Canada in Space

1982

Foreword

The remarkable progress of space technology has translated the dreams of visionaries to everyday practicalities. Canada recognized this potential at an early date and was the third nation in the world with a satellite in earth orbit. In 1982, we will commemorate the twentieth anniversary of the successful launch of that satellite named "Alouette".

1981 represents a milestone for the nation's space program. In order to establish a long-term strategy and to give a renewed impetus to space activities in Canada, I announced in April and December increases of $196 million on space from 1981/82 to 1984/85 which brings total government expenditures over this period to $476 million. My announcement in December coincided with the successful flight of the CANADARM on the space shuttle Columbia which brought great credit to Canada's technological capability.

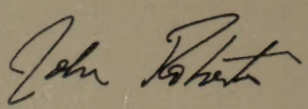
Our space policy has been to concentrate our efforts on those programs which offer the most economic social and cultural benefits to the nation and its people. As a result, we have taken a lead in the development and use of communications and earth resources satellite systems. Two major new initiatives taken in 1981 include the engineering definition of a mobile communications satellite (MSAT), and the commencement of studies in preparation for a remote sensing satellite (RADARSAT) using a radar technique for producing map-like pictures of the earth. In addition, several other newly-approved programs will increase benefits to Canadians of the data obtained from remote sensing satellites.

The policy, further, has deliberately focused technological design and manufacturing in the private sector. Over the years, Canadian industry has acquired design expertise, development and manufacturing capability and international recognition in many areas of satellite and earth station technology. Canada is among the relatively few nations in the world with the capacity to design and build complete satellites. Through its technology development programs, the government assists the Canadian space industry to maintain an up-to-date technological base.

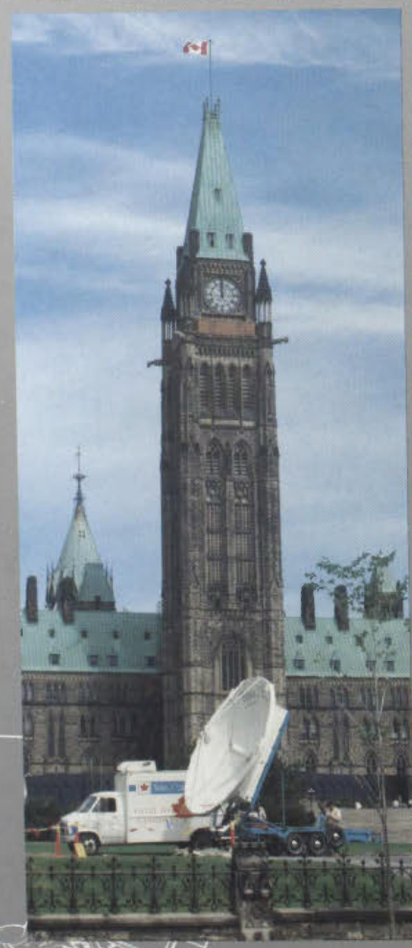
Another major thrust of the new initiatives is the strengthening of our international relationships in space through the conduct of joint programs. The most significant step in this direction is the decision to participate in the Large Satellite (L-SAT) and in the Remote Sensing (ERS) programs of the European Space Agency. These new undertakings add to existing cooperation programs with other countries.

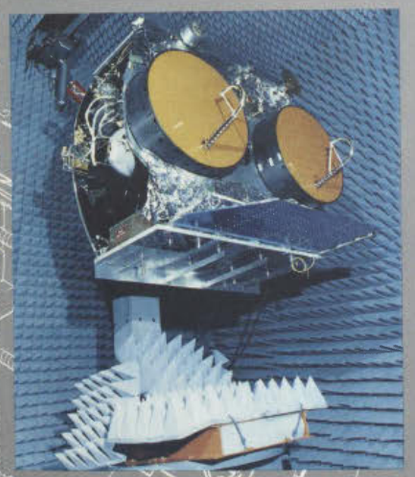
It is also noteworthy that Canada, who was a founding member of COSPAR, the International Council of Scientific Unions' Committee on Space Research, will act as the host of COSPAR's plenary and associated meetings in Ottawa in May 1982. Also, Canada will participate in Unispace '82, the United Nations Conference on the Exploration and Peaceful Uses of Outer Space, which will be held in Vienna in August 1982.

As the Minister responsible for overall space research and development policy and the coordination of space activities among government departments and agencies, I am pleased with the development of the Canadian space program. To date this program has been very successful. I look to 1982 as a year where past gains will be consolidated, and where unprecedented opportunities will be exploited by Canadian industry, universities and government.



John Roberts
Minister of State for Science and Technology



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Canada in Space

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This publication has been prepared under the auspices of the Interdepartmental Committee on Space with the assistance of the member departments and agencies.

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Outline of Space Activities

Introduction

When the science fiction authors of the early 1900's published their stories, nobody would have thought that such fantastic machines and feats were so close to us. Space technology has evolved so rapidly that one can see that part of this science fiction has already become reality. Within a quarter of a century of the launching of the first satellite, man has landed on the moon, explored the planets, and vastly improved his understanding of earth and the universe. 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. Indeed, it was on September 29, 1962 that the United States of America launched the Canadian-built scientific satellite, ALOUETTE I. This first venture into space opened the door to a series of four scientific satellites that have added immeasurably to man's knowledge of the ionosphere. Since then Canada has carried out ambitious programs of research, development and use of space technology. Nine Canadian satellites have been launched into orbit with six of them still operational. By the end of 1984, Canada will have launched four more satellites. These successful endeavours have earned the country's space scientists and engineers a reputation for performance and reliability respected around the world and have permitted Canadian participation in a number of international space programs.

Canada has a greater area than any other country in the world, except the USSR. The vast extent of the country necessitates that extraordinary attention be paid to the problems of gathering information and providing transportation and communications services. The harsh climate, complex topography and a widely dispersed population complicate matters severely. The existence of two official languages is a further challenge in the provision of communications services to as many Canadians as possible: about one million francophones are spread across the length and breadth of Canada outside Québec, while there are more than 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.

