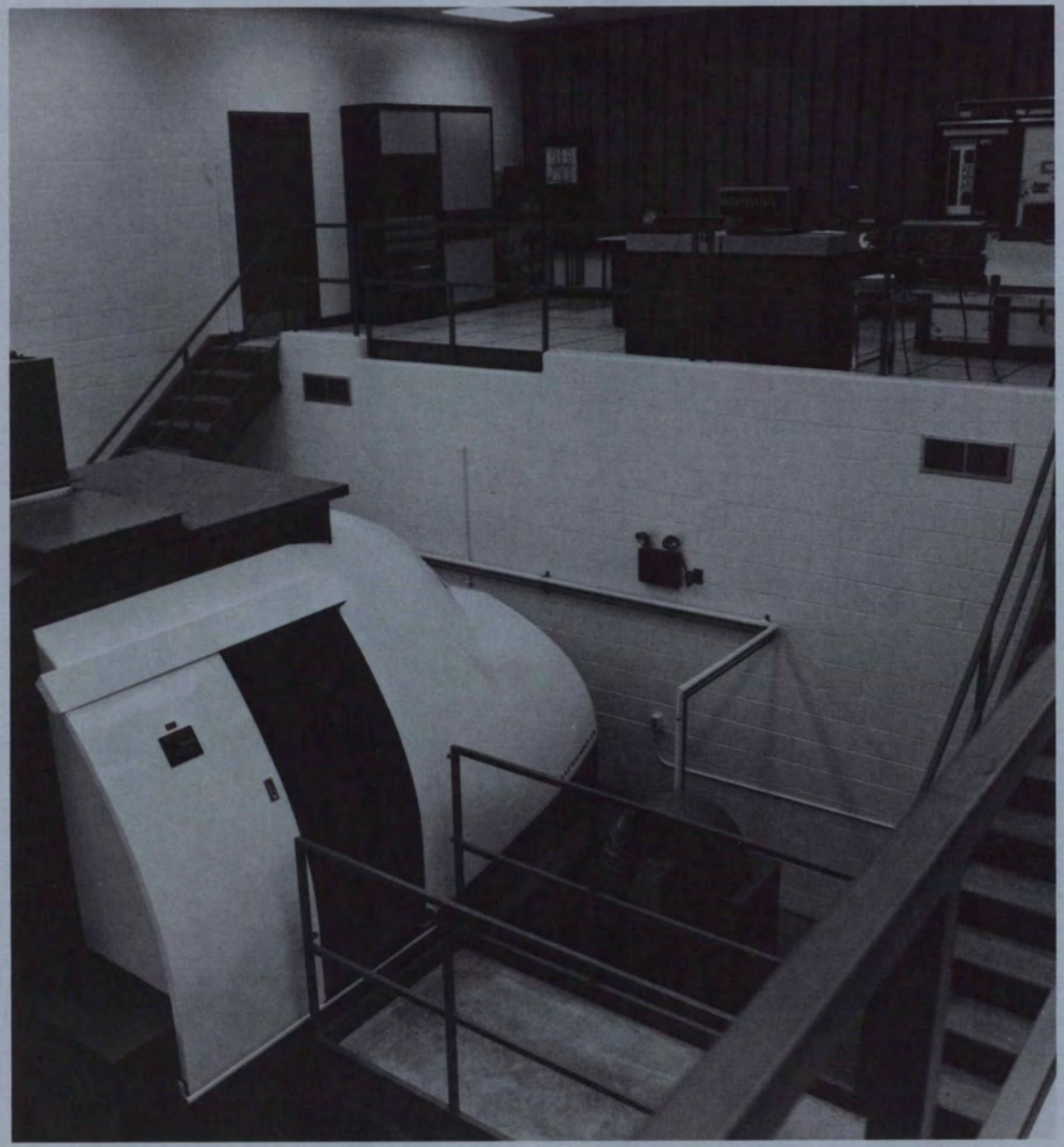
Phase B, the preliminary design phase, has been concluded following satisfactory completion on October 28, 1976, of the preliminary design review conducted by NASA. Phase C, the critical design phase, continued through 1977, leading to the critical design review scheduled for April 1978. The first flight unit of the SRMS is scheduled for delivery to NASA in July 1979 and is to be flown on a Space Shuttle test flight in September of that year.

The RMS Simulation Facility (SIMFAC)

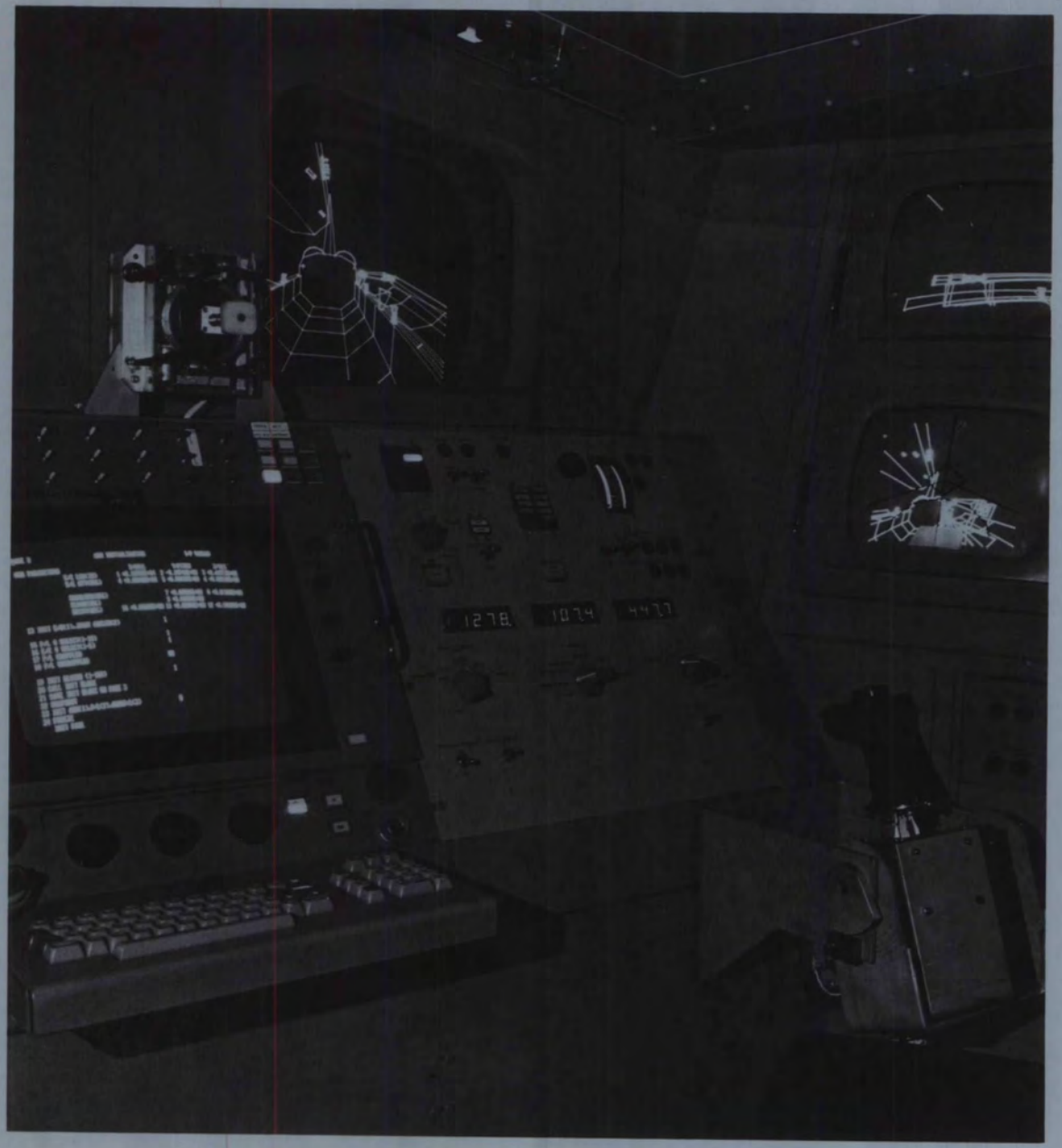
The high reliability requirement for the SRMS makes it necessary to develop means, during the design phase, to test the operating of the system under zero gravity conditions, as the arm itself cannot be effectively tested in a gravity environment. The general purpose manipulator system simulation facility (SIMFAC), located at SPAR's facilities in Toronto, uses mathematical modelling techniques and allows testing in two dimensions under simulated zero gravity conditions. The facility will also be used in the development of RMS systems for non-space applications.



Artists' conception of a satellite being loaded on board of the NASA Space Shuttle Orbiter. The Remote Manipulator can be seen in its stowed position along the port side of the cargo bay.



Remote Manipulator System, Simulation Facility, Toronto.



Shuttle simulator crew compartment.

Air and Sea Navigation Space Programs

The AEROSAT Program

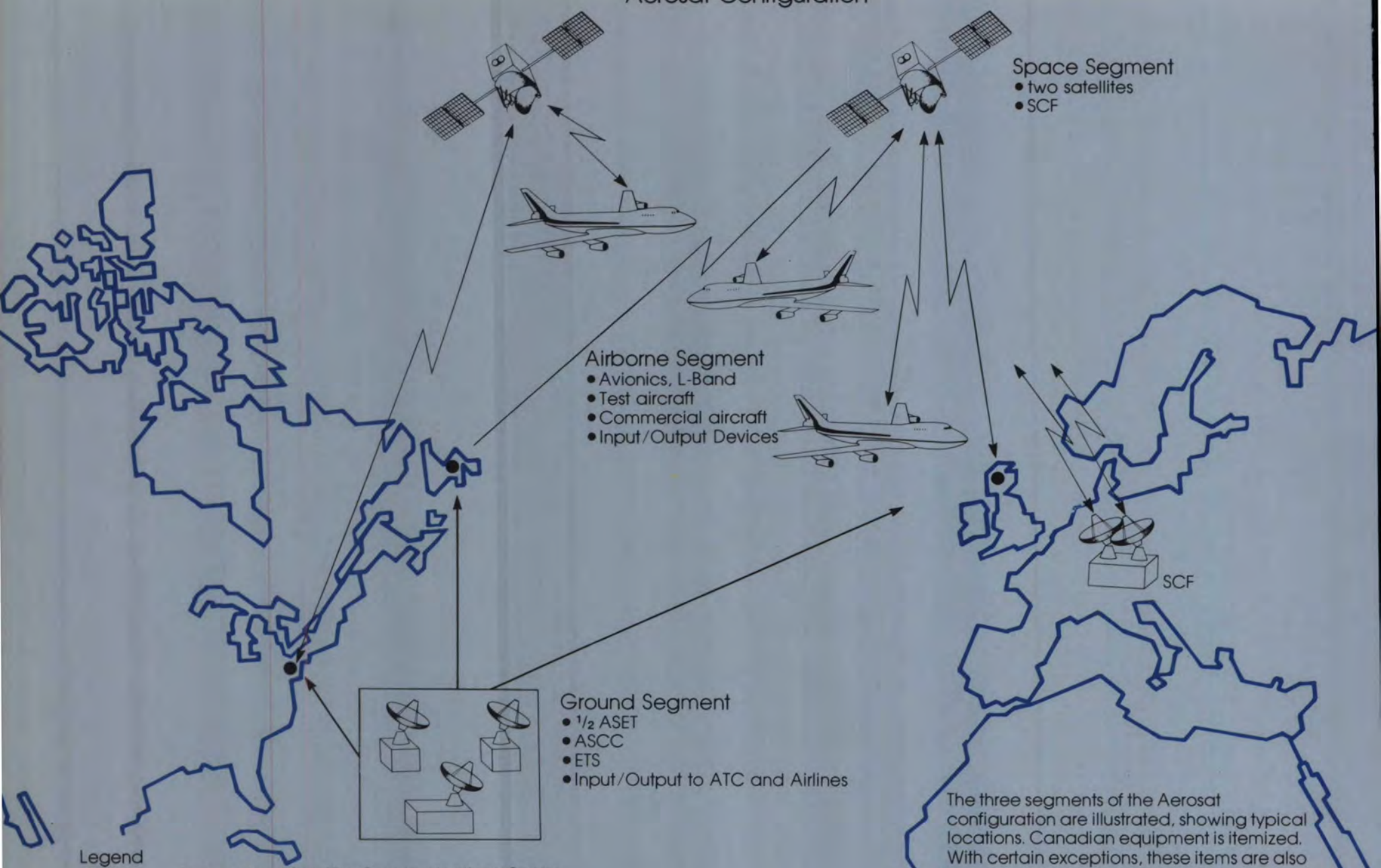
Canada is participating in the AEROSAT program with the United States and ESA. The objective of the program is to establish the criteria for an aeronautical satellite system for air traffic control in the mid-1980s. The Department of Transport (DOT) is responsible for Canadian participation in the ground and airborne segment, and the Department of Communications (DOC), the space segment.

DOT controls all international flights west of the Long. 30 degrees W. using the North Atlantic routes and is developing a transportable ground communication centre for AEROSAT, which will be built in Canada, to provide switching, control, data processing and computations. DOT is also responsible for one half of an aeronautical services earth terminal; this transportable facility will be of modular design, providing sufficient modems and channel capacity to make full use of the capacity of one satellite. A number of transportable electronic test sets, also to be built in Canada, will be used to test and calibrate communication channels and to monitor the satellite's forward-channel transmissions.

Flight trials, using the ATS-6 satellite, have been undertaken from a Canadian Jetstar aircraft in order to evaluate improvements made in a Canadian-designed linear phased-array antenna with automatic beam steering, and in Canadian-designed voice modems. Experiments have also been conducted to investigate the effects of multi-path interference in a satellite-to-air mobile environment.

The space segment requires the development, production, launching and operation of two satellites. Spacecraft costs are to be shared by the United States, ESA, and Canada in the proportions of 47 percent, 47 percent and six percent.

Aerosat Configuration

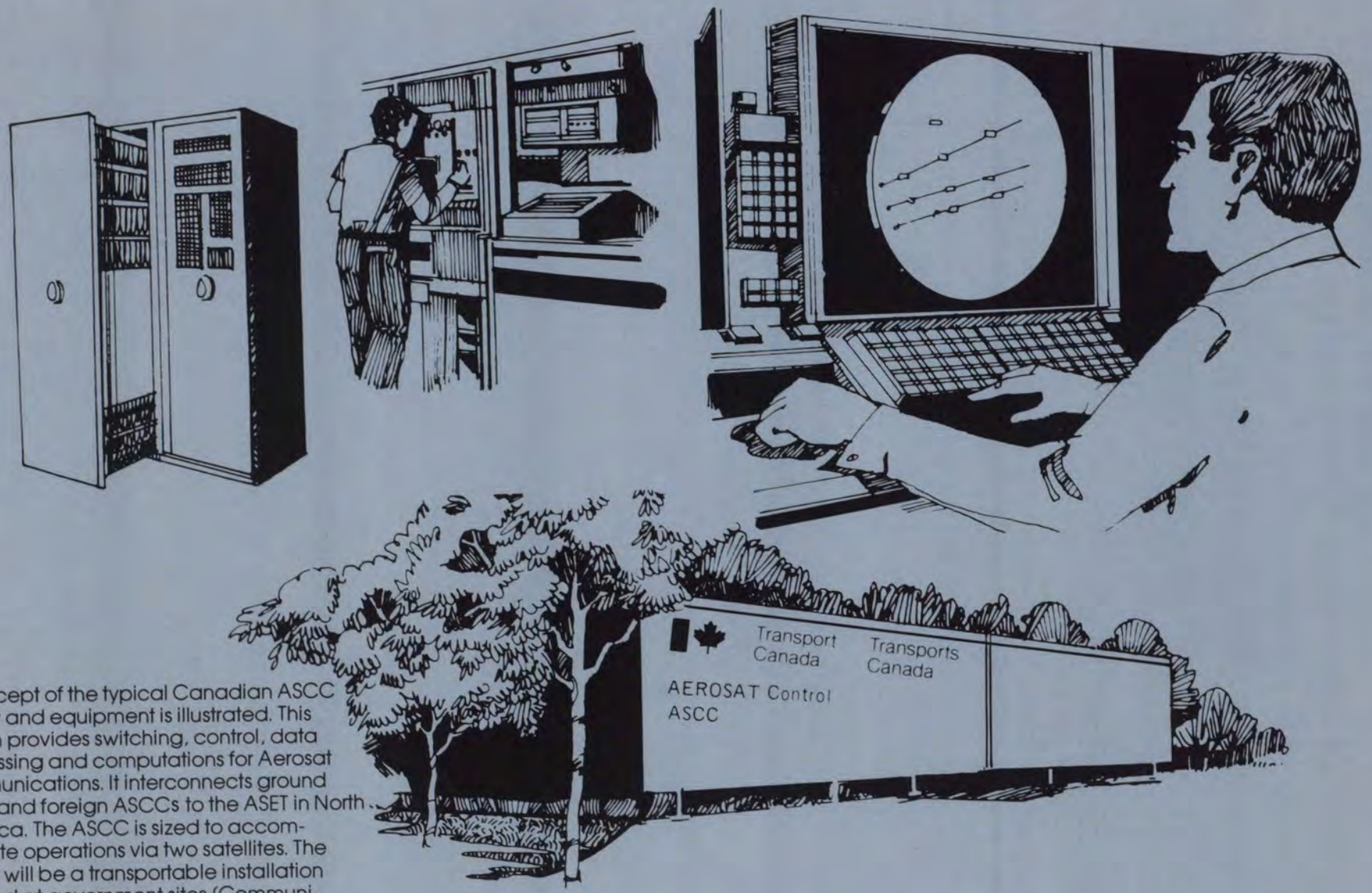


Legend

ASCC	Aeronautical Satellite Communications Centre
1/2 ASET	One half of an Aeronautical Services Earth Terminal
ATC	Air Traffic Control
ETS	Electronic Test Set
SCF	Satellite Control Facility

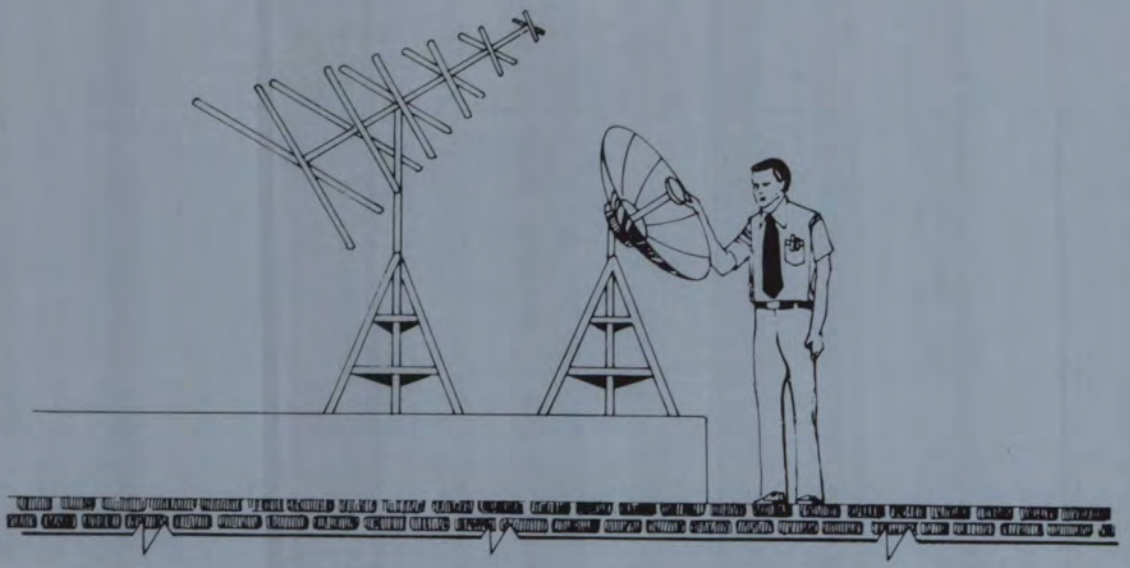
The three segments of the Aerosat configuration are illustrated, showing typical locations. Canadian equipment is itemized. With certain exceptions, these items are also typical of European and United States equipment. A significant variation is that Canada and the United States each provide only one-half of the North American ASET (1/2 ASET).

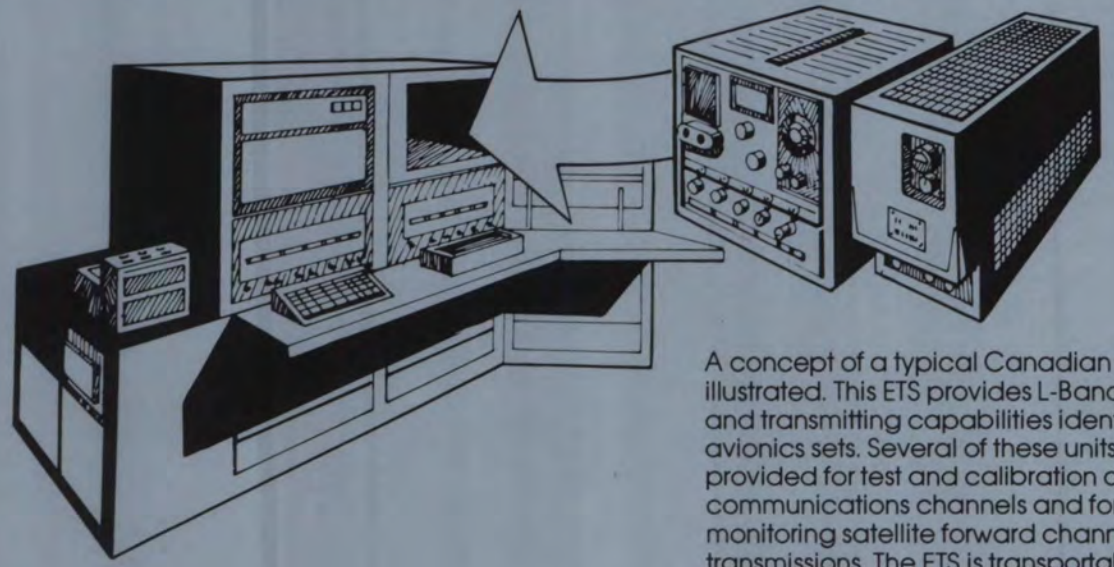
Canadian ASCC Components
(Aeronautical Satellite Communication Centre)



A concept of the typical Canadian ASCC facility and equipment is illustrated. This system provides switching, control, data processing and computations for Aerosat communications. It interconnects ground users, and foreign ASCCs to the ASET in North America. The ASCC is sized to accommodate operations via two satellites. The ASCC will be a transportable installation located at government sites (Communications Research Centre, Shirley Bay, Ontario and Gander Oceanic Control Centre, Gander, Newfoundland), for use during the Aerosat program.

Canadian ETS Components
(Electronic Test Set)





A concept of a typical Canadian ETS is illustrated. This ETS provides L-Band receiving and transmitting capabilities identical to avionics sets. Several of these units are provided for test and calibration of communications channels and for monitoring satellite forward channel transmissions. The ETS is transportable and may be located with a 1/2 ASET or at a remote geographical location to perform channel testing and/or ranging transponding. The ETS components will be adapted according to the needs of specific installations.

Canadian ice-breaker, the Norman McLeod Rogers, operating in the eastern Arctic.

MARISAT

The United States MARISAT satellites are now operating for maritime communications in the Atlantic. DOT installed a MARISAT terminal in one of its ice-breakers and undertook trials with the system while the ship was operating in the Eastern Arctic. Voice, Telex and facsimile communications by the satellite were tested, and despite some technical difficulties which developed, were generally found to be operationally satisfactory and of a better quality than can be achieved with present HF circuits. These trials showed that satellite communications are of great potential benefit to the maritime community.

INMARSAT

Canada has a special interest in the development of a satellite communications system that would help to ensure safe and efficient maritime transportation, because of the expanse of its coastal and inland waters and the large volume of shipping entering and leaving its ports. In September 1976, Canada participated in an international conference which ended with the adoption of the Convention and Agreement on the INMARSAT Organization. Pending ratification by governments, a preparatory committee has begun work. Subject to ratification by a sufficient number of countries, an INMARSAT worldwide system could be in operation in 1978.

Scientific Programs

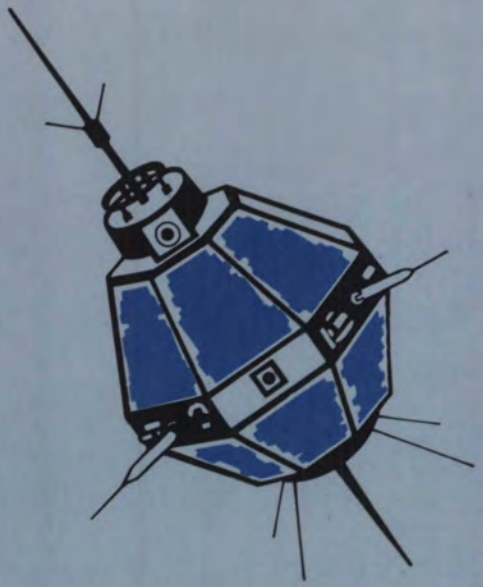
Ionospheric Research — The ISIS Satellites

Under a Memorandum of Understanding with the United States, Canada agreed to build several scientific satellites. The two satellites still in operation, ISIS I and ISIS II, were launched on January 30, 1969, and March 31, 1971, respectively.

Most of the ISIS II experiments and spacecraft systems are performing well. ISIS I and ISIS II are operating respectively for two and a half and four hours a day.

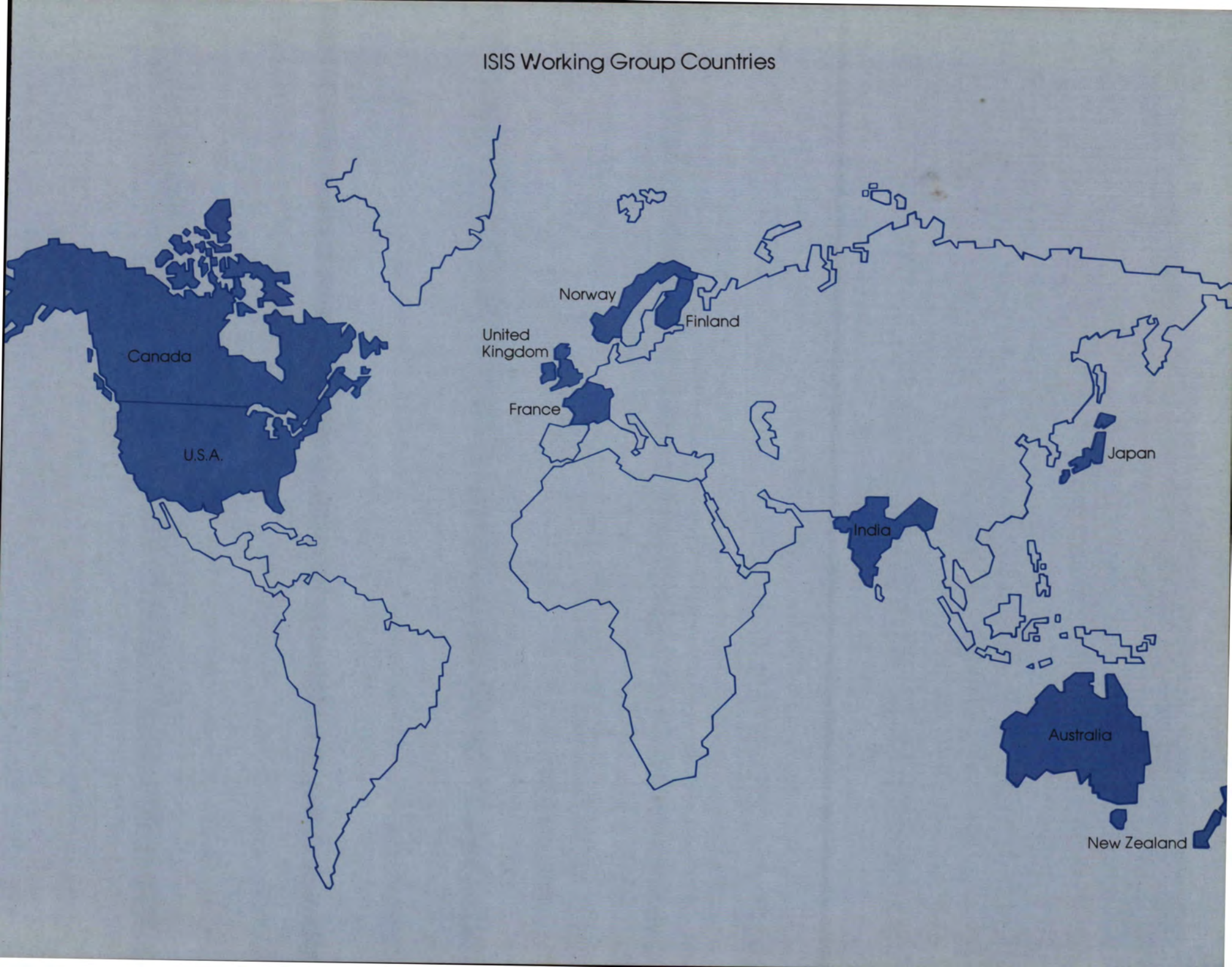
Under the ISIS program, CRC operates two telemetry stations at Resolute Bay, Northwest Territories, and Ottawa. The control station for the ISIS satellites and the data-processing centre are in Ottawa.

Countries participating with Canada in the ISIS working group are Australia, Finland, France, India, Japan, New Zealand, Norway, the United Kingdom and the United States. Ground stations outside Canada are located in Ascension Island; Terre Adelie, Antarctica; Santiago, Chile; India; in the states of Washington, Hawaii and Florida in the USA; French Guiana; Japan; New Zealand; Ecuador; Norway; and England.



The last of the ISIS series, ISIS II, launched in 1971, is still operating and performing well today.

ISIS Working Group Countries



Swept-frequency sounder	
Frequency coverage	0.1 MHz to 20 MHz
Transmitter power	400 W or 100 W
Pulse width	100 μs
Pulse repetition frequency	30 Hz or 60 Hz
Frequency sweep rate	Varying from 0.31 MHz/s to 1 MHz/s over band
Fixed-frequency sounder	6 frequencies: 0.25, 0.48, 1.0, 1.95, 4.0, and 9.303 MHz
VLF	
Receiver	Untuned 50 Hz to 30 KHz
Transmitter	Logarithmic sweep 400 to 0 to 17 000 Hz
Cosmic noise	From AGC of sounder receiver
Energetic particle	
Protons	50 keV to 20 MeV
Electrons	8 keV to 770 keV
Langmuir probe	
Electron density	10^3 to 10^6 electrons/cm^3
Electron temperature	400 to 5000° K
Ion mass spectrometer	Atomic mass range 1 to 20
Ion probe	
Ion density	10 to 6 x 10^6
Ion temperature	700 to 4000° K
Soft particle spectrometer	
Electrons and positive ions	10 eV to 10 keV
Beacon	137.950 MHz

ISIS II Experiments

Swept-frequency sounder	
Frequency coverage	0.1 MHz to 20 MHz
Transmitter power	400 W
Pulse width	100 μs
Pulse repetition frequency	45 Hz
Frequency sweep rate	Varying from 0.25 MHz/s to 1 MHz/s over band
Provision for automatic ionogram transmission	
Fixed-frequency sounder	6 frequencies: 0.12, 0.48, 1.0, 1.95, 4.0, and 9.303 MHz
VLF	
Receiver	Untuned: 50 Hz to 30 kHz
Transmitter	400 to 0 to 17 000 Hz
Antenna impedance measurement	
Cosmic noise	From AGC of sounder receiver
Energetic particle	
Protons	50 keV to 20 MeV
Electrons	8 keV to 770 keV
Langmuir probe	
Electron density	10^3 to 10^6 electrons/cm^3
Electron temperature	400 to 5000° K
Soft particle spectrometer	
Electrons and positive ions	10 eV to 10 keV
Beacon	137.950 MHz
Ion mass spectrometer	Atomic mass range 1 to 64
Ion probe	Ion density and temperature
Oxygen red line photometer	6300Å
Auroral scanner	3914 and 5577 Å

Rocket and Balloon Programs

The rocket program studies the interaction that takes place when the solar wind strikes the earth's magnetic field. In particular, studies concentrate on particles, electric and magnetic fields and currents, and auroral and cosmic x-rays, plasmas and emissions. The balloon program studies astronomical and atmospheric phenomena and constituents.

Astrophysics

The Herzberg* Institute of Astrophysics is engaged in a number of space and space-related activities. These range from laboratory work to determine characteristics (spectra) of molecules likely to be found in space, to astronomical observations using ground-based radio and optical telescopes, and to studies of the near-earth space environment using rocket and satellite techniques.

Much of the rocket and satellite work is aimed at acquiring an understanding of the interactions that take place when the solar wind strikes the earth's magnetic field. Some of these interactions result in the radiation belts which surround the earth and are made up of electrons and protons, magnetic storms that show up as variations in the earth's magnetic field, communication blackouts that sometimes occur at high latitudes, and the visual aurora or Northern Lights which are caused by atoms in the high atmosphere emitting light when bombarded by energized electrons and protons. The mechanisms responsible for the energization of these electrons and protons, and for their transport through the earth's magnetic field, form one of the space-related studies at the Institute.

* Dr. Gerhard Herzberg, a scientist on the staff of the NRCC, was awarded the Nobel Prize for Chemistry in 1971 for his work in the field of molecular spectroscopy.

Lunar Sample Investigations

Three Canadian laboratories are still active in lunar sample research. The Earth Physics Branch and the Geological Survey of Canada, both in EM&R, have been investigating lunar samples using petrographic microscopy and electron microprobe methods. The Department of Chemistry at McMaster University is measuring sulphur concentrations and studying the loss and gain of sulphur in lunar soil. The Department of Geology at the University of Toronto is investigating magnetic and electrical properties of lunar samples.

Environmental Applications

Atmospheric Environment Service

The Atmospheric Environment Service (AES) of the Department of Fisheries and the Environment operates three satellite ground read-out stations to acquire data from polar-orbiting and geostationary United States meteorological satellites. These stations provide coverage of North America as well as of northern Atlantic and Pacific areas for distribution to weather centres across Canada.

Operational satellite receiving sites are operated in Halifax and Vancouver. Both are equipped to reproduce data from visible and infra-red scanners as black-and-white photographic imagery and to distribute this on national facsimile circuits throughout Canada.

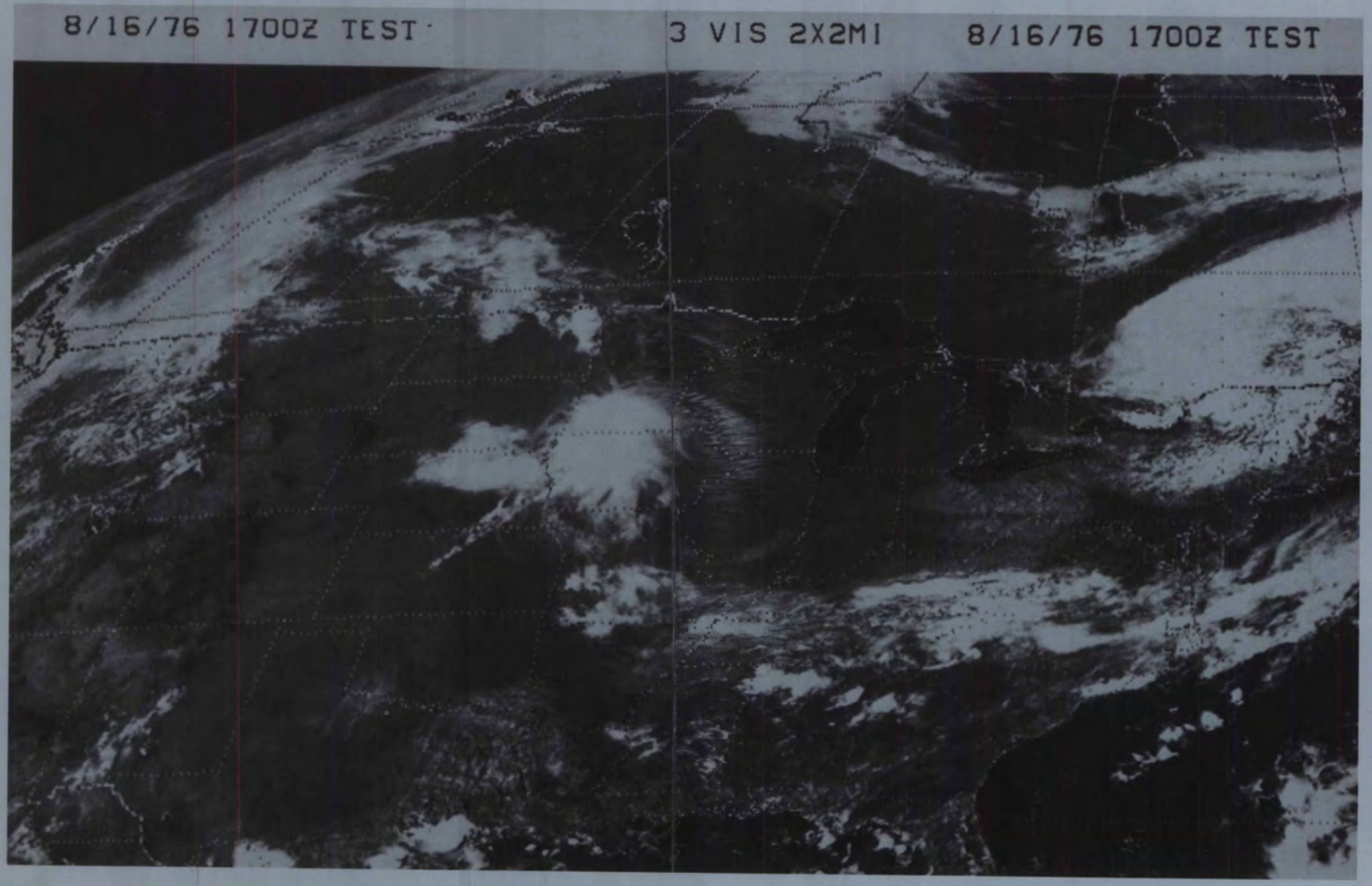
The Satellite Data Laboratory in Toronto is equipped to track and acquire full resolution data from the Very High Resolution Radiometer (VHRR) of the NOAA meteorological satellites and receive the WEFAX data from the GEOS geostationary satellites. It is primarily a research and development facility for meteorological, hydro-meteorological, ice-reconnaissance and other AES space applications. The laboratory also uses satellite images as an aid to its Arctic ice reconnaissance programs.

Environmental Management Service

Forestry Institutes of DFE conduct a variety of programs, including remote sensing for forest appraisal, fuel type mapping, forest damage detection, monitoring of logging operations, multi-stage inventory and forest type mapping.

The lands directorate has used LANDSAT imagery for biophysical mapping and for research into updating of land-use maps.

Other applications include snow cover studies with stress on run-off prediction, wildfowl habitat surveys for production estimates and lake color mapping in aid of research.



WEFAX-type imagery retransmitted by GEOS (SMS-3).

Other Applications

Oceanographers use LANDSAT and NOAA satellites for studying siltation and surface temperature patterns and have demonstrated the capability of a spaceborne altimeter to measure wave height.