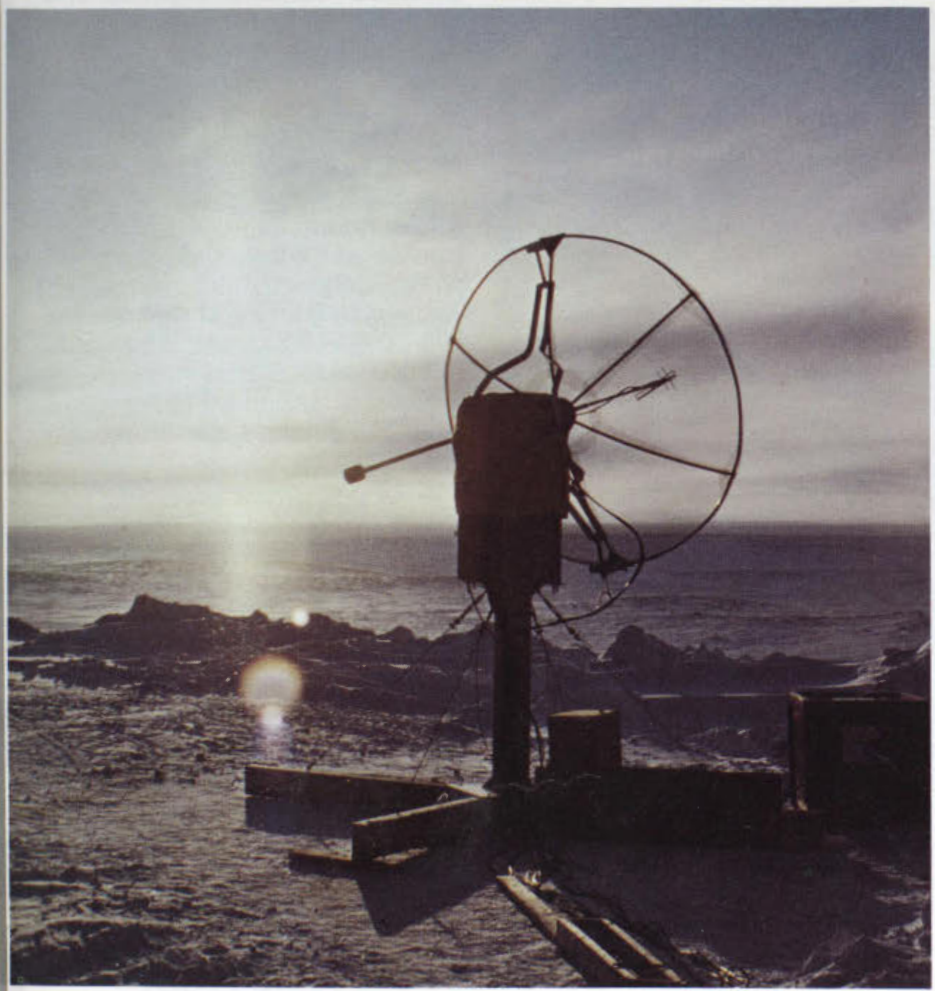
In 1968, a federal White Paper described the potential impact of satellite communications on Canadian broadcasting as follows:

"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 communications system trying to fulfill that prediction and to 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.

Associated with these advances in satellite technology Canadian efforts in space robotics have lead to the development of the CANADARM, which was successfully launched on the second U.S. Space Shuttle flight.

The future holds many opportunities in space. Canada is now studying the feasibility of mobile radio and telephone services by satellite (MSAT) and of satellite-borne radars (RADARSAT) to provide many new services. Furthermore, Canada is also participating in the European Space Agency's L-SAT program which will give access to a large satellite platform and open the door to potential export markets for spacecraft subsystems.



Satellite receiving antenna at Cambridge Bay, N.W.T.

Overview

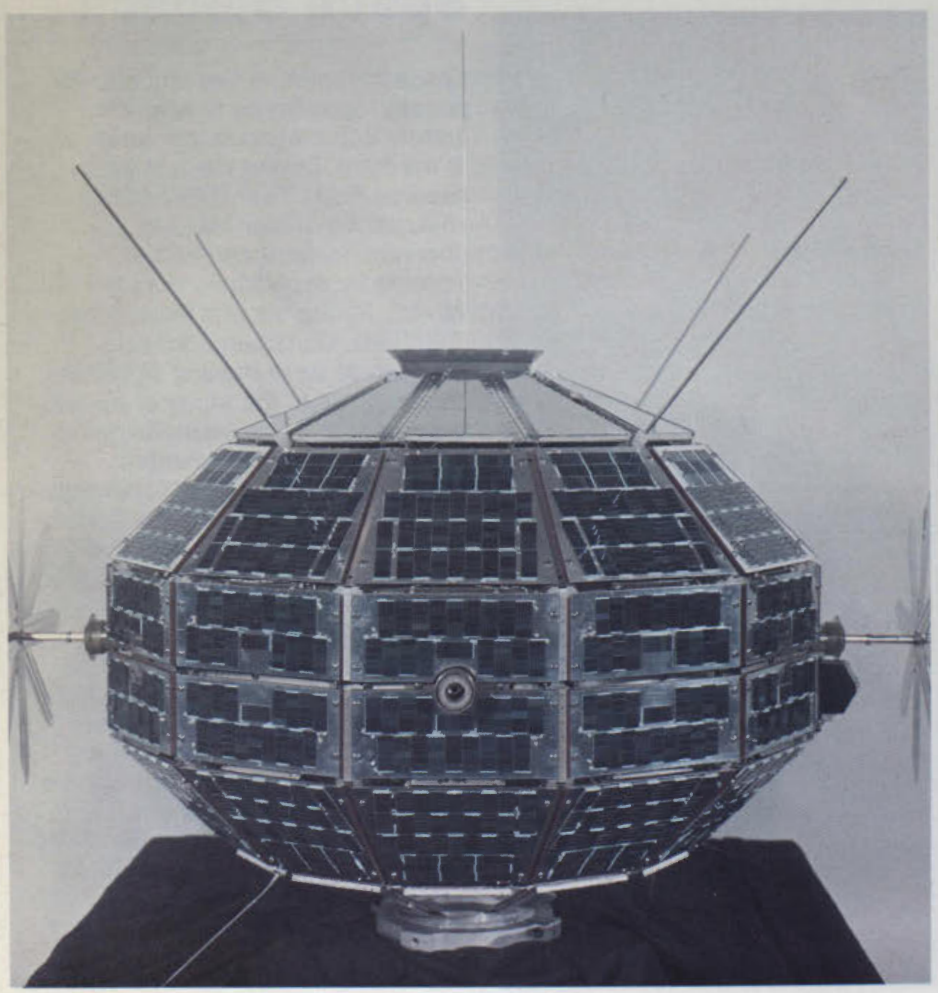
Canada's activities associated with space can generally be broken down into Space Sciences, Communications, Remote Sensing and Satellite-aided Navigation. Each topic is addressed separately below although in reality they all interrelate.