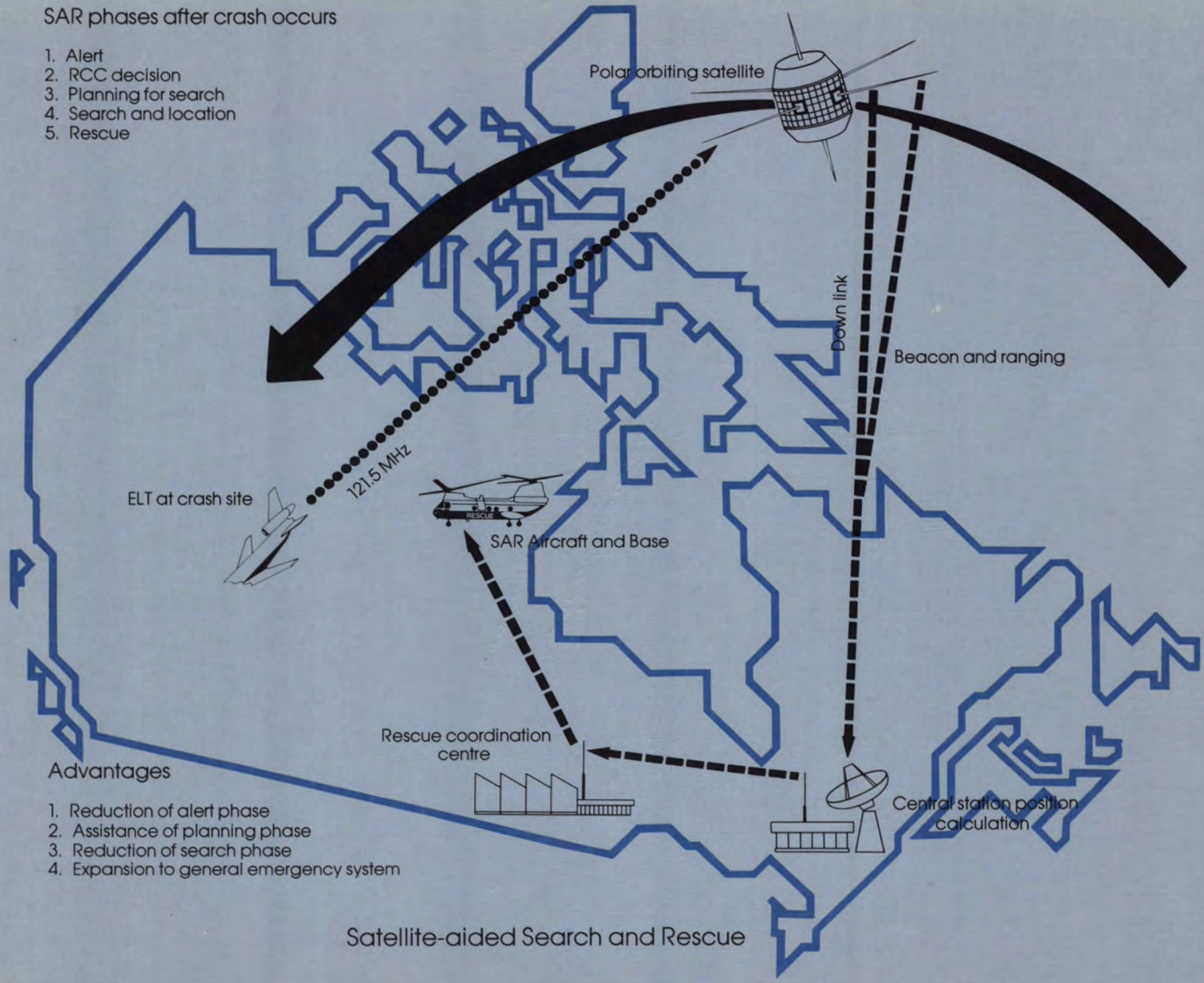
The extent of forest fires is mapped from LANDSAT images. Mine wastes have been mapped using LANDSAT. Research is being carried out using satellite data for agricultural yield prediction. The movement of the snow line is mapped commercially with the aid of satellite data.

LANDSAT image over Vancouver/Victoria area. The plume of fresh muddy water as it flows out from the mouth of the Fraser River into the clearer salt water of the Strait of Georgia can be seen.

Other Space-Related Activities

SARSAT — A Search and Rescue Satellite

A study of the feasibility of search-and-rescue satellites is being sponsored by the Department of National Defence. The Communications Research Centre undertook a 'proof-of-concept' experiment in 1976. The object was to demonstrate the feasibility of locating emergency locator transmitters (ELTs), by using polar-orbiting satellites. A special SARSAT processor was used in conjunction with the OSCAR-6 satellite of the Radio Amateur Satellite Corporation to demonstrate that a low-cost, low-altitude polar-orbiting satellite could pinpoint a crash site, to accuracies generally between two and eight km, within 15 to 20 minutes of first picking up the distress signal. Proposals for an operational system are now being evaluated.


SAR phases after crash occurs
1. Alert
2. RCC decision
3. Planning for search
4. Search and location
5. Rescue
Polar orbiting satellite
Down link
Beacon and ranging
121.5 MHz
ELT at crash site
SAR Aircraft and Base
Rescue coordination centre
Central station position calculation
Advantages
1. Reduction of alert phase
2. Assistance of planning phase
3. Reduction of search phase
4. Expansion to general emergency system
Satellite-aided Search and Rescue


indus

Air Industries Association of Canada

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The Air Industries Association of Canada (AICC) groups over 80 companies in Canada that have capabilities in the aeronautical and aerospace fields. The association has nine committees: aerospace electro-mechanical and electronics, contracts and finance, customs and tarriff, environmental monitoring, general aviation, marketing, product support, research and development, and technical standards and metric conversion.

In 1973, a space subcommittee was formed, grouping eight companies, to provide a focal point in the industry for the discussion and subsequent formulation of space policy for Canada, to assist the government in the direction and formulation of a co-ordinated space program as it can best relate to the Canadian space industry, to encourage the development of a "world class" industry through funding provided by the government, and to ensure that Canadian industry participates to the fullest in future Canadian space programs. Since its formation, the subcommittee has presented briefs to the government toward the development of space policy and improved the awareness in industry and government agencies of the increasing role of satellite systems for Canada's future development and of the benefits to the country of participation in future space programs by Canadian industry.

Telesat Canada

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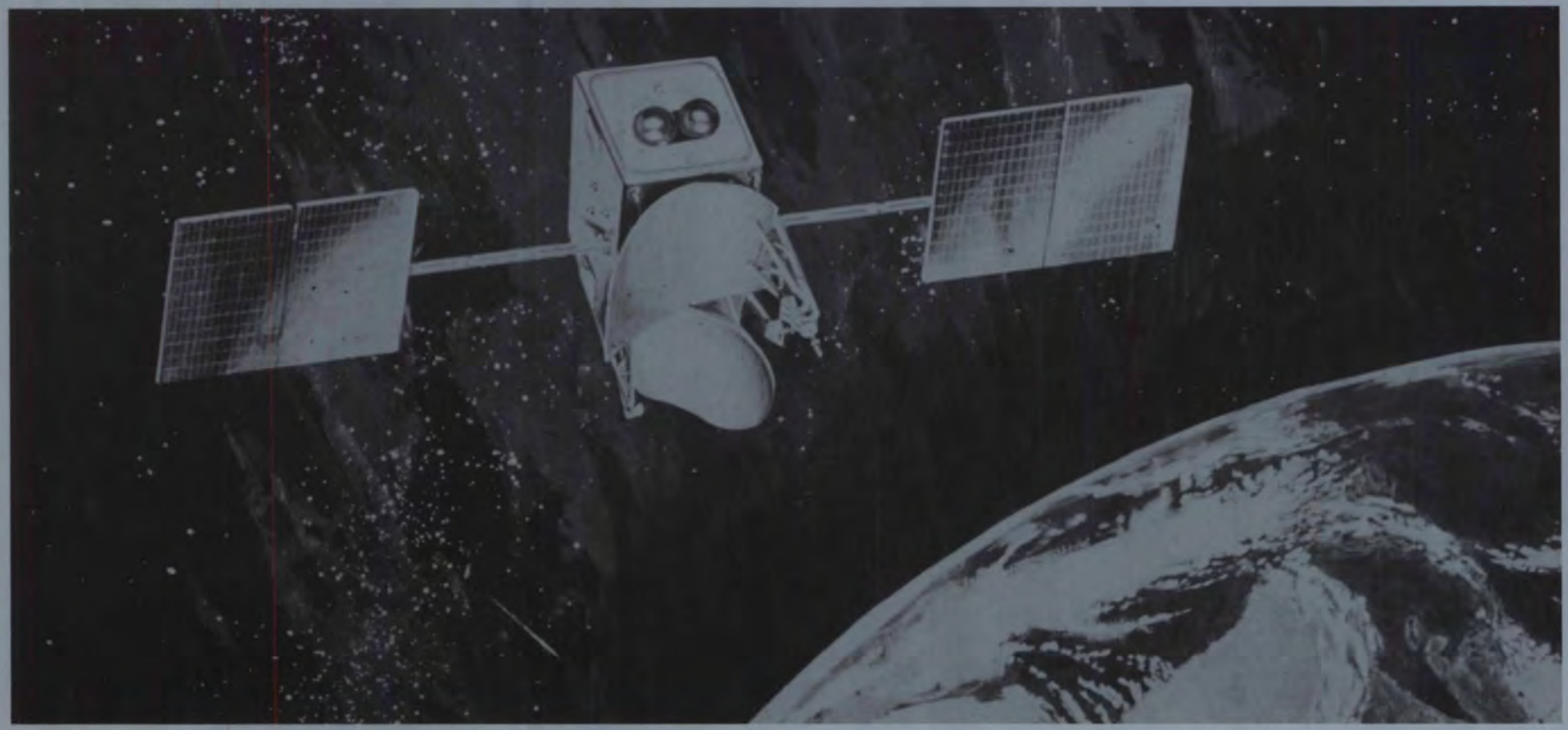
Following a proposal by a private broadcasting company for a Canadian domestic satellite communications system, a task force was established in July 1967 to examine future Canadian activities in the use of satellites, in particular communication satellites, and their potential role in Canadian telecommunication services. Recommendations were submitted in November 1967, and on March 28, 1968, the government published a White Paper titled "A Domestic Satellite Communication System for Canada", announcing its intention to establish a corporation to develop, own and operate both the satellites and the earth stations of the system.

Telesat Canada was accordingly incorporated by Act of Parliament in 1969. Its unique corporate structure has been the subject of interest by other countries considering the establishment of their own domestic satellite-communications systems. Telesat is not a crown corporation, and is not an agent of the government; it is incorporated as a commercial entity in which the equity is shared by the government and the principal Canadian telecommunication carriers, with provision for eventual participation by the general public. This structure accommodates the national interest and the corporate interests of the shareholders. Although, in most cases, Telesat's shareholders are also its major customers, this arrangement permits all parties to share financial, technical and managerial resources.

In November 1972, the first of the successful ANIK satellites was launched for Telesat. Canada became the first country in the world to have a nationwide domestic telecommunications system using geostationary synchronous satellites. Two more ANIK satellites have since been successfully launched and are in operation, and a fourth, the first of the ANIK-B series, now under construction, is scheduled to be launched in November 1978. Commercial operations began in January 1973 with one satellite and four earth stations; today, services are provided by three satellites and more than 70 earth stations covering the length and breadth of the country.



Artist's conception showing the ANIK B spacecraft scheduled for launch in November 1978.

At first, relatively large permanent earth stations were used; modular in concept, they were designed to accommodate future requirements for other services, including the transmission and reception of television programs through incremental additions to the station's electronic packages. As the demand for satellite communications grew, particularly in remote areas, and often for short-term requirements, smaller semi-permanent and transportable earth stations were developed. The smallest of these, with 3.6-m antennas, can be airlifted in bush planes to the most remote locations, where they can be put into service within a few hours of their arrival. Another recent development is the Frontier earth station, designed to provide radio and television reception for small communities not yet scheduled for inclusion in the national networks. The Frontier earth stations do not include the channel-switching capability and

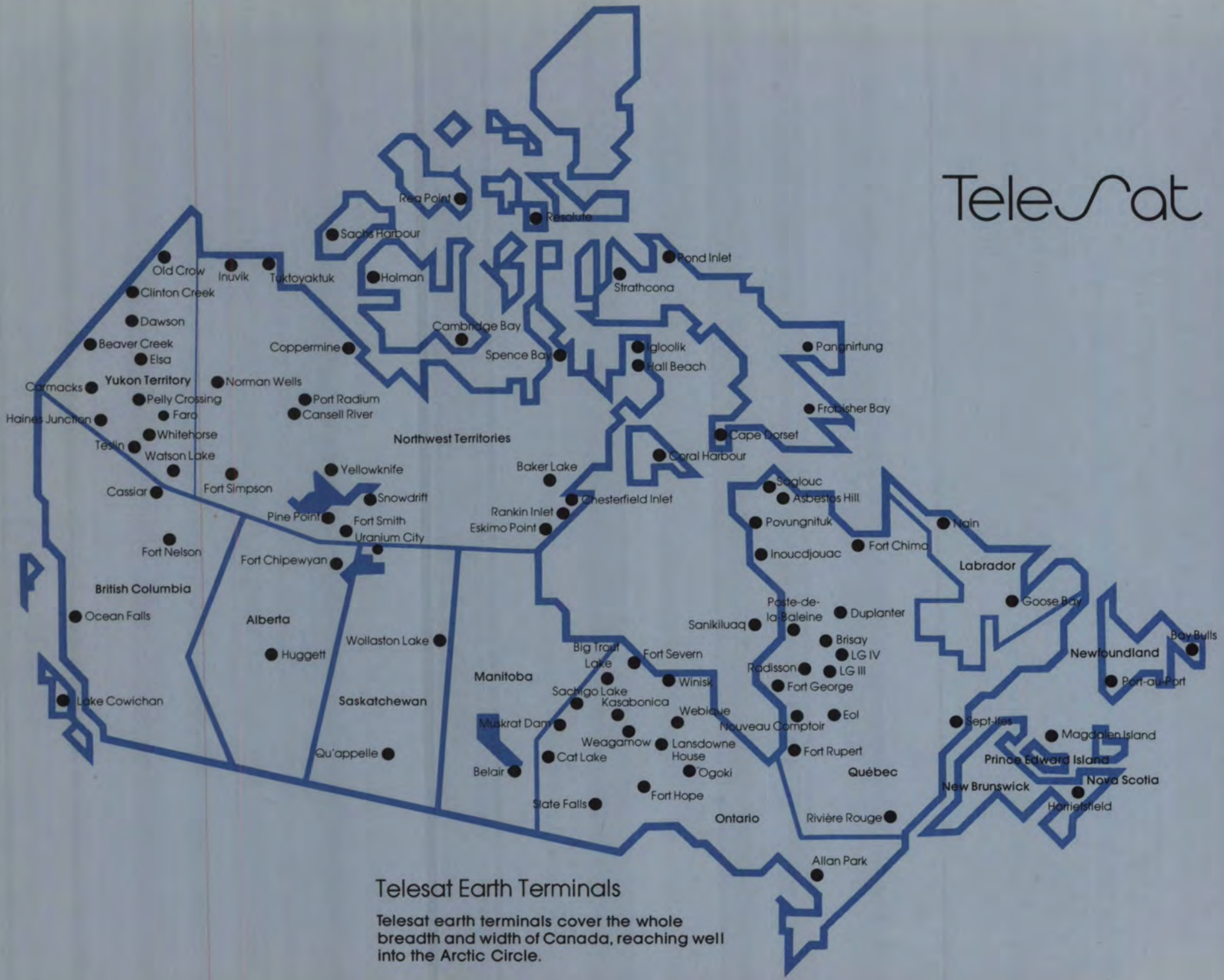
back-up features of the stations designed for the Canadian Broadcasting Corporation (CBC). They may be leased at lower cost by communities able to assume the costs and to provide housing and environmental protection. A number are already in operation in the Yukon Territory.

The Telesat system operates in the 6/4 gigahertz frequency band which is also used for the microwave relay systems of the terrestrial telecommunications carriers. This has the disadvantage that it limits the power to be used for satellite transmissions so as to avoid interference between the space and terrestrial systems. This limitation in turn necessitates larger and more costly earth stations, which have to be shielded from interference by nearby terrestrial communications facilities. These constraints generally make it necessary to locate the earth stations some distance away from major urban centres, and to relay the signals by terrestrial means. With fewer power restrictions and no interference problems in urban areas, Telesat would be able to provide smaller earth stations which could be installed at the downtown premises of its customers, thus eliminating the cost of back-haul to the outlying earth stations.

The ANIK B satellite will orbit conventional 6/4 gigahertz transponders and a number of RF channels in the 14/12 gigahertz range to take advantage of the fewer power restrictions and low interference problems in urban areas in this frequency band. The latter are to be leased by the government for continuing experiments in the applications of the higher frequency bands for satellite telecommunications. Studies at Telesat and elsewhere suggest the probability that many second-generation communications satellites will operate in the 14/12 gigahertz range. Other studies, some in collaboration with customers, are under way to identify customers' requirements for the 1980s. Consideration is being given to systems using larger hybrid satellites operating in both the 6/4 gigahertz and the 14/12 gigahertz ranges and to various other configurations that include a mix of separate satellites operating in one of the two bands.

An important customer of Telesat is the CBC; through three dedicated RF channels and one occasional use channel, its national and regional radio and television network programs are relayed in French and English throughout the country. Without the satellite system, many communities in remote and inaccessible areas would lack these services.

The Telesat earth station at Pangnirtung, N.W.T., Lat. 67 degrees N., provides telephone, radio and television services to the native communities in Baffin Island.



Telesat Earth Terminals

Telesat earth terminals cover the whole breadth and width of Canada, reaching well into the Arctic Circle.

The Trans-Canada Telephone System (TCTS), a voluntary association of the principal Canadian telephone companies, and Canadian National/Canadian Pacific Telecommunications (CNCP), are also customers of Telesat. The two organizations use ANIK channels with a capacity of almost 1,000 two-way circuits for service between Vancouver and Toronto. Bell Canada, in addition to its share in the east-west TCTS circuits, leases two RF channels providing message service for locations in the Eastern Arctic. Teleglobe Canada leases an ANIK channel to relay traffic between Toronto and the Canadian terminal of the transatlantic cable.

Since the successful inauguration of the system in 1973, Telesat has been approached by governments and private organizations around the world for assistance in the development of plans for satellite communications systems. In addition to formal consultative contracts, Telesat has co-operated with government departments in the presentation of detailed briefings and seminars on its own system for officials and telecommunications executives of several foreign countries, including Brazil, Taiwan and Indonesia and of the Commonwealth Telecommunications Organization. Technical papers are regularly presented at meetings of such organizations as IEEE, AIAA and other technical and engineering bodies and associations.

On January 1, 1977, Telesat became a full member of the Trans-Canada Telephone System. This involves no change in the company's ownership or management and is in full compliance with the Telesat Canada Act.

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Spar Aerospace Products Ltd. is a public company, 97 percent Canadian-owned, engaged in the design, manufacture and servicing of products for the space, air and ground transportation markets.

The result of successive groupings and mergers, Spar began operating on January 1, 1968. The experience and technological capabilities of its predecessors have been refined and extended by Spar's management, enabling it to serve, in a variety of capacities, the commercial, scientific and military advanced technology markets in North America and overseas. The company's Toronto-based capabilities are complemented by the technological expertise of its wholly owned subsidiary, Astro Research Corp. in Carpinteria, California.

Early in 1977, Spar acquired a substantial portion of the assets of the government and commercial systems division of RCA Ltd., Montréal. The agreement provides for the acquisition of the business as a going concern including equipment, assets and liabilities and the leasing of space in RCA's Ste-Anne-de-Bellevue facility and in a plant on Lenoir Street in Montréal. The capabilities acquired are complementary to those of Spar and will enable Spar to undertake the complete development of satellite-communications systems. The RCA business acquired produced revenues of about $17 million in 1976 and employs about 500 people. The government and aerospace systems division of RCA comprised two subdivisions: aerospace and government systems, and communications systems, the first concerned with satellite-borne communications and the second with those that are earth-based.

Operations

From modest beginnings in 1968, when the company took over the operations of the special products and applied research division of De Havilland Aircraft of Canada, Spar has grown into an industrial complex employing more than 1,350 people including close to 400 scientists, engineers and skilled technicians.

Originally located at Malton, Ontario, Spar moved in 1969 to a modern facility which now comprises 20,900-m² of floor area on Caledonia Road in Toronto. Constantly modernized and upgraded, Spar's plant today represents an outstanding manufacturing and testing facility which provides a solid base for the company's precision gear production and the manufacture and assembly of spacecraft structures, subsystems and components. Six specialized engineering laboratories and direct access to a high-power scientific computer support the company's diversified research and development programs. In addition, Spar has designed and built a computerized test track facility, unique in Canada, for urban transit vehicles, particularly those propelled by linear induction motors (LIMs).

A new 3,350-m² facility in the north western section of Toronto is the location for the remote manipulator systems division. Anticipating future needs, the company has obtained an option on land adjacent to the new plant, sufficient in size for the construction of another two-storey building of 3,700-m².

Spar's subsidiary, Astro Research Corp., originally located in Santa Barbara, has recently consolidated its operations in a new 2,200-m² plant in Carpinteria, California.