Space Science

Space research in Canada encompasses many areas of scientific activity that preceded the actual use of the term. During the first International Polar Year (1882-83) investigations of high-latitude phenomena were carried out in Canada by expeditions from the "Old World". By the second Polar Year (1932-33), Canadian scientists themselves were making significant contributions to the study of auroral phenomena. In the years following World War II new techniques appeared in Canada which revolutionized these studies and put Canadian scientists in the forefront of this research. A number of distinguished groups were formed and they participated in the International Geophysical Year (1957-58). Since that time, Canadian space research has continued to expand and now covers such subjects as the ozone layer, cosmic rays, the auroral ionosphere, the magnetosphere, the sun, meteors, interplanetary media, galactic stars and planetary nebulae. In support of this activity Canada main-

tains and operates rocket and balloon launching facilities and observatories for use by Canadian and foreign space scientists.

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 USA undertook to launch a satellite designed, developed and built in Canada. On September 29, 1962, ALOUETTE I was launched from the USA'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.



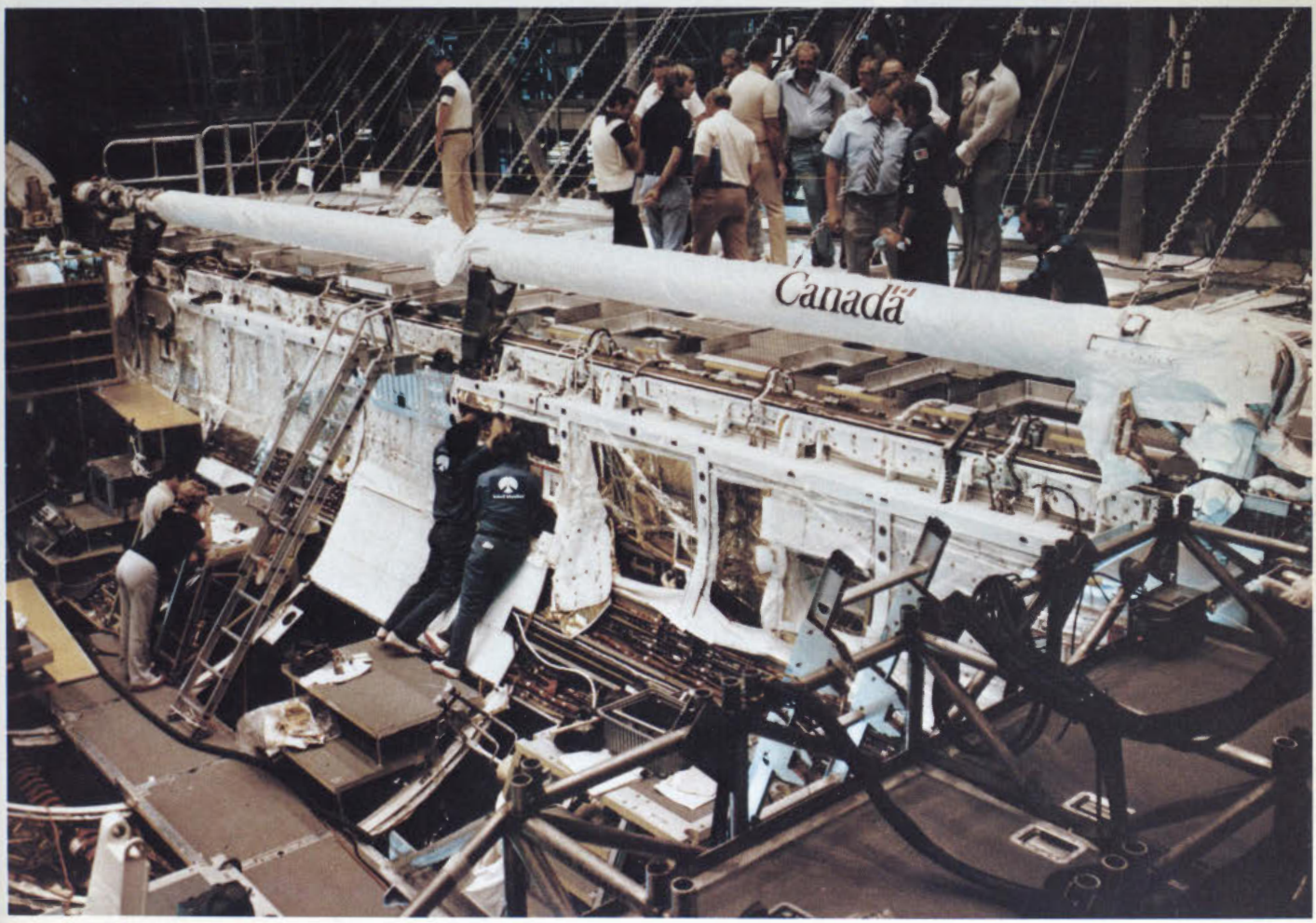
ALOUETTE II launched on November 29, 1965

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.

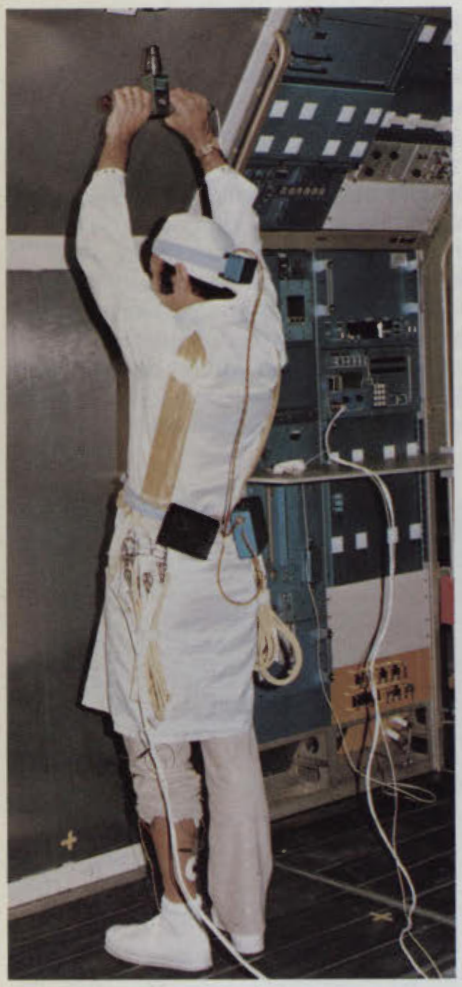
On another front, Canada, beginning in 1974, has been participating with the USA to design, develop and construct in Canada a remote manipulator system known as CANADARM. It is an arm-like device which will be used to deploy and retrieve payloads, satellites and other space devices which will be carried

in the USA Space Shuttle's cargo bay. It was successfully flown and tested on the second Space Shuttle mission November 12-14, 1981. Canada's participation in this exercise has lead to the development of a robotics capability in Canadian industry as well as further strengthening the proof of Canadian space-related industrial competence.

As a result of these successes and the developing capabilities in Canada, Canadian scientists have frequently participated in bilateral and international space science programs. Sometimes this has been as guest experimenter while at other times it has involved the flying of instruments under cooperative arrangements. At present, work is in hand to design, build and fly three instruments (a mass spectrometer to study the ambient ion concentration in space, a high frequency sounder to investigate radio wave-particle interactions and an imaging interferometer to observe ionospheric temperatures and winds) on USA Space Shuttles, an ultraviolet auroral imager on the Swedish VIKING



CANADARM



satellite, a collaborative life sciences experiment on Spacelab, and a material sciences experiment on the Long Duration Exposure Facility to be put into orbit by the USA Space Shuttle system.

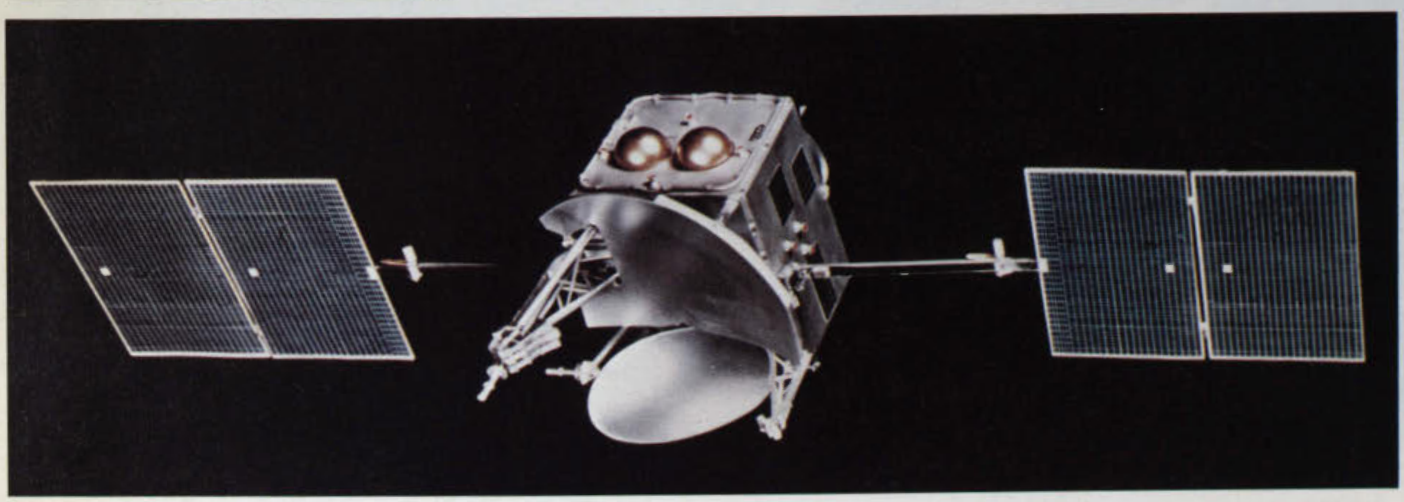
For the long term, national and international discussions are in progress to put into orbit an active module for studying the Earth's magnetic-field and a 1 metre telescope for stellar investigations. It is also expected that the current Canadian space-science program use of rockets and balloons as high altitude platforms for stratospheric, ionospheric and space studies will continue into the foreseeable future.

Satellite Communications

In 1964, the International Telecommunications Satellite Organization (INTELSAT) was established to own and operate a global commercial satellite system. Canada was one of eleven original signatories to the INTELSAT Interim Agreement. The number of participating countries has since increased to 106. The first commercial satellite of the INTELSAT series, "EARLY BIRD", was launched into geosynchronous[1] orbit on April 6, 1965. This has been followed by groups of satellites called INTELSAT II, III, IV-A and V with a VI group in the proposal stage, each incorporating the latest technological advances. Canada has participated actively in the development of the technological and commercial aspects of this global satellite communication system. Currently Canada operates four INTELSAT compatible satellite earth stations: two at Mill Village in Nova Scotia, one at Lake Cowichan in British Columbia, and one at Weir in Quebec.