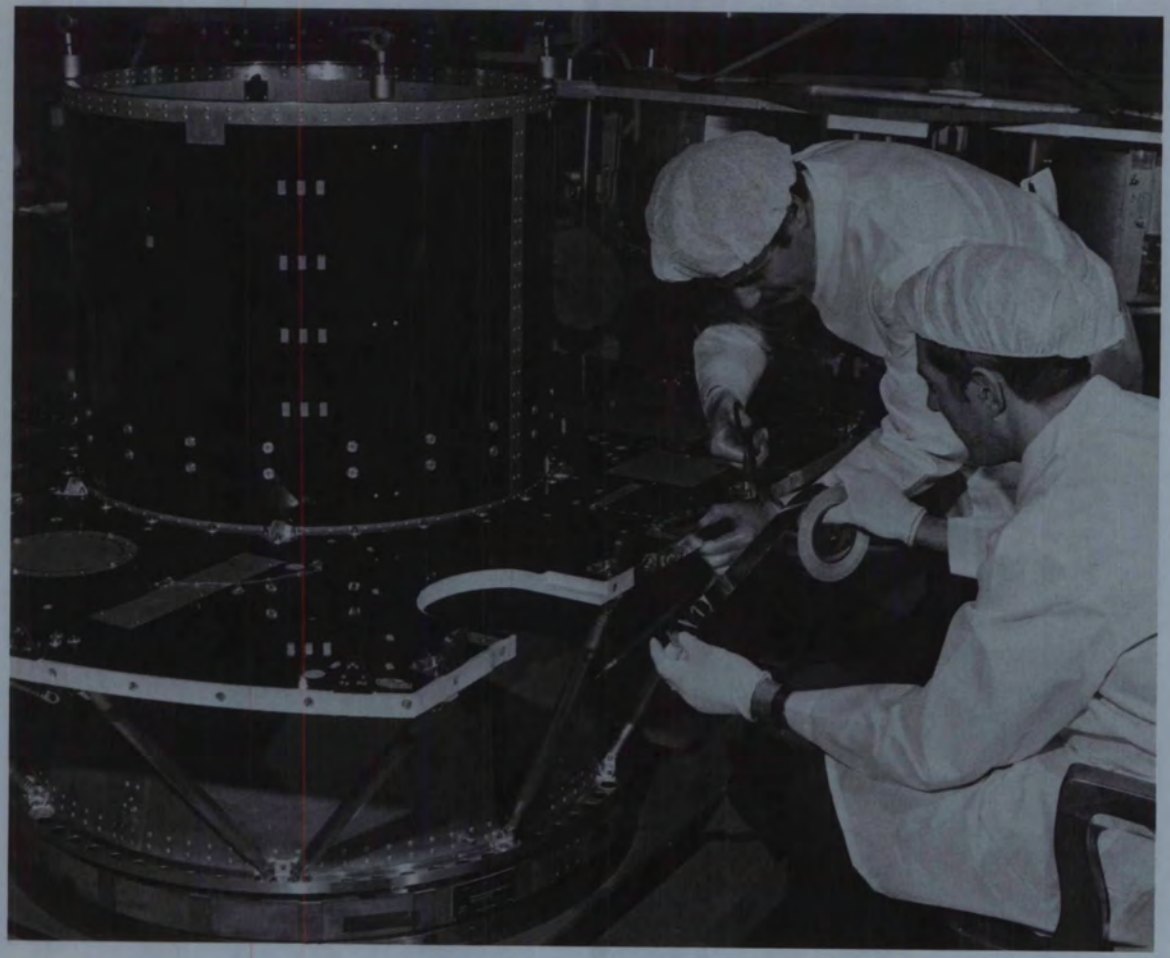
Repair and Overhaul (R&O)

This division provides repair and overhaul services for a wide range of aircraft instruments and mechanical components. These include electrical, oxygen, navigational, autopilot, hydraulic and air-conditioning systems as well as constant speed drives, accessory gearboxes and components of electrical flight control, landing gear and heating systems. A substantial part of the R&O business is derived from agreements with a number of aircraft equipment manufacturers who have appointed Spar an exclusive "service station" for some of their products. Spar's repair and overhaul business is very stable because it is entirely related to the number of flying hours of the aircraft whose equipment Spar overhauls. During the past eight years, this division has shown consistent growth in sales and profit. Revenue from repair and overhaul in 1975 amounted to $11.8 million, representing 41 percent of over-all sales.

Engineering

Spar is the principal Canadian company engaged in the design, development, manufacture and assembly of spacecraft structures, subsystems and components. Among the more significant achievements of Spar and its predecessor companies in the field of space engineering has been the manufacture of structures for all Canadian satellites now in orbit – the ALOUETTE I and II the ISIS I and II and the three ANIK communications satellites.

During the years 1970-75, Spar was under contract to the government for the design, development, fabrication and testing of various subsystems of the communications technology satellite HERMES, such as the spacecraft structure, its thermal control system, the solar array mechanical system and the attitude control system. Work was completed by the end of 1975. HERMES was launched from Kennedy Space Center in Florida in January 1976. The satellite is now in geostationary orbit with all Spar systems aboard continuing to perform faultlessly.



The structure of HERMES comprises only seven per cent of the spacecraft's total weight at launch.

Space has for many years been involved in research and development of remote heat-sensing technology. Under successive government contracts, the company designed, developed and produced an infra-red passive acquisition system for military use. Spar-built remote sensing units have been tested extensively by the Canadian Armed Forces and the U.S. Navy. The company is, at present, working on advanced versions of its infra-red surveillance equipment for shipborne applications by the Canadian and other navies.

In the field of transportation, Spar is one of the leading companies in the development of the linear induction motor (LIM) and of associated power conversion equipment. The company has completed a program, funded jointly by the government and Spar, to develop and test a LIM propulsion system. Spar has carried out studies regarding the application of linear induction motors to the proposed Intermediate Capacity Transit System (ICTS), currently under consideration by the Ontario Urban Transportation Development Corporation (UTDC). In June 1976, the Ontario Legislature authorized UTDC to proceed with the development of such a transit system and Spar's management is confident that its LIMs and power conversion equipment will be used to propel ICTS trains.

Manufacturing

As one of five independent aerospace gear manufacturers of comparable capacity in North America, Spar is the only company in Canada with comprehensive capabilities in this highly specialized field. These capabilities include the design, manufacture, assembly and test of complete gearboxes and transmissions for jet engines, helicopters and ground transportation vehicles. Among important contracts received by Spar have been orders from General Electric for accessory gear boxes for the J85-21 and the T700 jet engines; from Bell Aerospace Canada for a drive transmission system for the Viking air-cushion vehicle; from Westland Helicopters in England for the Lynx transmission and accessory drive gearing; and from Aerospatiale in France for Puma helicopter gearbox components.

Early in 1976, Spar was awarded a $3.2 million contract to supply gearboxes and axle couplings for the Canadian Light Rail Vehicles (CLRV) which will progressively replace the present Toronto Transit Commission streetcars. The gearboxes and couplings will be manufactured by Spar under a 1975 agreement with Carl Hurth Machinen und Zahnradfabrik of Munich, West Germany, which granted North American manufacturing and marketing rights for this line of Hurth power transmission equipment to Spar.

Remote Manipulator Systems

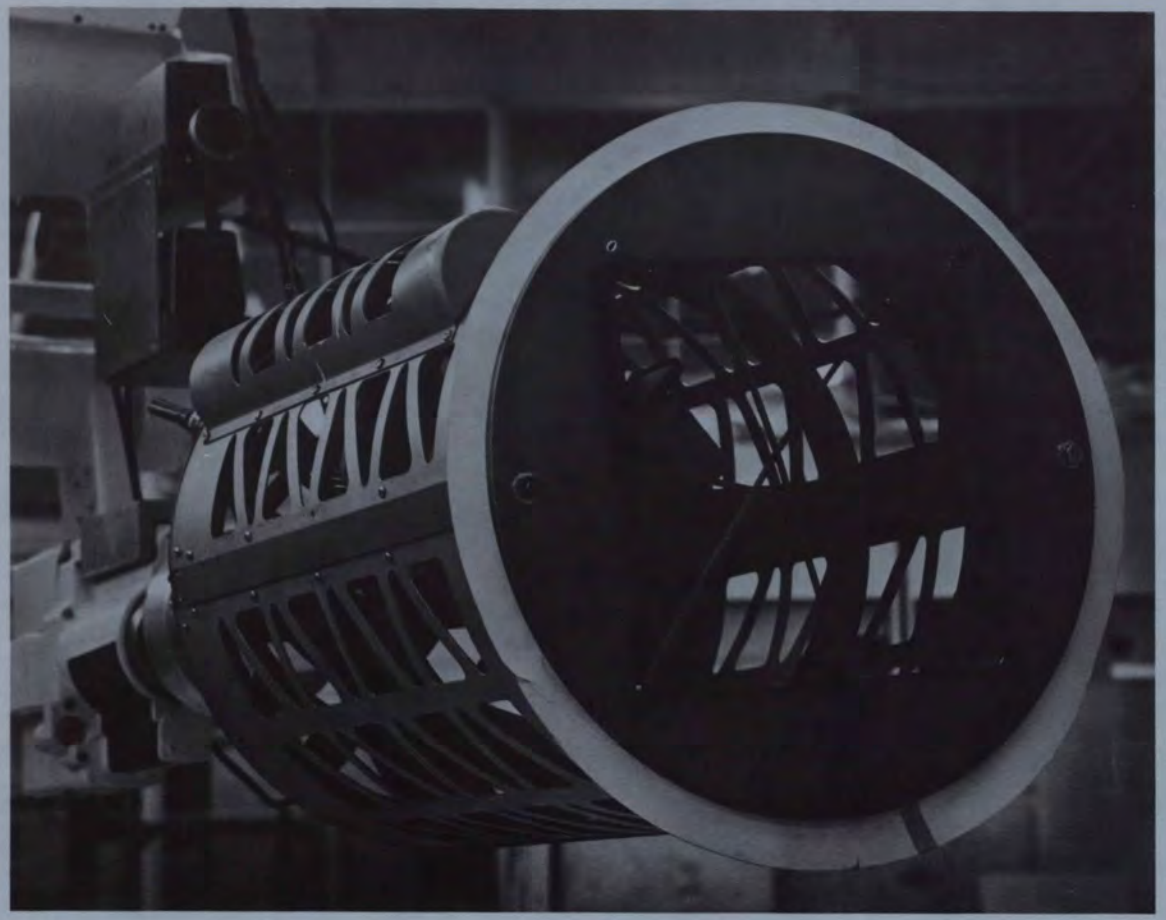
Under Canada-United States co-operative arrangements, a four-company Canadian team led by Spar has been working since 1971 on two specific RMS applications for the United States' Space Shuttle program.

At the end of 1975, Spar was awarded two contracts totalling $19.7 million by the Department of Supply and Services on behalf of the National Research Council of Canada to design the Remote Manipulator Systems (RMS) for the U.S. Space Shuttle and to build a remote manipulator simulation facility.

Highly sophisticated gearboxes which will act as shoulder, elbow and wrist joints in the 15-m-long mechanical arm, now being designed, will also be produced by Spar.

Remote manipulator devices, controlled by human operators, can be used to perform complex tasks in other hostile environments — under ground, under water and in conditions of extreme heat, cold or nuclear radiation.

Full-scale mock-up of the Space Shuttle Orbiter with modular exchange mechanism and, behind it, the Remote Manipulator System arm, seen at Rockwell International's facility at Downey, Calif.



The end effector – equivalent to a human hand – of the Space Shuttle's RMS arm, capable of handling satellites weighing up to 30,000kg.

Astro Research Corporation

A wholly owned Spar subsidiary located in California, Astro is involved in the design and development of lightweight portable structures for space and ground applications. These include the patented ASTROMAST deployable structures to support large solar cell arrays as well as the Spar-developed STEM product line.

Marketing

During the nine years of its corporate existence, Spar has developed a highly specialized marketing and planning organization. It is staffed by Spar's own sales engineers and supported by field sales representatives in Europe, the United States, Japan and Latin America. In addition, Spar employs marketing consultants in Canada and overseas. The marketing and planning organization maintains liaison with government departments and agencies in Canada and abroad as well as with major international aerospace customers.

Bristol Aerospace Limited

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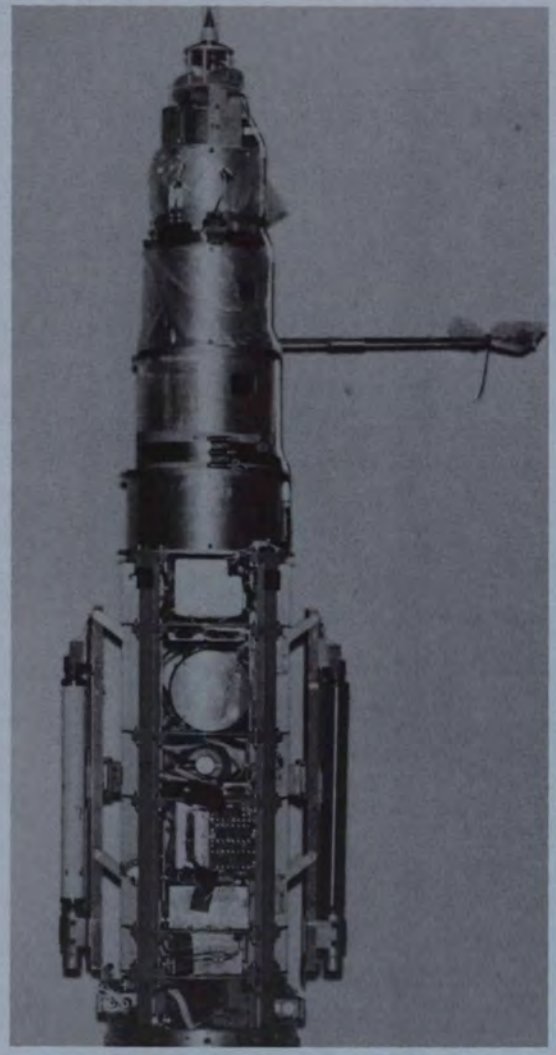
The company was founded in 1930 for repair and overhaul of aircraft and manufacture of sea plane floats. Since then, it has been considerably enlarged, broadened and modernized, particularly in its engineering, development and manufacturing capabilities. Bristol facilities are located at two Manitoba sites: in Winnipeg, where the corporate office is located as well as all other activities of the company, except for the propellant plant located in Rockwood. Bristol employs more than 1,000 employees.

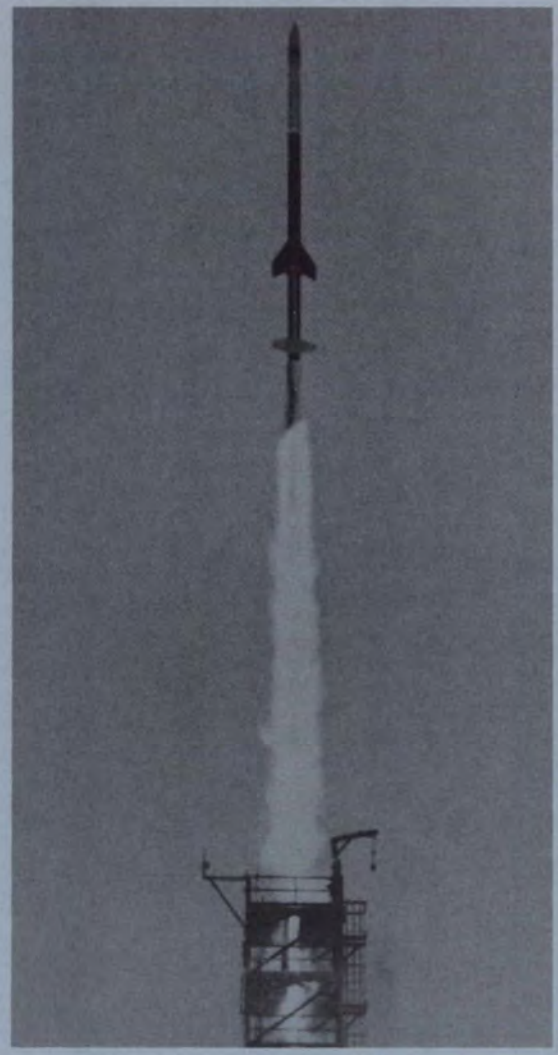
Bristol's experience covers the broad fields of systems engineering, metallurgy, structural plastics and solid propellants.

Capabilities include design, development and manufacturing technology in welded fabrications, mechanical testing, chemical analysis, x-rays, filament winding, aircraft, rocket and space structures and upper atmosphere research vehicle systems including airborne electronics.

Black Brant IV rocket being fired at the Churchill Research Range.



A typical 25 mm-diameter sounding rocket payload being prepared for preflight environmental testing.



Nike-Black Brant V launch.

The company's principal space systems products are the Black Brant sounding rockets, Black Brant rocket instrumentation and systems, satellite electronic components, data collection platforms, telemetry transmitters and light-weight advanced composite materials. The company is also involved in aircraft repair and overhaul, light alloy aircraft structures, jet engine hot section components and CANDU nuclear reactor components.

From its beginning, the company has been active in development and fabrication of high technology components for the aerospace industry. For approximately 15 years, Bristol Aerospace has carried out development, fabrication and flying of instrumented payloads on its own Black Brant rockets. Tested in the Arctic and in desert and equatorial regions, more than 200 Black Brant rocket flights have been flown for scientific purposes for American, Canadian and European agencies. The system engineering requirements included data transmission, sequencing, monitoring and many functions involving the conversion of electrical signals into mechanical action.

As a result of this capability to provide both satellite and ground-based data systems and components with outstanding reliability under severe environmental conditions, Bristol Aerospace was selected to provide the communications technology satellite (HERMES) command decoder and power switching unit.

Bristol Aerospace also produces remote sensing satellite stations for meteorological purposes which, when used with other physical snow data, allows Avalanche Forecast Group in Canada's Rocky Mountains to locate potential avalanche courses and predict the proper moment to dislodge them by gunfire. These battery-powered sites are designed for unmanned operations because of their difficult accessibility.

Similarly, Bristol has designed an ice-base meteorological acquisition and telemetry station for use on the Beaufort Sea in the Canadian Arctic. To ensure that ample electrical power will be available for the long-term unmanned operation of the station, Bristol has developed a vertical-axis wind turbine which will be used to recharge the battery power source.

Re-enforced plastics have been an important part of the over-all manufacturing capability of Bristol Aerospace for more than a decade.

HERMES – command decoder.

HERMES – power switching unit.

Many glass re-enforced components have been developed based upon the filament-winding process. It was this process which prompted the development of a tape-wrapping technique which now forms the basis for the success Bristol Aerospace has enjoyed in the exploitation of specific properties of advanced composites. Considerable experience has been gained in design, analysis and production in high technology applications for the nuclear, space and aircraft markets.

Bristol manufactured composite material waveguide and support structures for advanced satellite systems such as the experiment deployment boom and sunshade cone for the NASA Pioneer Venus program and the antenna radiation skirt for the communications technology satellite HERMES program.

SED Systems Ltd.

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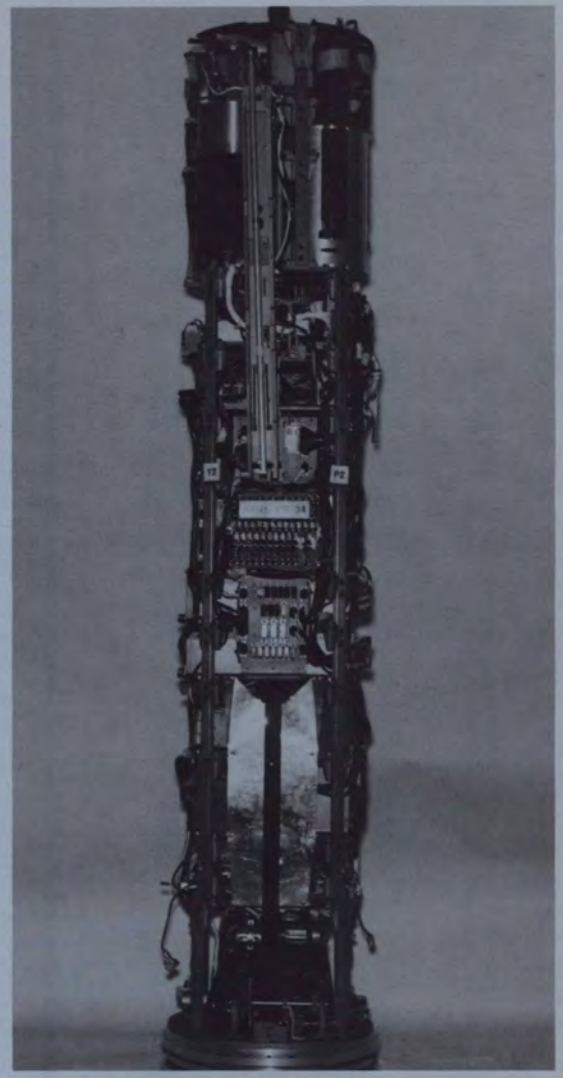
SED Systems Ltd., originated in 1965 as the space engineering division of the physics department of the University of Saskatchewan, and was incorporated as a private company in July 1972. The company employs some 140 people and has an annual turnover in excess of $5 million. Activities are organized under the following four divisions.

Aerospace Products Division

This division is a major supplier of rocket payloads, balloon payloads and launch services in support of scientific research in the upper atmosphere. The division designs, manufactures and tests instruments and mechanical and electrical systems for aerospace activities. Such equipment requires miniaturization, ruggedness and a very high order of reliability. Most of the items produced have been highly specialized and several have applications for remote monitoring, particularly in a severe environment.

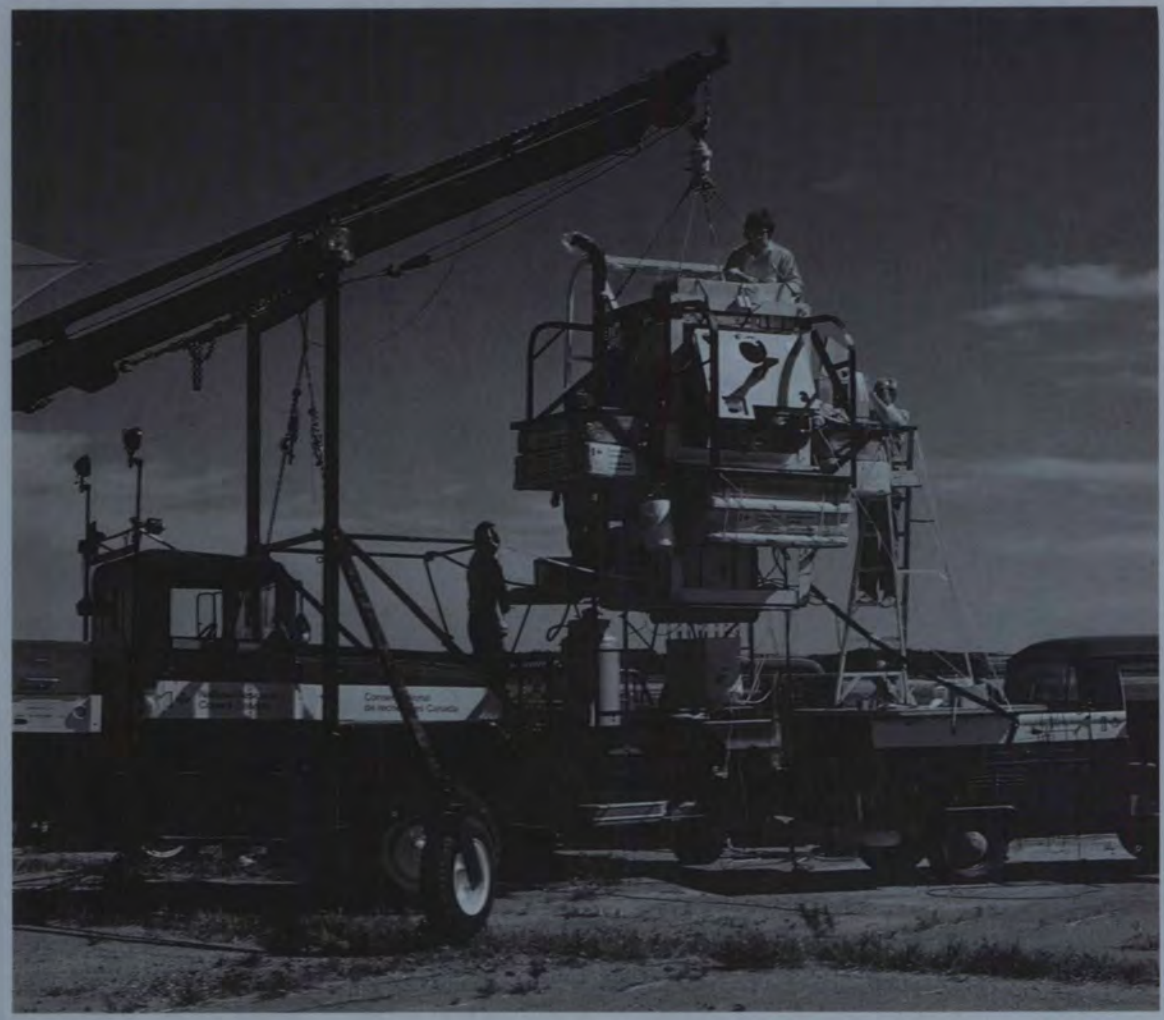


Rocket payload – SED Systems Ltd., is a major supplier of rocket payloads for rockets launched in Canada.

They include:

- scientific instrumentation for use in satellites, sounding rockets or balloons, particularly optical instruments which transmit the data obtained as electrical signals;
- telemetry systems, using PCM or other modulation techniques, which are particularly suitable for use wherever large quantities of data have to be transmitted from remote or hazardous locations;
- check-out and data processing equipment, to test telemetry systems and process the data they provide;
- power supplies for electronic equipment, which provide a range of accurately regulated voltages from a single source with current limitation;
- specialized electro-mechanical systems to control the position of remotely located scientific equipment.

The Mobile Balloon Launch Facility, which was designed and built under a contract with NRCC, became operational in August 1976. It is capable of handling balloons up to 500,000-m^3 in size, which can be flown to altitudes of 45,000 m. High altitude balloons are being used increasingly for upper atmosphere and astronomy experiments and are expected to provide a relatively



Balloon payload being readied at NRCC mobile balloon launch facility, designed and built by SED Systems Ltd.

low-cost means for proving experiments prior to the launching of the Spacelab and the Space Shuttle. With this new launch capability, SED now provides a full range of services from basic sensor design through launch, including pointing systems, telemetry, power systems, payload recovery and data reduction.

SED is currently engaged in a two-year study of the ozone layer of the troposphere sponsored by the Atmospheric Environmental Service of the Department of Fisheries and the Environment. The objects of this study are to determine the extent of possible damage caused by supersonic aircraft emitting nitric oxide and to investigate the effects of chlorine compounds created by excessive use of aerosol cans. A new pointing system developed by SED, which locks onto the sun during ascent at an altitude of about 7,500 m and maintains pointing accuracies of one-tenth of a degree throughout flight, provides scientists with the best available data on the chemistry of the ozone layer.

The aerospace products division has also supplied specialized space hardware, such as the photometer baffle systems for ISIS II, and a microwave attitude sensing system for the Japanese Broadcast Satellite. The advantage of this system over other systems is that it can provide all three attitude parameters – roll, pitch and yaw – with better accuracy using a single sensor.

Monopulse antenna used with the microwave attitude sensing system for the Japanese Broadcast Satellite.

Satellite Earth Stations Division

This division has undertaken five major projects in the supply of earth stations and related equipment.

Under a government contract, SED designed, built, installed and now operates the satellite earth station at Prince Albert, Saskatchewan, for the LANDSAT program. This entailed remodelling the Prince Albert radar laboratory and extensive modification to the 26-m dish antenna and to the building as well as the design, manufacture and installation of a new complement of equipment. This was the first operational LANDSAT earth station in Canada. Its function is to receive and record data from the satellite and convert the data into photographs showing features such as available resources and polluted areas.

During 1973, SED produced a very different and much smaller earth station for Telesat Canada, a telemetry and command station used to control the ANIK communications satellites. Although this is a permanent installation at Allan Park, Ontario, it is so designed that it could readily be dismantled, transported by a DC 3-size aircraft and easily assembled in a remote location.

Mobile earth station designed and built by SED for the HERMES satellite.

In 1975, SED designed and built two mobile stations, each installed in a fifth-wheel trailer, to receive and process television programming and experimental data from the communications technology satellite, HERMES, at 14/12 gigahertz. These stations can also be carried by rail flatcar or large aircraft. One can also be dismantled and its operating equipment (including the antenna) carried by a small aircraft, such as the Twin Otter.

During 1975, SED designed, built and installed six new remote television (RTV) stations and upgraded seven existing earth stations for Telesat Canada. In July 1976, Telesat Canada commissioned SED to design and manufacture 20 Frontier earth stations and a number of additional satellite communications television receivers operating in the 3.7 to 4.2 gigahertz frequency band.

SED has also established an Advanced Microwave Integrated Circuit Laboratory to develop Low Noise GaAs FET amplifiers, Schottky Barrier mixers, oscillators and filters for satellite earth station applications.

Industrial Products Division

This division supplies digital electronics equipment and instrumentation to the telephone, agricultural equipment and power distribution industries.

Satellite communications television receiver. Designed and fabricated by SED Systems Ltd. for Telesat Canada, it operates in the 3.7 to 4.2 GHz band.

Systems Division

This division was formed to provide a multi-disciplinary engineering approach to complex control problems. SED engineers developed the attitude acquisition flight operations procedures for HERMES. This involved the design and development of a complex set of computer programs to control the spacecraft during attitude-acquisition manoeuvres and the simulation of the entire spacecraft and ground control system to test these programs and train staff. Further responsibilities included:

- developing all the flight plans and procedures required to perform the attitude-acquisition manoeuvres;
- planning and executing the related operator training program and mission compatibility tests;
- operating the computer programs and selecting appropriate manoeuvres.

Continuing SED involvement with HERMES includes the development of detailed non-standard and on-orbit procedures, the training of CRC duty controllers and the provision of qualified flight dynamics experts for spacecraft emergencies.

SED systems engineers also developed the orbit frequency utilization simulation (OFUS) which does the calculations necessary for analysis of the performance of geosynchronous communications satellite systems operating in an environment of mutual interference. OFUS will undoubtedly facilitate planning for optimal utilization of limited orbit and frequency resources and for satellite system calculations in general.

Andrew Antenna Company Ltd.

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Andrew Antenna Co. Ltd., a subsidiary of Andrew Corp. in the U.S., was incorporated in Canada in 1953. The company specializes in the design and manufacture of antennas, transmission lines and related equipment; employs about 110 people and has an annual turnover of approximately $7 million.

In 1955, Andrew Antenna provided the 12 dual polarized one-gigahertz feed horns and waveguide systems for POLE VAULT, the world's first troposcatter system, reaching from Goose Bay, Labrador, to Thule, Greenland. Further contracts ensued with the Government of Canada and NORAD for equipment of the Mid-Canada Line. Equipment for military use was supplied to the Canadian Armed Forces and those of USA, France, Sweden and Korea. In 1972-73, Andrew

Andrew provided the 12 dual polarized one-GHz feed horns and waveguide systems for the world's first troposcatter system, reaching from Goose Bay, Labrador to Thule, Greenland.

Antenna supplied 41 eight-m 6/4 gigahertz earth station antennas to Telesat Canada, most of which are installed in Arctic regions. Other radio equipment manufacturers have purchased 3.7-m 6/4 gigahertz earth station antennas for resale to Telesat Canada, which can be equipped with Cassegrain or feed-at-the-focus feed systems. Most are portable units so that the reflector can be easily disassembled into four pieces small enough to fit into Twin Otter aircraft. They are designed to stand up to many complete assemblies and disassemblies. Andrew Antenna has also manufactured 14-m L-band and 6.3-m S-band airport surveillance radar antennas for installation at Canadian and Indian airports respectively.

Almost all users of communications equipment in Canada use Andrew antennas, waveguide or coaxial cable. The largest customers include CNCP Telecommunications, the CBC, Ontario Hydro, Québec Hydro and Bell Canada. The company has also participated in projects in Norway, Sweden, the Middle East, South America, Australia, the Philippines, Korea and India.

8m antenna fabricated by Andrew for use by Telesat Canada in one of its earth stations.

S-band surveillance radar antenna constructed by Andrew for India.

Engineering

The professional engineers on the company's staff are supported by complete laboratories, test facilities and a model shop. The laboratories are equipped with precision sweep-frequency reflection co-efficient measuring equipment covering all the standard RF bands in common use throughout the world. Microwave antennas from one to 12.5 gigahertz, and up to 3.7-m in diameter, can be accommodated. A 670-m fully instrumented antenna-radiation pattern range is equipped with receivers operating over the entire frequency range from 30 megahertz to 70 gigahertz and a precision recorder with a dynamic range of 60 dB. The 17-m tower and rotator, receiver and polar recorder are used in the design of VHF/UHF antennas.

The development of microwave antenna feed-horns at frequencies up to 18 gigahertz is done on a 300-m range at the plant. Other facilities include instrumentation and fixtures for the mechanical testing of antenna and mount deflections under wind loads simulated by the application of static forces. The loads are calculated by computer, using programs developed to assist the design and fabrication of unusual space frame structures.

Specific objects of research and development include parabolic and shaped reflectors, horns, tropospheric scatter equipment, earth stations, radar antennas, RADIAX*-slotted coaxial cable, UHF TV broadcast antennas, high-wind and ice-loading antennas and HELIAX* coaxial cable and elliptical waveguide. RADIAX-slotted coaxial cable was developed to permit efficient VHF and UHF two-way radio communications in mines, tunnels and other large enclosed areas. HELIAX coaxial cable has been produced up to 20.3 cm in diameter. Low-VSWR four-cm and 2.2- cm cable assemblies are produced for two gigahertz microwave systems.

*RADIAX and HELIAX are registered trade names.

Manufacturing

In the company's main plant, about 4,600-m^2 are used for manufacturing operations. Any antenna up to 10 m in diameter can be constructed. The facilities include a well-equipped drafting department, machine shops, light and heavy assembly departments, a paint shop and a fibreglass shop. The Ashburn, Ont., plant at present comprises a 460-m^2 high-bay building for the manufacture of antennas requiring a lot of specialized tooling, including 6.3-m S-band and 14-m L-band radar antennas. HELIAX coaxial cable and elliptical waveguides are now produced in a new 4,200-m^2 factory, equipped with the most up-to-date machinery and facilities on the Ashburn site.

Canadian Astronautics Limited

Suite 201, 1024 Morrison Drive
Ottawa, Ontario
K2H 8K7

(613) 820-8280

Canadian Astronautics Limited,is a Canadian company incorporated in 1974, is engaged in satellite system design studies and consulting work for space projects and in the development of electronic systems, engineering software and mechanical ground-support equipment. The company employs 12 professionals and technicians and has an annual turnover of $450,000. Customers have included several Canadian government departments, Telesat Canada and a number of other companies in Canada and in the U.S.

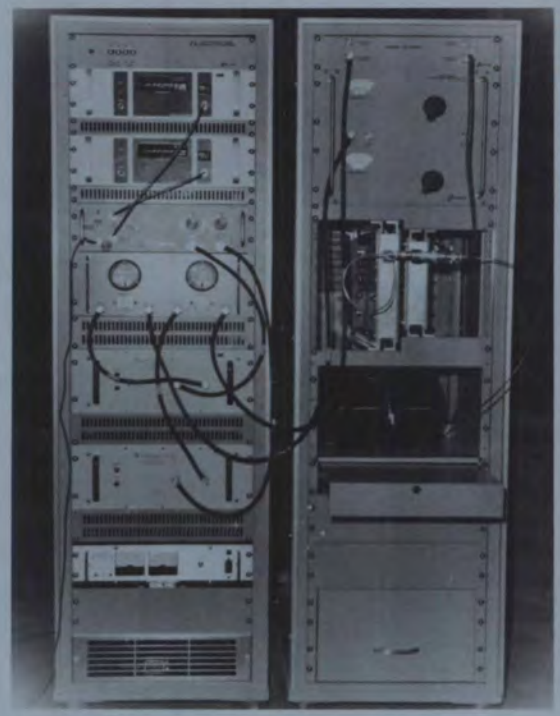
The company has undertaken the design of a remote sensing satellite mission, utilizing radar and optical sensors and of the Canadian baseline surveillance system for aircraft location under the AEROSAT program, which involved the development of a complete system-simulation software package. Two satellite system design studies have recently been undertaken, both based on a Scout-launched, low altitude, polar-orbiting satellite concept. One is a data collection and fisheries surveillance mission to gather data from a large number of remote unattended data platforms and to locate fishing vessels by the use of Doppler position-location techniques. The other, for search and rescue applications, uses Doppler measurements to locate the emergency locator transmitters (ELTs) carried by aircraft. These projects involve the conceptual design of the entire system, detailed performance analysis, preliminary engineering design and cost estimates.

A low-cost satellite tracking antenna system operating at HF frequencies, designed for the Communications Research Centre, involved the development of electronic servo-control loops and an antenna with the associated mounting structure. A passive intermodulation test facility for the UHF satellite program was developed in association with Sinclair Radio Laboratories Ltd. and a third project involved the development of several complex vibration test fixtures for the SRMS.

Engineering software has been developed for several specific applications, mostly related to mission analysis and orbit mechanics. Orbit prediction and position-location software, using Kalman filtering techniques, was developed for CRC in the search and rescue (SARSAT) demonstration program using the OSCAR satellite. A sophisticated software system was developed to support the orbit perturbation measurement experiment under the HERMES program. Launch and mission support has been provided to Telesat Canada and Western Union Telegraph Co. in connection with geosynchronous communication satellite launches. The HERMES program has also been supported in the areas of mission planning and transponder performance assessment.

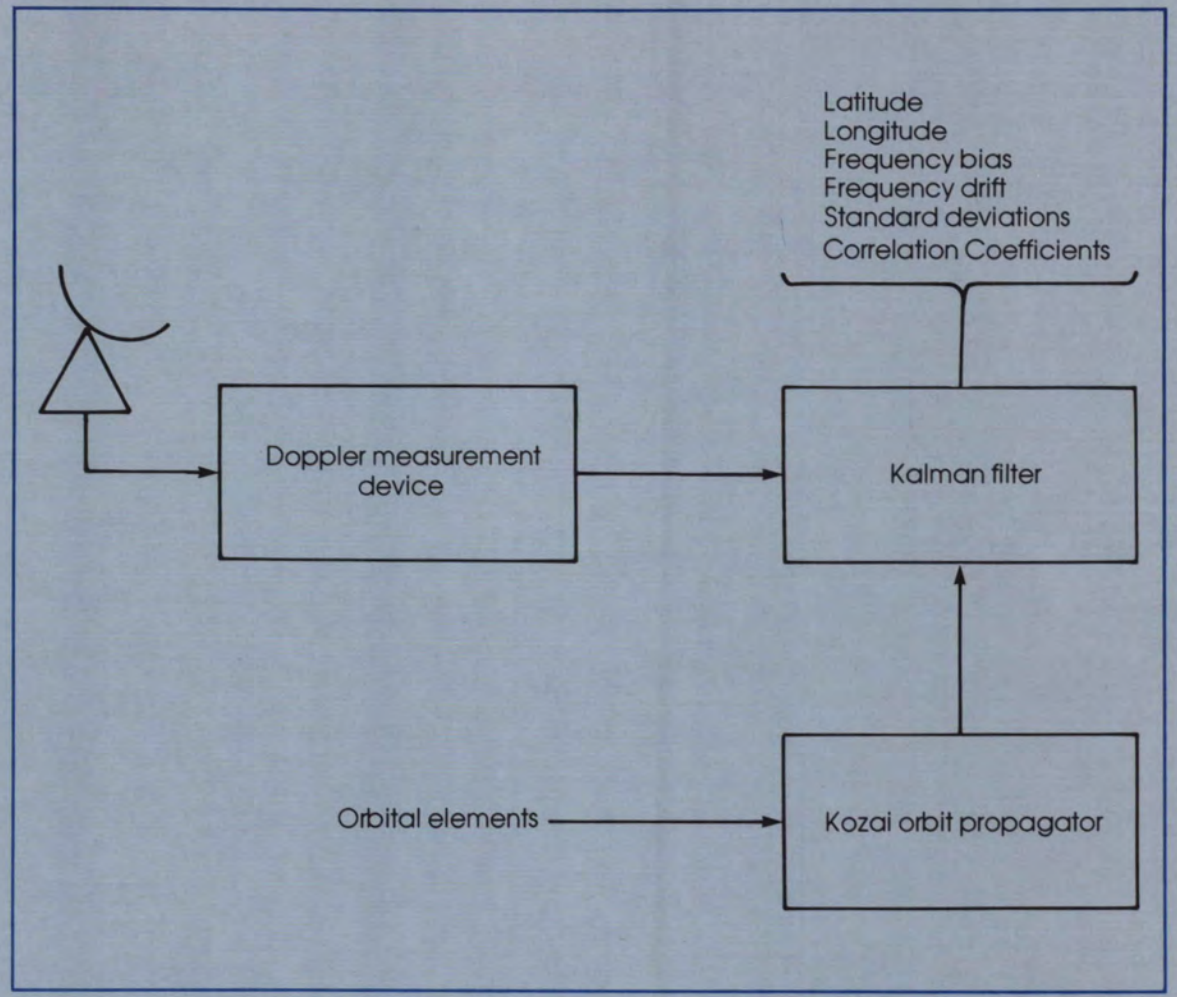
Canadian Astronautics Limited offers capabilities in the design of satellite systems and the development of electronic hardware, mechanical support equipment and engineering software as well as engineering support and consulting services in a wide range of disciplines, including electrical/electronics, mechanical structures, thermal analysis, mission analysis, applied mathematics, signal processing and computer engineering. The capability includes development of special purpose electronic systems, primarily in the area of RF and analog design but extending to digital interfaces and units. It is especially applicable to situations calling for custom design to exacting specifications and for production in relatively small quantities. A similar capability has recently been developed for mechanical support systems, for which the company can specify, analyse, design and develop special test fixtures, mechanisms and structures.

Canadian Astronautics Limited has a hardware development laboratory which is equipped for electronic system development and light mechanical work. Heavier work is usually contracted out to local machine shops. The company is thus able to undertake system design, prepare specifications, develop special circuits and parts, and integrate and test complete systems before delivery.