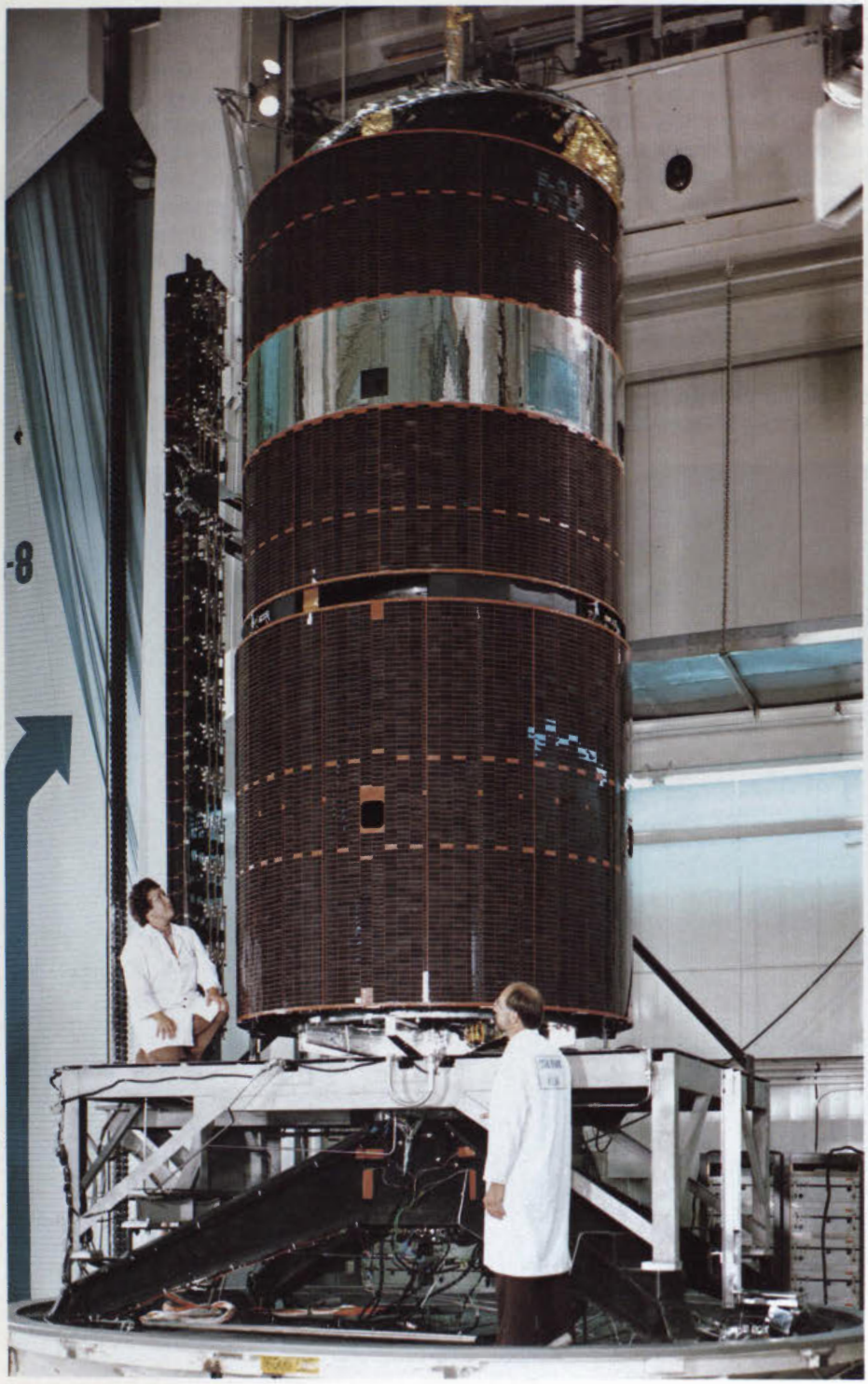
In 1969, Telesat Canada, an entity owned jointly by the government and the principal Canadian telecommunications carriers, was incorporated to operate a domestic satellite communictions sytem using geostationary satellites and fixed earth

[1]Geostationary satellites (satellites in geosynchronous orbit) rotate at the same angular velocity as the earth and are located above the equator at an altitude of approximately 35,900 km. At that distance and position the satellite appears stationary from a point on the earth.



Alternate flight equipment for Spacelab-1 life-science experiments being used for crew training

Artist's concept of the ANIK-B spacecraft launched on December 15, 1978



ANIK-C spacecraft being built for Telesat Canada and scheduled for launch in the Fall of 1982

stations. The system, the first in the world, started service on January 11, 1973 with one ANIK-A satellite and four earth stations. A second ANIK-A was launched in April 1973 and a third in May 1975, by which time there were fifty earth stations. In December 1978 a dual band satellite, ANIK-B, was launched. In addition to carrying commercial traffic, it is being used for advanced communications experiments, a result of another line of government research detailed below.

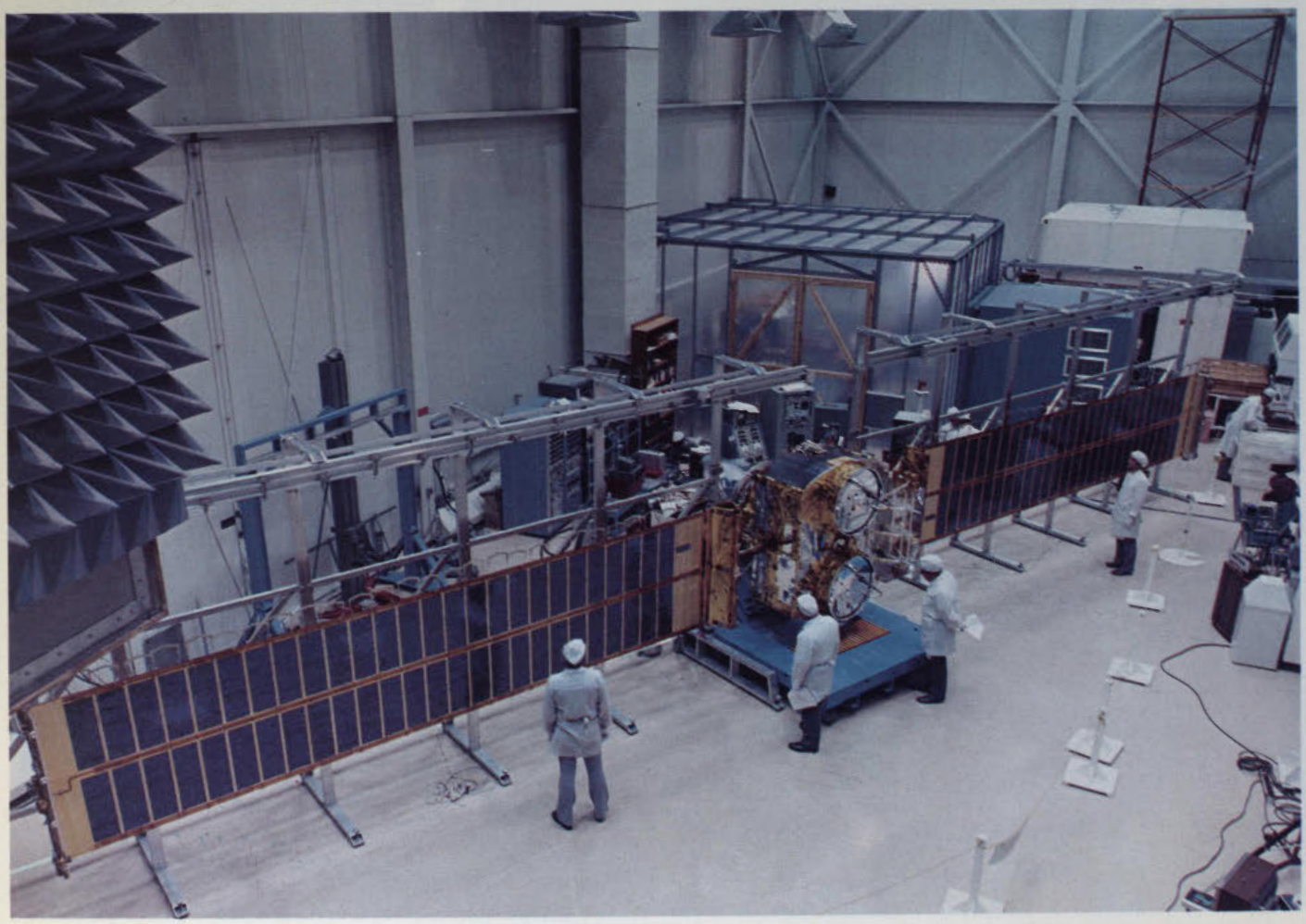
Today, Telesat is providing telephone and television service via satellite to telephone, broadcast, mining and oil companies. There are over one hundred Telesat owned earth stations across Canada, and compact rapidly deployable earth terminals are available. Many other earth terminals, not owned by Telesat, receive the television signals for rebroadcast, distribution by cable or private use.

In 1982, the first of the ANIK-D series of satellites will be launched to replace the aging ANIK-A's. These will be more versatile and have more power and capacity. Also in 1982, building on the experience with ANIK-B, the first of a new series of satellites, ANIK-C, will be launched on the first commercial flight of the Shuttle. These latter satellites will be operating at a higher radio frequency (14/12 GHz) than their predecessors (6/4 GHz) and will work with earth stations located in major city centres.

In 1971, building on the experience gained in the ALOUETTE and ISIS Programs, Canada and the USA agreed to undertake a joint Communications Technology Satellite (CTS) program. The objectives of the

project were to advance technologies relevant to future communication satellite systems, particularly those operating in the 14/12 GHz band and/or at high power. The spacecraft was designed and built by the federal government through contracts with Canadian industry. The USA provided an experimental Travelling Wave Tube (TWT), conducted prelaunch testing and launched the spacecraft. CTS, later renamed HERMES, was launched on January 17, 1976, and continued operation until November 24, 1979, almost two years longer than its design life.

The communications experiments program on HERMES was shared equally between the USA and Canada, and involved groups who used the satellite to study and test new communications services made possible by the high power of the satellite. This high power enabled the use of smaller earth antennas than previously possible with the generation of operational satellites then in orbit.

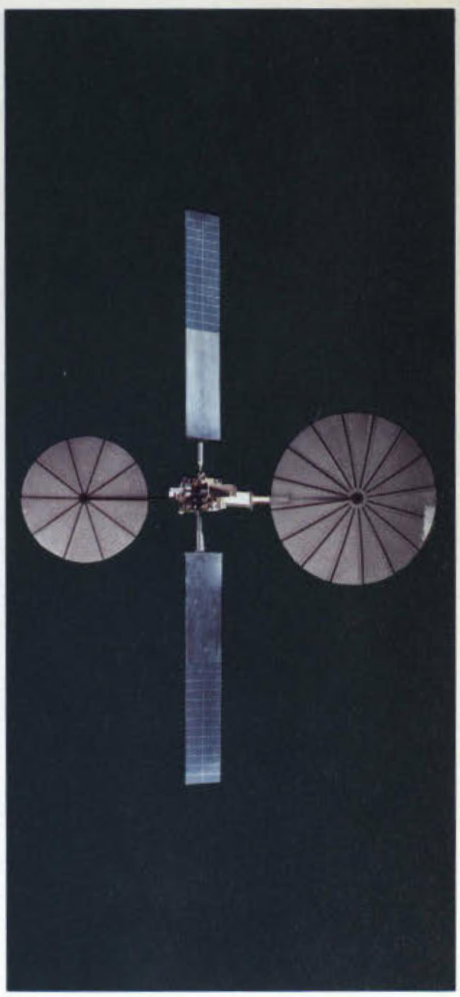


The HERMES flight-model spacecraft during full-scale solar array deployment test in the high-bay of the David Florida Laboratory

Over the operational life of the satellite, many communications experiments were completed in the areas of tele-health, tele-education, community interaction, administration and technology. These involved the use of a large number of earth stations having antennas ranging from 3m in diameter for two-way television voice and data, to as small as 60 cm in diameter for television receive-only. In addition, the major technology objectives of the HERMES project were attained. These were related to three advanced technology subsystems: a light-weight, flexible, solar-power array which tracked the sun and provided operating power; a three-axis stabilization system; and a 200 watt travelling wave tube amplifier.