Passive Intermodulation test facility produced by Canadian Astronautics for DOC for the MUSAT program.

Position Location System
SARSAT Demonstration Program.



Com Dev Ltd.

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Com Dev Ltd. designs and manufactures microwave devices and subsystems which have found extensive application in communications satellites, satellite earth terminals, radio relay systems, aerospace and defence systems, and scientific research. The company's products and services include:

- advanced technology multiplexers, filters and ferrite devices for communications satellites;
- high-power switching, diplexing and combining networks for satellite earth terminals;
- low-cost, superior-performance, microwave components and assemblies for radio relay and radar systems;
- wideband components and subsystems for ECM application;
- precision high-directivity couplers and other microwave components for laboratory and scientific measurement systems;
- consultative services on systems analysis and hardware trade-offs in satellite communications systems.

Com Dev Ltd. has been audited and approved as a qualified source for the design and manufacture of space flight-quality hardware, which complies with the quality assurance requirements of NASA NHB 5300.4 (IC), MIL-Q-4858A, and MIL-I-45208-A.

The company has designed, qualified and supplied flight hardware, microwave components and subsystems at frequencies ranging from two to 30 gigahertz. Satellites incorporating Com Dev products include HERMES, the United States domestic communications satellite (SATCOM), the Japanese communications satellite (JCS), the Telesat Canada ANIK B and the tracking data relay satellite (TDRSS).

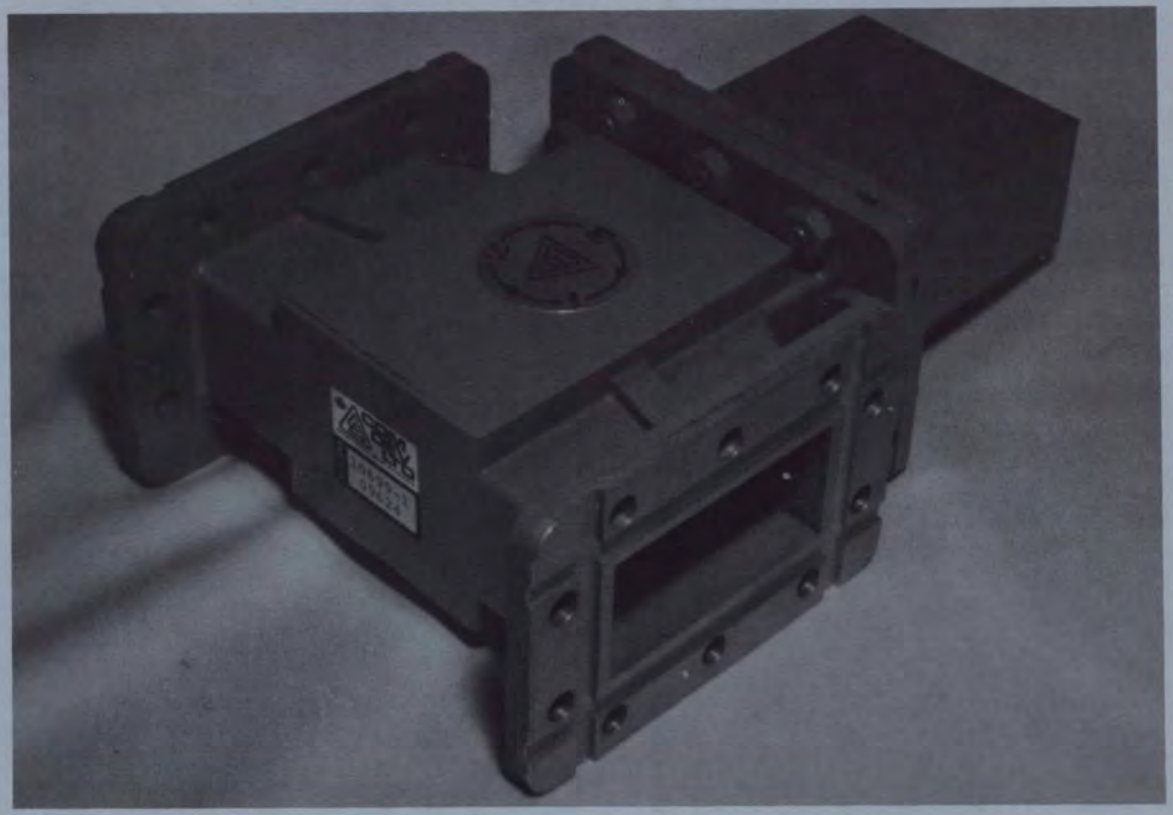
The company is a member of the GE Valley Forge Team, the successful bidders on AEROSAT, and is responsible for the design, qualification and production of VHF transmit and receive networks, and L-band output multiplexers and receive filters. Com Dev Ltd. is designing and developing the 11 gigahertz output multiplexers for INTELSAT V, using the new low-loss dual mode filter structure*. Other INTELSAT V equipment being supplied by Com Dev includes harmonic filters, wideband pre-selector filters and ferrite circulators and isolators. Com Dev Ltd. has completed the initial development of the multiple-access diplexer for TDRSS and successfully bid for the supply of filters at two, 12 and 14 gigahertz.

*Patents applied for.

The company has a complete product line of microwave subsystems for use in the high-power transmit and low-power receive segments of satellite earth terminals for all purposes. In the 11, 12, and 14 gigahertz bands Com Dev Ltd. has the most complete product line of qualified high-power and low-power microwave components in the world.

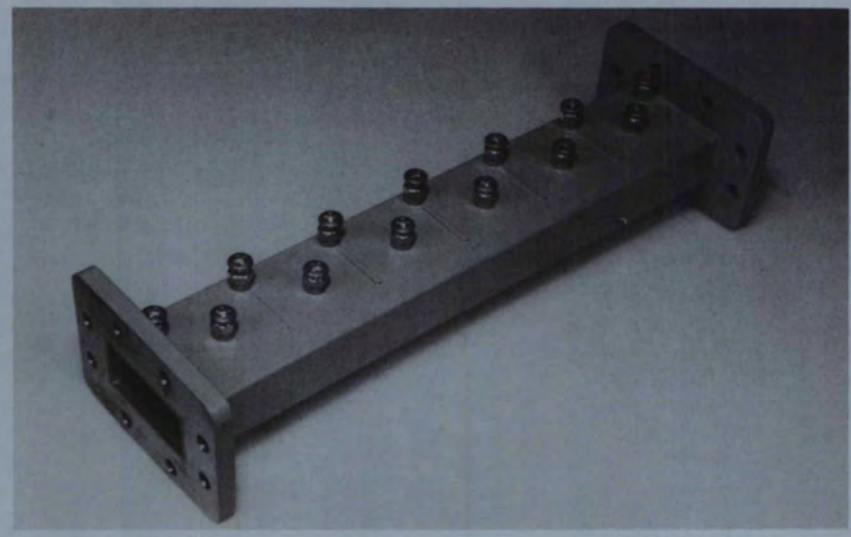
The company's achievements in junction design, material optimization and mechanical packaging have yielded a line of reliable ferrite devices for applications in terrestrial communications systems, including waveguide circulators and isolators, coaxial circulators and isolators, and resonance isolators. Com Dev Ltd. microwave filters and multiplexing networks span the frequency spectrum from 100 megahertz to 40 gigahertz. Their design, making extensive use of computer software and new designs, can be evolved and evaluated within three working days.

The company's engineering staff includes systems experts with long experience in the design of space and terrestrial segments of communications satellite systems, enabling Com Dev Ltd. to offer consultative services in conceptual, hardware and systems design and optimization of transponders and communications subsystems for satellites; trade-off analyses, layout, and hardware design for switching, combining, and multiplexing in satellite earth terminals; and over-all communications systems studies.



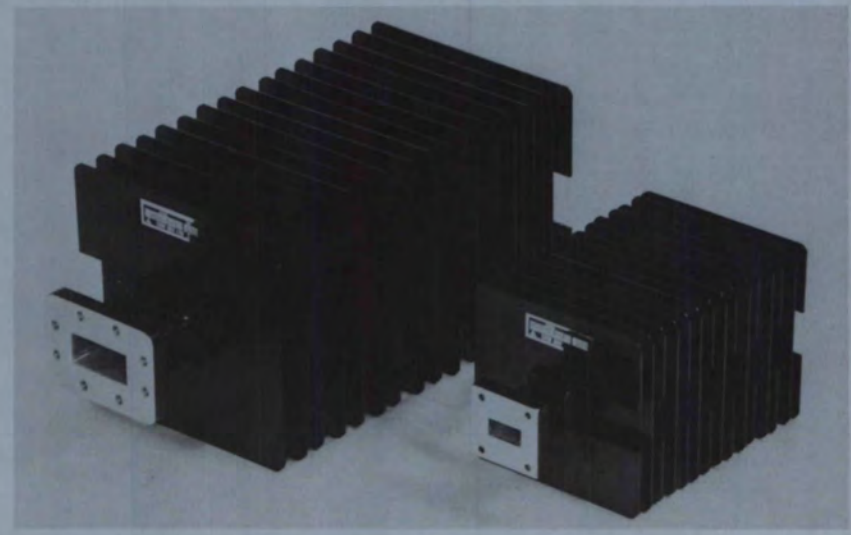
Ferrite technology
Waveguide circulator

Low-loss dual filter



Microwave filter

TEM filter



High power microwave components

Computing Devices Company

CONTROL DATA

P.O. Box 8508
Ottawa, Ontario
K1G 3M9
(613) 596-3810
Telex – 053-4139
TWX – 610-563-1632

Computing Devices Company, established in 1948, is a division of Control Data Canada Ltd. and employs more than 1,000 people in the design, assembly and testing of advanced computer systems and electronic equipment. Major activities relate to navigation display, processing equipment for military use, and sensor data-processing techniques and systems for underwater surveillance. The company has also achieved an outstanding reputation in such areas of electronic engineering as command and control display systems, digital scan conversion, process control, data-communication testing, artillery fire control and satellite image-processing for earth resource applications.

Two electronic systems for LANDSAT image data-processing have been designed and delivered; the first, built for Canada, has been in operation since 1972, while the second (IPS II) has been operating successfully at Fucino, Italy, since late 1975. The latter was the first to apply corrections to the satellite pictures in a totally digital mode of operation. The company is now investigating and applying automated techniques for interpreting and classifying picture information. An advanced version of IPS II is used in the company's facilities in methodology research and in obtaining practical results from high-speed, digital, multi-spectral image classification and analysis.

In addition to its engineering and production facilities in Ottawa, the company maintains a subsidiary, Computing Devices Co. Ltd. (CDCo), in Hastings, England.

Italian LANDSAT data-processing system ordered in 1974. IPS II has been operating at the Fucino, Italy, station since the latter part of 1975.

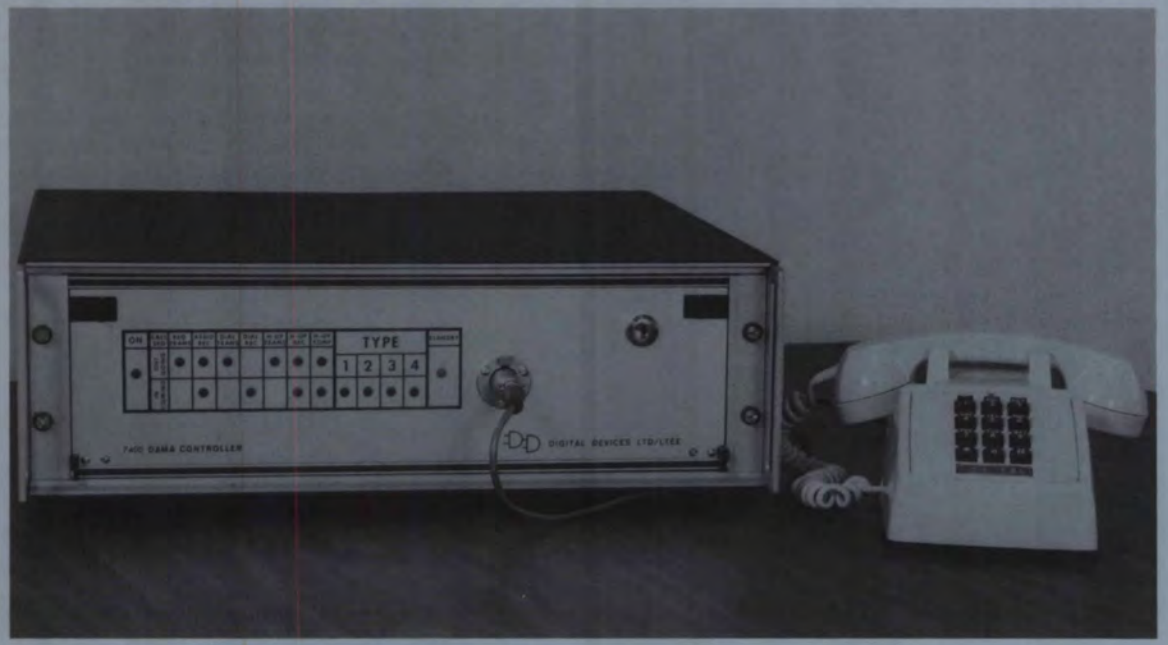
Digital Devices Ltd.

8235 Mountain Street, Suite 300
Montréal, Québec
H4P 2B4
(514) 739-1761

Digital Devices Ltd., a Canadian company incorporated in 1969, is engaged in the development of special purpose electronic systems, space communications systems, experimental computers and communications earth station controllers. The company employs six professionals, and has an annual turnover of $1 million. Products include electronic displays, electronic scoreboards, special-purpose terminals for business applications and remote digital data-capture terminals for point-of-sale and process control applications.
The company is also involved in medical systems development and is developing pulse-rate monitors for use in dynamic conditions and an oxymeter for both chemical and dynamic conditions. Future plans include the development of other cardiovascular non-invasive monitoring instruments.

The company's communications terminal controller, for application to thin-route communications in developing countries and remote territories, has been successfully used with HERMES and can easily be modified for other systems. It interfaces to a wide variety of single-channel per carrier equipment. A design study is underway seeking additional applications for UHF and SHF space communications systems. A special purpose computer designed for DOC to facilitate Demand Assignment Multiple Access (DAMA) algorithm development, permits the researcher to operate interactively for real-time algorithm changes and can be used without interrupting communications. It is used in the design of DAMA controllers for the diverse requirements of remote communications.

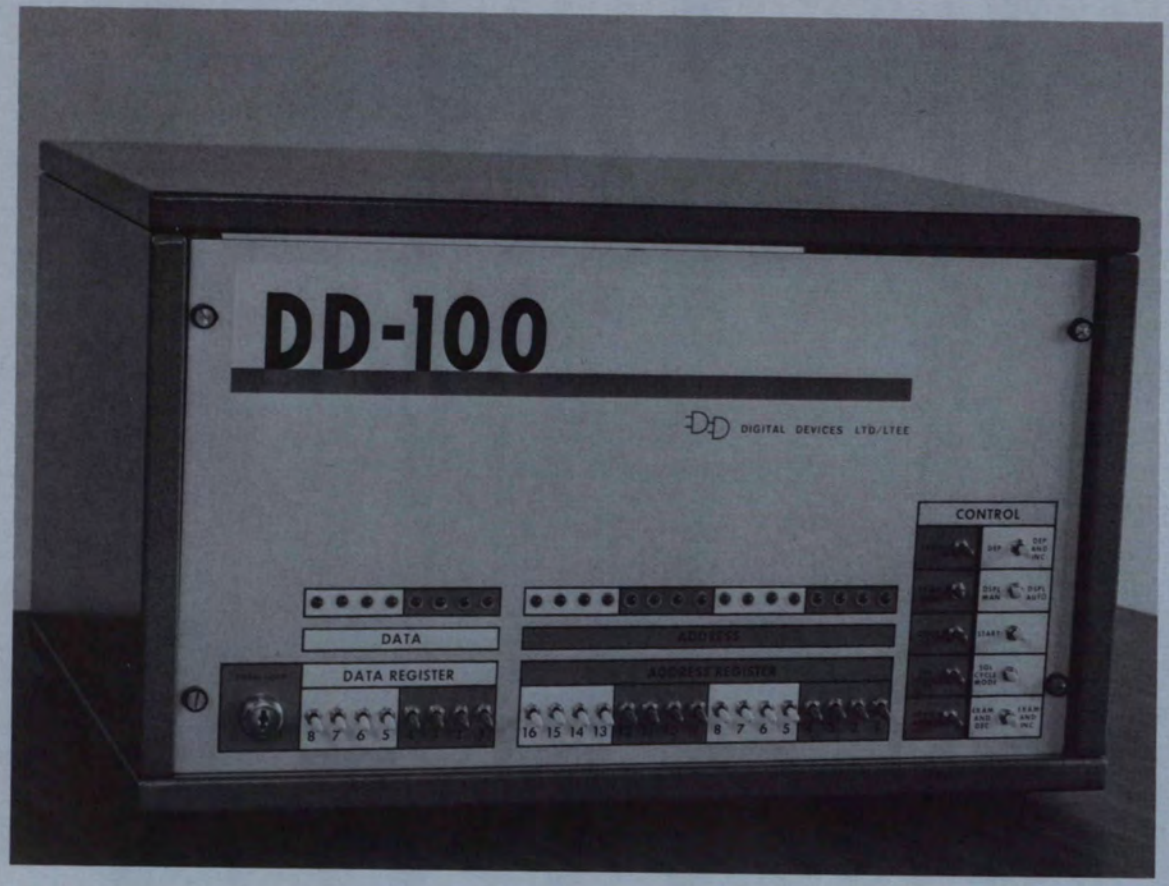
The company manufactures and markets a complete line of electronic score-boards, ranging in price from the CHAMP line at $1,500-$5,000 to large specially-designed installations costing $200,000-$300,000.



Demand assignment multiple access controller for applications to thin-route communications.

Typical remote data-capture terminals produced by the company read magnetic-stripe cards and will interface to any computer with an RS 232 signal. A variation is the remote data-entry system which is now in production. The remote terminal consists of a hand-held keyboard data-input device jack-wired to a small computer and memory, which is worn bandolier-fashion by the user, who is thus mobile and can telephone the data digitally to a central station on the data set provided. The company also produces a telephone answering computer which will store and print out received data or furnish data to another computer with which it will interface.

Digital Devices Ltd. also manufactures special electronic devices to unusual specifications, such as an interface between tag readers (widely used in the garment industry) and computers, paging devices and table reservation systems for restaurants.



DAMA algorithm computer. A special computer designed for DOC to facilitate DAMA algorithm development.

Digital Methods Ltd.

1736 Courtwood Crescent
Ottawa, Ontario
K2C 2B5
(613) 225-1171
Telex – 053-3661

Digital Methods Ltd. (DML) offers consulting services on computer systems and programming, including project management; analysis, design, specification and implementation of information-retrieval and database systems; analysis and organization of associated manual systems; and technical support and training. The company employs 75 employees and has an annual turnover of $2.5 million. Activities are evenly divided between small and large computers. DML has executed contracts for more than 15 government departments and over 20 clients in business and industry, including systems projects relating to air traffic control, navigation, flight test data-reduction, satellite tracking and ground control, laboratory data-management, Telex switching and vehicle dispatch.

DML developed the software system for the HERMES ground control station, which employs a dual minicomputer configuration and is used for acquiring data from HERMES for position control and specific experiments. The system provides:

- the operating system to schedule all system functions and to interface with all input/output devices;
- the processing required to decommutate telemetry signals and convert them to engineering units;
- the processing to monitor spacecraft health and generate alarms; limit checking is done on the incoming telemetry data to provide a quick means of detecting alarm conditions on the spacecraft;
- the transmission and validation of spacecraft commands;
- the generation of digital data records and command data for subsequent processing, providing two types of data accumulation:
  a) continuous telemetry and command data storage on digital magnetic tape of all data received from and transmitted to the spacecraft; and
  b) calibrated telemetry data storage on digital magnetic tape at selected intervals over a 24-hour period;
- an extensive group of keyboard commands for operator-computer communication;
- the addition of various calculated parameters to provide more spacecraft information.

HiTech Canada Ltd.

68 Highway 7, Suite 103
Ottawa, Ontario
K2H 8P5
(613) 820-1200

HiTech Canada Ltd., a Canadian company incorporated in 1973, employs 30 professionals and has an annual turnover of $1 million. The company offers consultative and development services for high technology systems and computer software, particularly in the areas of aerospace, communications and computer systems, and of reliability and quality assurance. The company will assume "turnkey" responsibility or provide support staff for systems, but does not engage in the commercial manufacture or sale of hardware. Major clients include the Department of Communications, the Department of Transport, the Canada Post Office, CN Hotels, Spar Aerospace Products Ltd., and RCA Ltd.

The company's capabilities include:

- aerospace program and project management, including space systems planning and project control systems;
- flight systems engineering, including mission analysis, mathematical modelling and simulation, spacecraft system design and spacecraft support systems design;
- ground systems engineering; including ground station architecture, design, integration, test and operation; orbit and attitude determination; and real-time and batch tracking, telemetry and command data handling system design and software development;
- total space communication systems, simulation and traffic studies, and specification and testing of transponder systems;
- terrestrial communications systems, including network system and terminal planning and specification; data communication systems and interfaces; major system analysis and optimization, and command control and communication networks;
- computer systems, including software system definition; specification and implementation of software control, design, documentation and testing procedures; and analysis of existing systems for optimization or expansion;
- software engineering, including scientific and commercial design, implementation, documentation and testing of software for maxi-, mini-, and micro-systems.

Selected contract experience includes:

- consulting support for the AEROSAT on earth terminal specification, the experimental plan, simulation and test, and multi-path problems;
- consulting support in transponder design and testing and special problems on the RCA SATCOM;
- development of a transmission data-compression system for application in communication networks, particularly message- and packet- switched networks, including common-user systems;
- development of a computer data handling system for HERMES experimental data, operating in near real-time;
- development of an interactive real-time system for the analysis and display of HERMES telemetry and command data;
- development of a real-time spacecraft telemetry and command system, using an HP2100 computer;
- design and implementation of the ACS Status Display System, utilizing an IMP16L microcomputer, to process data from the HERMES attitude control system test set;
- design and implementation of a process control and data-archival system for the four thermal vacuum chambers at the Communications Research Centre, which will be extended to include the vibration and anechoic chamber;
- definition of the software management plan for the Space Shuttle Remote Manipulator System (SRMS);
- planning for the procurement and evaluation of high-reliability devices for the UHF satellite and a report on the reliability of integrated systems;
- an extensive feasibility study on electronic mail systems;
- automation of the CN Tower restaurant in Toronto, including on-line systems for reservations, point-of-sale, table status, patron notification and personnel entry;
- development of a generalized language for use with graphics display systems, using DEC/PDP-11 computers;
- development of the executive and operating software for a microprocessor designed and developed by Digital Devices Ltd.

Macdonald, Dettwiler and Associates Ltd.

MDA

Nootka Building
10280 Shellbridge Way
Richmond, British Columbia
V6X 2Z9
(604) 278-3411
Telex – 04-355599

MacDonald, Dettwiler and Associates Ltd. (MDA) is a Canadian company incorporated in 1969 as a digital electronic systems engineering organization, with capability covering the complete range of hardware and software design and implementation. Activities are grouped in two main areas: scientific/government projects, and commercial/industrial systems. The company employs 75 professionals and has an annual turnover of $4 million.

MDA has been increasingly engaged in the development of remote sensing and resource-data handling, including data-acquisition systems for environmental sensing in airborne, shipborne and submersible programs, and systems to analyse and reproduce the remotely sensed data. Work on airborne systems has included the use of inertial navigation systems (INS) for resource flying and their integration with other navigation systems.

Following early involvement in the LANDSAT ground-station program, MDA has supplied equipment to each of the LANDSAT ground stations built outside the United States and has been responsible for the successful construction of the complete earth resources ground station at Shoe Cove, Newfoundland, built under a "turnkey" contract involving a high degree of new development. The company is engaged in the development of digital filter technology and microcomputer technology, including the use of high-density recorders for the storage of large volumes of resource data. This work has led to the development of a new high-performance digital recorder based on the use of a small videotape recorder which can record at more than 400 thousand bits/cm at a data rate of 7.2×10^6 bits/second.

Portable earth resources ground station that was transferred from Vancouver to Shoe Cove, Newfoundland. The station is capable of receiving and processing data from both the NASA LANDSAT and NOAA/ITOS series of satellites.

Completed MDA projects in data handling include development and production of:

- a Multi-Spectral Scanner (MSS) demultiplexer, and a Quicklook formatter and Sync Pulse Extractor and Videoprocessor (SPEVOR), both for the Canadian LANDSAT ground station;
- an airborne data-acquisition system (ADAS) for the Canada Centre for Remote Sensing;
- a specialized interface between the Litton Systems LTN-51 INS and ADAS;
- a computerized data-acquisition systems (MIDAS) for the marine sciences directorate (now ocean and aquatic sciences) of the Department of Fisheries and the Environment;

MDA designed and supplied:

- a special low-power data-acquisition system for use in small deep-diving submersibles (SUDAS);
- a ground station for playback and analysis of data recorded by ADAS (GRAMS) for the Canada Centre for Remote Sensing;
- a VHRR synchronizer for the Atmospheric Environment Service of the Department of Fisheries and the Environment;
- a format synchronizer and MSS test pattern generator/signal simulator for use in the Italian LANDSAT ground station;

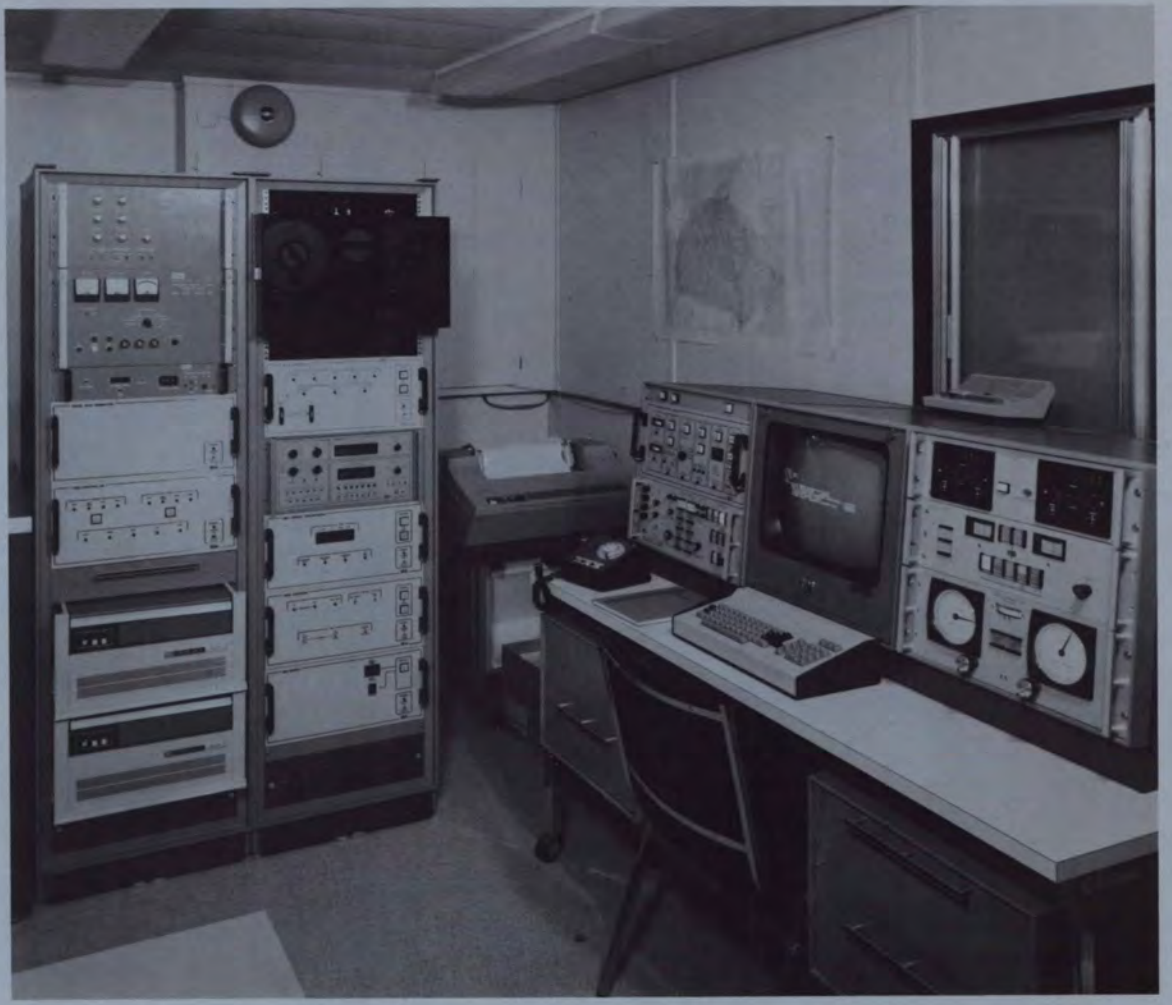
- a rugged microcomputer-controlled data-acquisition system (PRODAS) for shipborne and airborne use;
- a portable high-performance ground station (PERGS) for reception and processing of LANDSAT and meteorological satellite data for the Canada Centre for Remote Sensing;

MDA also supplied:

- a demultiplexer Quicklook formatter and SPEVOR units for use in the Brazilian LANDSAT ground station;
- custom-built digitizers for an airborne MSS (SMD-X) for NASA and others;
- studies of Inertial, Doppler, and VLF navigation systems and their optimal interaction to produce steering signals for air navigation;
- a study of the application of the LTN-51 INS to resource flying.

The experience gained and the success achieved in these projects have been followed by a number of important ongoing contracts, which include:

- a real-time multi-image processing system (MIPS) using a laser-beam film recorder to image the four spectral bands of LANDSAT MSS data;
- a stand-alone microprocessor-based weather image processor system (WIPS) to receive and process NOAA VHRR data;
- a computer-based ground processing system for use with the ESA METEOSAT data.



Quick-look display system where real-time imagery is generated for inspection.

Miller Communications Systems Ltd.

39 Leacock Way
Kanata, Ontario
K2K 1T1
(613) 592-3020
Telex – 053-4164

Miller Communications Systems Ltd. is a Canadian company incorporated in 1974, which specializes in the provision of engineering services to clients engaged in the planning, implementation or extension of satellite telecommunications services. The company will participate directly in clients' projects if required. It offers consultative services, including system feasibility studies, system analysis and software development, system design definition, earth terminal specification and design, project management, system expansion planning, service rearrangements and additions, technical evaluation of services and equipment, and technical staff training. The company will serve as a "systems house" to provide engineering-intensive facilities on a custom basis to meet the experimental or operational requirements of telecommunication users.

The company at present has a full-time staff of 12 experienced engineers and several technicians, working principally in the area of satellite communications applications and techniques. Also available are a number of full-time associates engaged in a wide range of consulting engineering, from satellite design and mission planning to broadcasting and telephone system planning as well as short-term services from key specialists expert in the technical and economic aspects of communication systems. In addition to a small laboratory, the company has access to a comprehensively equipped transmission-developed laboratory for special testing or design, and also to computer facilities.

Past and present clients include the Government of Canada, the Territorial Government of Yukon, and the Government of Ontario; the CBC; Telesat Canada; Bell-Northern Research and Northern Telecom; and several other companies. Important projects include:

- the design construction and demonstration of a low-cost earth terminal to provide CBC broadcasting service to small communities in the Yukon. System performance fully meets CBC and Telesat standards. Another terminal now in operation at Teslin, Yukon Territory, was constructed by the community association. It is a standard non-agile microwave receiver, similar to equipment made in large quantities for carrier applications. The quality of the received satellite signal exceeds the Department of Communications' specifications for cable TV.
- a study for DOC describing the concepts of a baseline communications system as a proposed solution for the diverse requirements of the large number of government departments and agencies operating in remote regions. The system configuration would use a satellite transponder with SHF for up/down links to regional and central stations, and UHF for up/down links to transportable, mobile and remote fixed stations, meeting requirements for field and toll quality voice, facsimile, data and teletype communications;
- a study for DOC of the technical constraints on integrating multi-purpose UHF satellite systems with the switched telephone network;
- a preliminary study of the inherent capability of satellite communications to provide electronic mail service to the northern regions of Canada;
- an evaluation of various concepts for a regional television distribution system utilizing low-cost receive-only ground terminals on the sites of local television stations or CATV head-ends using the 6/4 gigahertz and 14/12 gigahertz frequency bands;
- an evaluation and analysis of new methods of improving telecommunications in the North on the existing Bell Canada/Telesat thin-route single channel per carrier network, including additional facilities for automatic dialing and demand assignment;
- provision of all systems engineering and technical facilities for the "Staff Training by Satellite" experiment of the Public Service Commission using the HERMES satellite;
- the system analysis, development and hardware implementation, in connection with the SARSAT program, of a receiver system capable of periodically measuring, to an accuracy of ± 1 hertz the Doppler frequencies of up to eight emergency locator transmitter (ELT) signals appearing within the same 12 kilohertz frequency band;
- an examination of possible television and radio-ground distribution systems for remote location use in conjunction with a high-powered broadcasting satellite.

TIW Systems Limited

629 Eastern Avenue
Toronto, Ontario
M4M 1E4
(416) 461-8111

TIW Systems Limited is a Canadian company producing satellite antenna systems and related equipment and services. It offers a complete capability for the design and implementation of antenna systems, including the following equipment groups: antenna structure and mechanical components; feed and subreflector; electrical drives; electrical power distribution; servo-control and tracking system; foundation and site construction; feed and deflector de-icing; heating and ventilating equipment.

On a typical major custom-built antenna system, TIW Systems will, if required, develop design-plan and equipment specifications; design the structural and mechanical hardware; design the electrical power distribution system and cable plant; design mechanical furnishings and access; specify and procure the feed; specify and procure the electrical drive system; conduct customer design reviews; fabricate the antenna structure; develop and publish operation and maintenance manuals; and erect, install and check out all equipment on site.

The company also offers a capability in the design of the following related products:

- large optical telescopes, including mount and tube design, power distribution and cable plant design, electrical drive system design, servo-control specification, and dome enclosure design;
- large rotating platforms, including rolling element, structure, and mechanical and electrical drive design;
- special structural systems, including the design of test fixtures, cranes, material handling systems, and related electrical drives and controls.

TIW Systems also offers engineering services which include the preparation of specifications for antenna systems for satellite communication earth stations; assistance to developing countries in antenna systems product development; design evaluation and product implementation; computer analysis of complete structural systems; and consulting services for the evaluation and development of overseas facilities for antenna manufacture.

Extensive steel fabrication facilities are available in the plants of two sister companies: Toronto Iron Works and Central Bridge. Central Bridge has developed a panel shop for the manufacture of aluminum panels of large parabolic reflector structures, which are available either as part of an over-all antenna system or as panels only for customer-fabricated antennas.

TIW Systems is in the process of developing a complete product line of antenna systems for satellite communications, comprising:

- a 10-m antenna system, ASYS-10, developed for use as a ground terminal for operation at C-band, providing geostationary orbit coverage in overlapping 45° increments on an hour-angle declination mount;
- ASYS-5, a five-metre antenna system for use at C, X, or K band with minimal manual positioning capability, suitable for roof-top operation or remote-site single-channel communications;
- ASYS-20, a 20-m antenna system for satellite communications at C or X band; a wheel and track mount permits complete coverage of geostationary orbit, and the antenna system comes equipped with a "step-track" tracking system and an environmentally controlled upper equipment room;
- ASYS-30, a 30-m antenna system for satellite communications at C band, intended primarily for use with the INTELSAT network. This is a wheel and track system providing coverage of the entire hemisphere and comes equipped with a "step-track" tracking system and an environmentally controlled upper equipment room.

Typical antenna system designed and fabricated by TIW Systems Ltd.

For these antenna systems, TIW Systems provides system design, electrical power equipment, structural and mechanical components and furnishings. Feeds and servo-control components are subcontracted to such specialists as RCA Ltd., Rantec and NEC for feeds, and Randronics and Electrosystems for servo-controls.

Space-Related Activities in Canadian Universities

Background

One of the most challenging problems facing mankind involves the understanding of processes controlling the terrestrial environment. An important portion of this environment consists of the atmosphere, ionosphere and magnetosphere, three dynamically interactive regions which are influenced by external processes in the sun and the interplanetary medium and various internal processes originating near the surface of the earth and the oceans. The external solar influence on the ionosphere and magnetosphere has long been recognized, particularly in radiocommunications, where solar flares and solar wind-related disturbances cause ionospheric storms which disrupt communications.

The extent to which the earth's environmental systems are interdependent has been dramatically emphasized through a growing concern over the potentially damaging effects that man-made nitrogen oxides and chlorine compounds can have upon the concentrations of naturally occurring stratospheric ozone. In studying this problem, it has been found that the quantitative assessment of the effect of these man-made contaminants upon the stratosphere depends upon a unified knowledge of atmospheric energetics and dynamics.

Canada's northern communications are frequently affected by processes in the polar regions. Consequently, there has long been interest in studying these phenomena resulting from the interaction of the earth's magnetic field, the auroral zone and the solar wind. The auroral zone extends deep into the Canadian land mass to Lat. 55 degrees, where it can be studied by balloons and rockets. On the other side of the pole, the auroral zone is over the sea, which is less convenient for ground-based studies. With such natural phenomena available, many Canadian universities have become interested in this area of research.

Several decades of observations from ground-based, balloon, rocket and satellite-borne sensors have mapped out the main morphological features of the atmosphere, ionosphere and magnetosphere. Recent advances have emphasized, however, that there are many different processes that act to couple these regions in quite complex ways. Acquiring an understanding of these basic coupling processes is a necessary step towards clarifying the means by which solar energy is transferred to the atmosphere and magnetosphere, and the ways in which this captured energy is partitioned to cause important natural phenomena ranging from magnetospheric storms to disturbances in weather patterns.

The University of Alberta

Edmonton, Alberta
T6G 2E1

Institute of Earth and Planetary Sciences

The Institute of Earth and Planetary Sciences has been engaged in making ground-based measurements of magnetic-field perturbances caused by magnetosphere-ionosphere current systems. Research efforts have been directed towards an understanding of the source-current systems and the conductivity-structure of the earth by inference from perturbations associated with currents induced in the earth by variations in the source-current systems. As a contribution to the International Magnetospheric Study, a set of 25 inexpensive three-component magnetometers has been built and techniques have been developed for using them in large two-dimensional arrays. The Institute has co-operated with some countries in combined array studies involving up to 46 stations recording simultaneously over areas in the order of one million km^2, and in studies of solid-earth conductive structures in North America, Australia, South Africa and Britain.

The Institute has pioneered the development of data-link hardware and software for the transmission of data over long distances and its subsequent preprocessing and recording. The data link at present connects the University Observatory with the data-processing centre at the Institute. Magnetic and magnetotelluric data can be received directly at the centre. Video-output capability permits rapid evaluation of magnetospheric activity.

Members of the Institute have collaborated in recent years with colleagues at the University of Texas at Dallas; the University of Utah; the California Institute of Technology; NOAA, Boulder, Colorado; the University of Alaska; the Applied Physics Laboratory of Johns Hopkins University; Lockheed Palo Alto Research Laboratories; TRW Laboratories, Los Angeles, California, in the U.S.; the National Physical Research Laboratory of South Africa; the Australian National University; and the University of Edinburgh, Scotland.