Although HERMES demonstrated the technical feasibility of satellite communications including direct broadcasting of TV signals to small, low-cost earth terminals, the need was foreseen for a follow-on program of extensive pilot projects, to develop further the more promising of the communications services identified with HERMES. To this end, the federal government entered into a

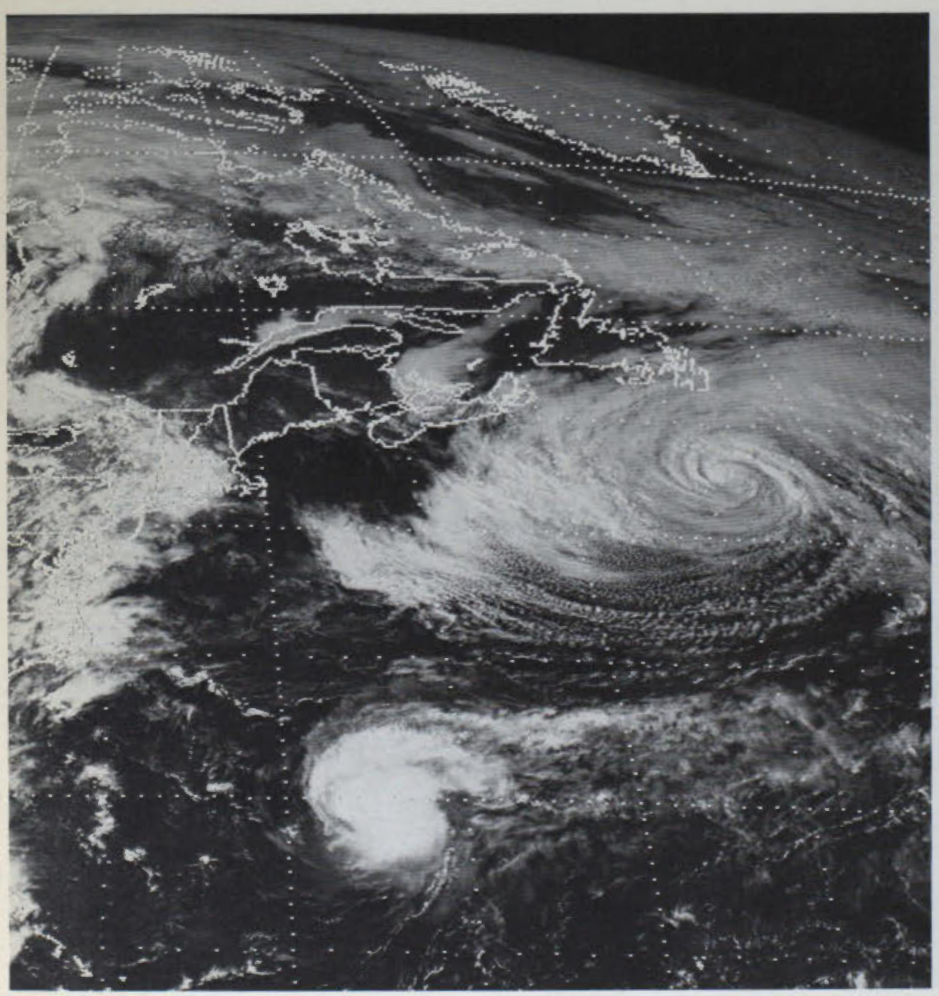
A check-out on one of the 81 cm. diameter earth stations used in direct-to-home communications field trials



Model of one of the possible designs of the MSAT spacecraft (30.5 m tip to tip, and the antenna diameters are 6.7 m and 9.0 m)

financial agreement with Telesat to include a 14/12 GHz capability in the ANIK-B satellite.

In 1977, the government signed an agreement with Telesat Canada to lease the 14/12 GHz portion of Telesat's ANIK-B satellite. The lease provides satellite facilities for the government to conduct communications pilot projects to follow on from the HERMES experiments and, where appropriate, to provide interim commercial service. These projects are designed to continue for an extended period so that user agencies can determine how to make the most effective use of the satellite communications medium, and can evaluate benefits and limitations with respect to their particular operations. The projects include work on tele-health, tele-education, public telecommunications applications, advanced technology experiments, and television program delivery.

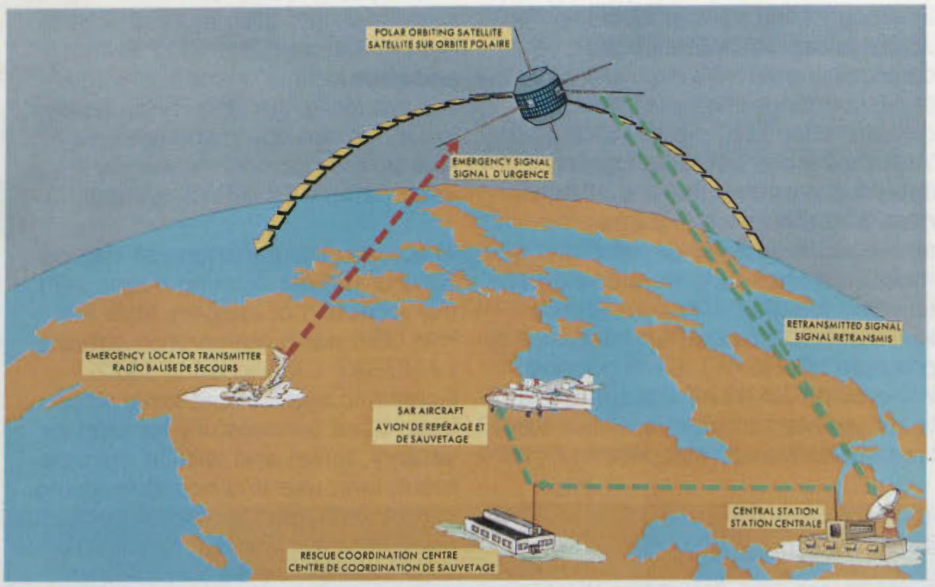


A satellite image showing hurricanes Floyd (29° N, 68° W) and Emily (42° N, 55° W)

Direct broadcasting to individual home receivers has emerged as a dominant new application of satellite technology for the 1980's. Canada was the first country to demonstrate to the world the technology to do this in 1976. The government commenced a comprehensive, multidisciplinary study program designed to provide the information necessary for making decisions on the implementation of a broadcasting satellite service in Canada.

A Mobile-Satellite (MSAT) Program is also underway in Canada. The objective of this program is to provide a facility to satisfy urgent national needs for improved mobile communications to remote areas of Canada, including resource development activities in the North. The MSAT Program will introduce satellite services to mobile terminals in Canada in a cost-effective and timely manner and will contribute effectively to industrial development, through the development, manufacture and launch of a UHF communications satellite. Conceptual design studies were begun in 1980 covering concept definition and feasibility. In December, 1981, approval was given to commence the program definition stage.

Satellite-aided Search and Rescue (SARSAT)



LANDSAT image produced on the Colour Image Recorder. On this image of the Kamloops Lake area in B.C. the bright red areas along the Thompson River are irrigated land, and the checkered patches in the darker brown areas are clear-cut logged areas in the coniferous forest.