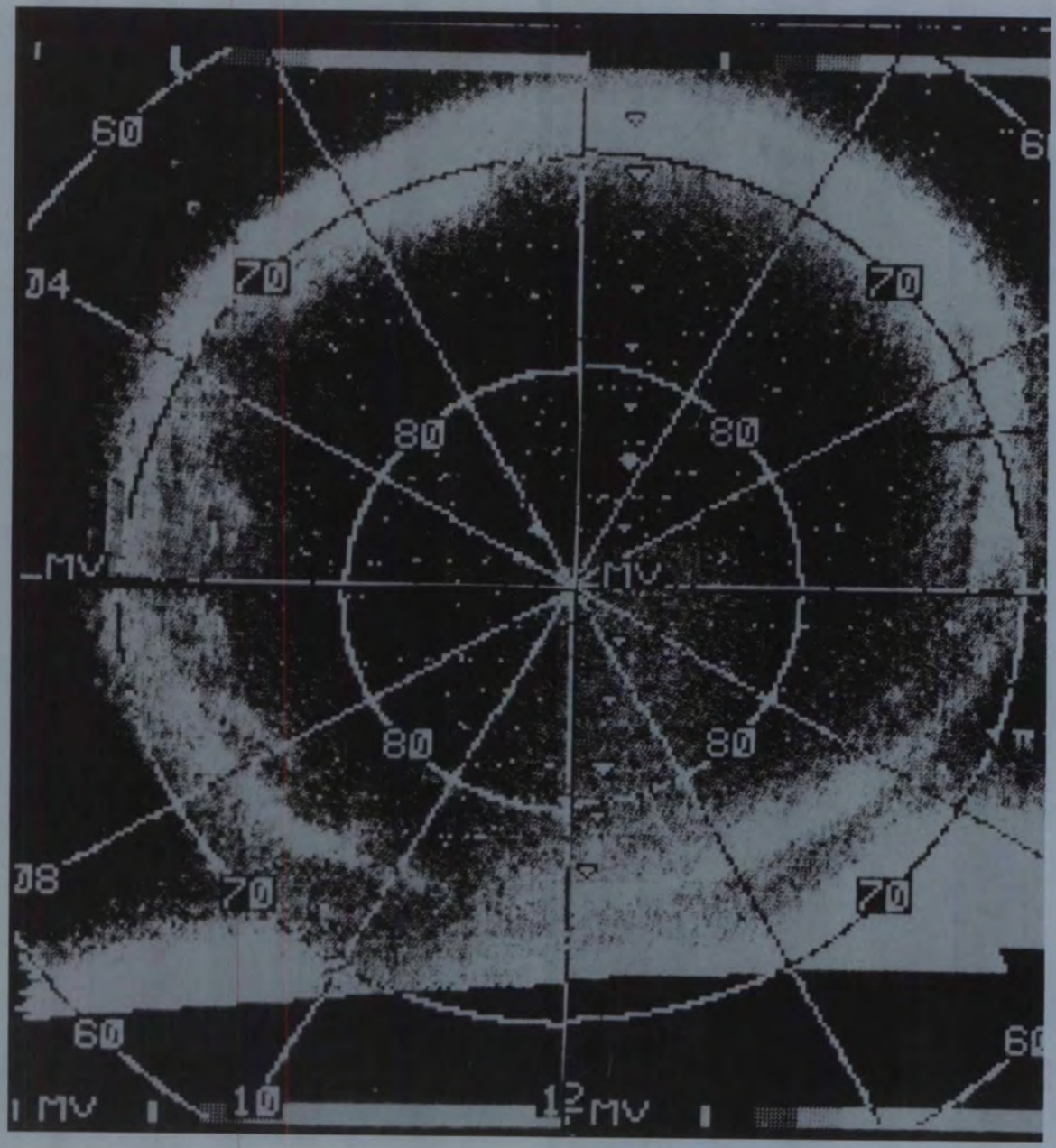
The University of Calgary

2920 24th Avenue North West
Calgary, Alberta
T2N 1N4

Aeronomy

Research efforts are broadly concerned with electromagnetic emissions in the upper atmosphere as a means of studying the chemistry and physics of the upper atmosphere itself. Observational techniques include optical sensing of auroral or airglow emissions, using specially designed spectro-photometers and counters from platforms on the ground, on balloons and rockets, and on satellites. The Aeronomy Group pioneered the development of high-speed all-sky photometers and published the first pictures of the aurora and airglow as seen from above.

The Group's experiment in the ISIS program is a unique photometer providing global coverage of two prominent optical emissions, 5577Å and 3914Å. The instrument utilizes the combination of orbital motion, satellite spin and internal scan to achieve television-like coverage at a resolution equivalent to about 10 km on the earth. Auroral pictures are studied to determine the spatial distribution, dynamic behaviour and physical cause of the diffuse aurora, and to elucidate the causes and effects of auroral substorms.



Photograph of auroral oval taken with ISIS II scanning photometer. University of Calgary, Alberta.

For other studies, a scanning photometer has been flown on rockets launched by the space research facilities branch of the National Research Council of Canada which is capable of providing excellent spatial and temporal resolution of auroral optical emissions at two wavelengths. A high-speed, high-resolution aurora-imaging device, using an image-intensifier TV system, has been developed and used to record the rapidly fluctuating features of auroras. Theoretical and experimental studies are made of the Bremsstrahlung X-rays produced in the atmosphere by electron precipitation, for which it is important to make simultaneous observations of primary electrons at the top of the atmosphere and of x-ray incidence at above balloon altitudes. The latter are obtained by using rockets carrying x-ray detectors to a height of 60-70 km and then deploying a parachute which allows the detector to float down gradually making measurements at altitudes above those normally reached by balloons. Simultaneous multi-balloon observations of auroral x-rays are also used to investigate the morphology of auroral electron precipitation.

Astronomy and Astrophysics

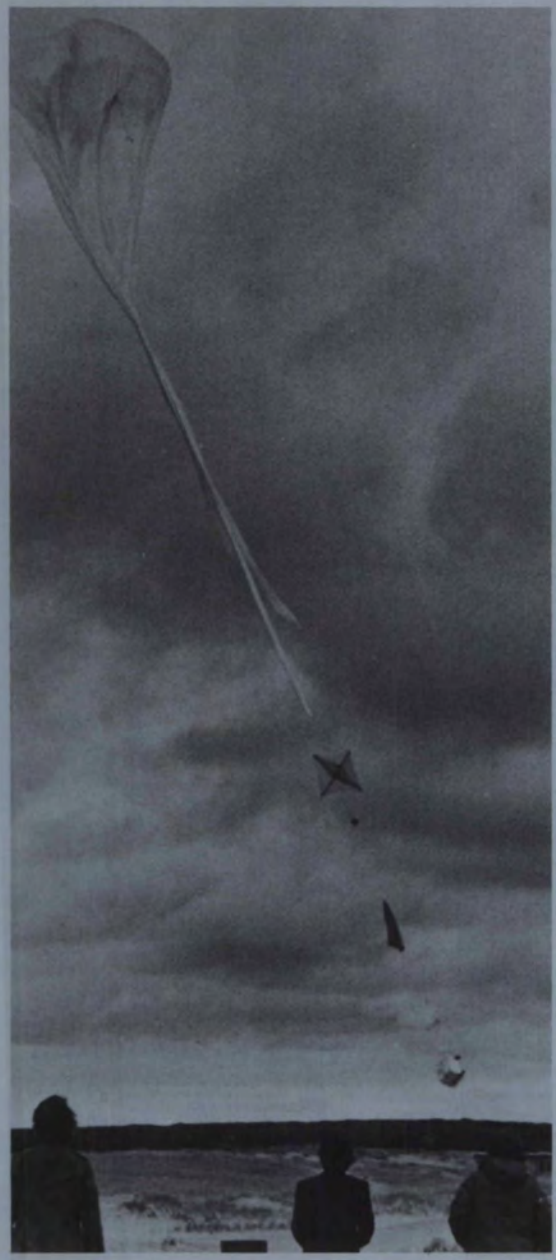
Research activity ranges from theoretical work on stellar evolution and solar physics to observations of the visible infra-red and the ultra-violet on the sun and stars, particularly variable stars and extra-galatial objects. Facilities include the Rothney Astro-physical Observatory at Priddis, Alberta, which has a 406-mm telescope equipped with photoelectric photometry and image tube.

Atmospheric Physics

A research program is being undertaken to study the physics of the lower atmosphere and features such as clear-air turbulence, stratifications, inversions, and wind and temperature profiles, which are all pertinent to air pollution problems. The novel techniques being tested, including remote sensing by acoustic radar and lidar devices, are expected to facilitate the regular monitoring and understanding of the atmospheric conditions that promote the heavy build-up of pollutants.

Cosmic Rays and Solar-Planetary Relations

Cosmic ray studies are conducted at the Sulphur Mountain Cosmic Ray Laboratory in Banff, Alberta, using monitors at Sulphur Mountain and Calgary. Data that are valuable in the determination of the energy spectra of cosmic ray intensity variations are being used by cosmic ray scientists all over the world.



Balloon launch, Poste-de-la-Baleine, Québec. Studies of auroral x-rays. University of Calgary, Alberta.

Laurentian University

Ramsey Lake Road
Sudbury, Ontario
P3E 2C6

The University has facilities for monitoring radio beacons from the ISIS satellites at a radio site 32 km from Sudbury, Ontario. A_3-type absorption is routinely recorded using CHU signals on 3.33 megahertz. Three spaced receiver stations were in operation to record meteor scatter signals from CW transmitters at Winnipeg, maintained and operated with the support of the University of Western Ontario. The facilities were also used for one year to track the high-altitude meteorological balloons flown by the United Kingdom Meteorological Service across the Atlantic and the northern parts of Canada.

McMaster University

Hamilton, Ontario
L8S 4K1

The Department of Chemistry is continuing its lunar research program. Sulphur concentrations and isotope-abundance ratios are determined in grain-size fractions of selected samples of lunar dust. Variations of the measured parameters in relation to dust-particle size provide information on the processes of fragmentation, comminution and mixing, and on the micrometeorite impact experienced by the particles.

The University of Saskatchewan

Saskatoon, Saskatchewan
S7N 0W0

The University of Saskatchewan was a pioneer among Canadian universities in space research when, in 1939, a joint program with the University of Chicago was undertaken to study cosmic rays in the upper atmosphere, using balloons. Rocket experiments began in the late 1940s in collaboration with the Defence Research Telecommunications Establishment (DRTE), and space research, in one form or another, has continued ever since.

Institute of Space and Atmospheric Studies

The Institute of Space and Atmospheric Studies is a component of the Physics Department, but has been involved in many projects that extend beyond the physics of the atmosphere alone. Dynamical studies of the mesosphere and lower thermosphere have continued. Measurements and analyses of

wind data, obtained from a partial-reflection radiowave system by using the drifts technique, have permitted an assessment of the relative importance of gravity, planetary waves and tidal waves as perturbations to the mean flow in the 60- to 110-km altitude range. A study of the major stratospheric warming in December 1974 and January 1975 has revealed the presence of associated planetary waves to altitudes of at least 100 km, and the data will soon be published. An assessment has been made of coupling events between the stratosphere, ionosphere and magnetosphere at mid-latitudes in the Southern Hemisphere from 1969 to 1974, which complements a long-term study by colleagues in New Zealand.

As part of the International Magnetospheric Study, work has continued on electron precipitation, using ground-based optical and riometer techniques, but the use of partial-reflection techniques is being investigated through special recordings of the ratio of polarized waves reflected at 2.2 megahertz. A multi-channel scanning photometer is being used, and arrangements are being made for the construction of a broad-band log-periodic polarized antenna and additional electronic equipment to transmit and receive pulsed signals. This will permit temporal and spatial variations in aurora and airglow to be related to ionization and atmospheric motions under quiet and disturbed conditions.

Continuing analysis of data from rocket and balloon flights provides new information about zone distribution up to 100 km from the ground at high latitudes. A new form of optical sonde is being developed to extend the present synoptic observations of ozone-height profiles.

Simon Fraser University

Burnaby, British Columbia V5A 1S6

The Department of Physics has been engaged in x-ray astronomical research since 1964. Until recently, these studies were concentrated upon the cosmic x-ray diffuse background in the two to 10 kilo-electron-volts region. Since 1970, the emphasis has been shifted to the development of instrumentation to extend measurement capability to lower energies and higher sensitivity.

The University of Toronto

The David Dunlap Observatory

Richmond Hill, Ontario
L4C 4Y6

An important area of research provides ground-based x-ray observations which are indispensible for the interpretation of observations from orbiting satellites. A program of research in astronomical infra-red spectroscopy began in 1976 and it is likely that this can lead to projects related to the NASA Space Shuttle program. Two experiments have been developed for the International Ultraviolet Explorer satellite, launched in 1977. The satellite will be used to test models by means of data on the ultraviolet spectra of quasars, and the ultraviolet spectra of some 2,000 stars will be used for purposes of low-dispersion classification.

The Institute of Aerospace Studies

4925 Dufferin Street
Toronto, Ontario
M3H 5T6

A rocket is scheduled for launch in 1977 as part of studies of the atmospheric densities of N_2O_2 and atomic oxygen above 85 km. The Institute made an important contribution to the instrumentation used by the VIKING probe through the Martian atmosphere. In collaboration with the University of Minnesota, a mass spectrometer was calibrated to permit an inference of the chemical constituents of the atmosphere. Work has begun on the dynamics and control of remote manipulator systems in space.

The University of Victoria

P.O. Box 1700
Victoria, British Columbia
V8W 2Y2

The Department of Physics has made observations of enhanced twilight lithium airglow emissions following rocket releases of atomic-lithium vapour trails into the upper atmosphere at Poker Flat, Alaska, in March 1976.

The University of Western Ontario

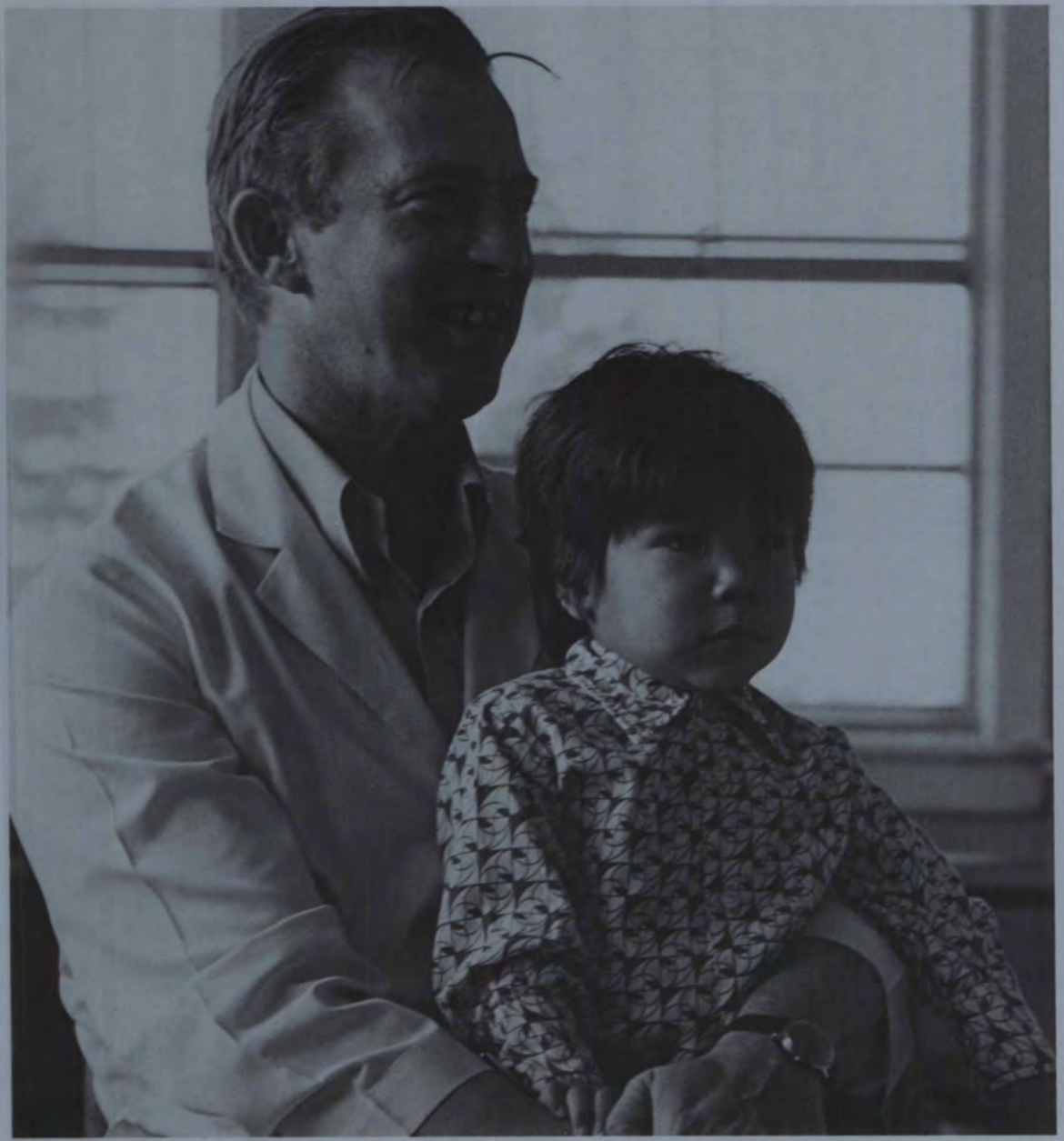
London, Ontario
N6A 3K7

The Centre for Radio Science (CRS)

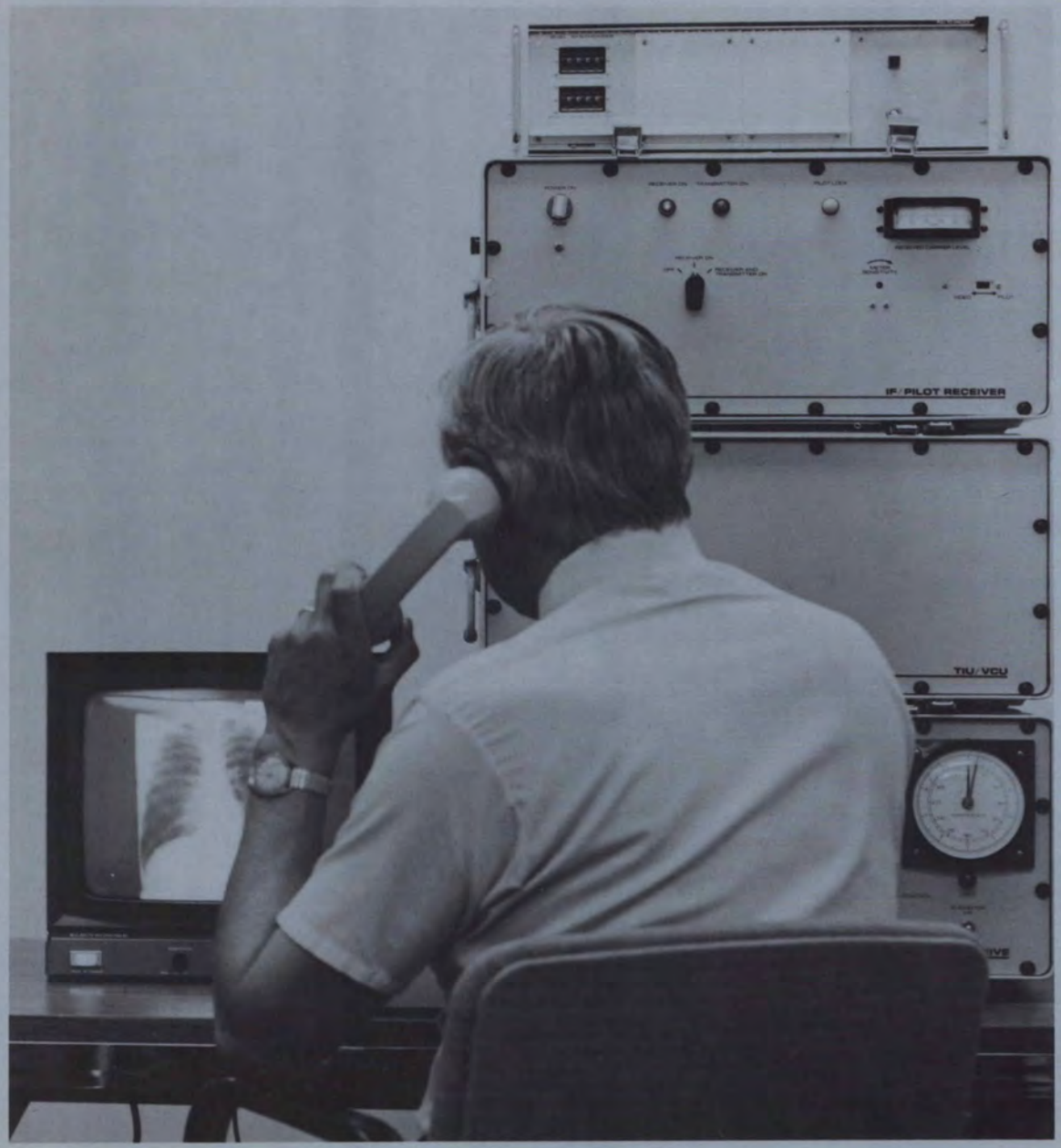
Since the establishment of the CRS in 1967, the Upper Atmosphere Physics Group has undertaken some 70 projects. Much of the research has been on the use of the RF spectrum as a diagnostic tool for investigation of the upper atmosphere. Ionospheric studies have used data from ground-based observations, rockets and satellites.

The Department of Engineering and Medicine

The Engineering and Medicine faculties have collaborated in the preparation of an experiment using HERMES for the provision of remote-access medical consulting services.



A doctor at Moose Factory, Ontario, consults with specialists at the University of Western Ontario Hospital at London, Ontario.



York University

4700 Keele Street
Downsview, Ontario
M3J 1P3

The Centre for Research in Experimental Space Science (CRESS) is a component of the Science Faculty and engages in observational, laboratory and theoretical activities in astronomy and astrophysics, aeronomy, atmospheric science, earth science and chemical physics. Laboratory research projects in astrophysics include intensity measurements on molecular spectra and the calculation and theory of realistic high-resolution synthetic emission and absorption spectra. Data are also obtained from balloons, rockets and the ISIS II satellite.

Typical telemedicine scene where a specialist in a large hospital in London, Ontario, is consulting with a base doctor and nurses in a small northern community hospital in Moose Factory, Ontario.

Append

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