Canada also cooperates with other nations in communications satellite programs to acquire and develop new technical and industrial capabilities for mutual benefits. Canadian participation in the European Space Agency's L-SAT program is a good example of such endeavours. It will give Canada access to a large satellite platform, the possibility of experimental use of the satellites and new export markets.

Remote Sensing

Remote sensing in Canada has primarily concentrated on the application of science and technology to the reception, processing and use of signals received from aircraft platforms or foreign satellites. The satellite portion began in earnest in 1963 with the first regular reception of data from a USA meteorological satellite. Now, through the use of its own reception facilities in Vancouver, British Columbia, Edmonton, Alberta, and Toronto, Ontario, and by using signals received from the USA and Greenland, the government obtains real-time digital data from space-borne sensors and systems in both the polar orbiting (NOAA) and the geostationary (GOES) modes. These signals permit such activities as the production of infrared and visual imagery, the determination of cloud motions, the generation of vertical temperature profiles in the atmosphere and sea surface temperature distributions, the observation of sea ice distribution, and the collection of data from surface based sensors in remote land locations or on buoys all in support of weather, ice and sea state services throughout Canada. Problems such as data assimilation, information distribution and the use of active sensors in space are current topics of active research.

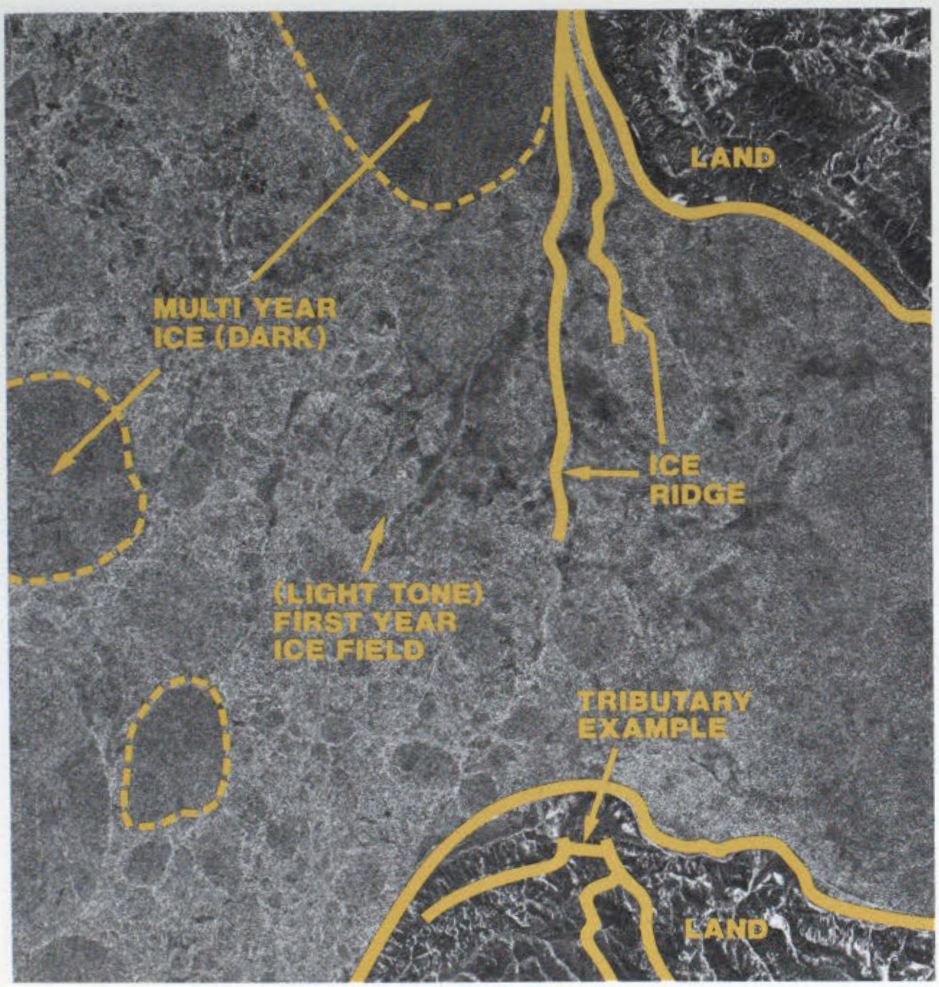
In a country as vast as Canada, the ability to rapidly and accurately locate missing aircraft and vessels and to rescue distressed personnel from disaster sites is of prime importance. With their large covering capacity, satellites may improve the effectiveness and efficiency of these activities. In order to develop and demonstrate such satellite-aided detection and location, Canada, France and the USA initiated an international program (SARSAT). Each country will provide SARSAT instrumentation to be installed on USA weather satellites. Performance evaluation of the system should start in 1982. It is expected that satellite-aided search and rescue may become a world system since the USSR has agreed to launch two complementary satellites as part of their technically-interoperable COSPAS system.

The resource-management applications of remote sensing began with the reception of imagery from the first USA earth observation satellite LANDSAT I, launched in 1972. Economic applications have since been used successfully for crop inventory, forest and wildlife management, land-use and ocean mapping, ice reconnaissance, and mineral and petroleum exploration utilizing the data from the visual and infrared sensors of the LANDSAT and later NOAA satellite series.

Through reception stations at Prince Albert, Saskatchewan, and Shoe Cove, Newfoundland, imagery is now provided to Canadian users from these satellites for research and operational use. Image analysis facilities, information services and scientific advisors are also provided to assist resource managers in applying the technology to their problems. While the federal government has developed the analysis capability to undertake operational inventories of water and land resources, remote sensing expertise and analytic capability is also available from provincial remote sensing centres, notably in Alberta, Manitoba, Ontario and Quebec, and is being developed in Canadian universities. A new field currently under development involves pushing this land-based expertise and interest offshore to produce the capability to monitor ocean chlorophyll levels from space as a measure of ocean productivity.

LANDSAT image of an agricultural area along the Peace River in Alberta

To date, Canada has concentrated remote sensing activities on the ground segment of satellite remote sensing systems (data reception, processing and analysis) where Canadian industry has demonstrated leadership in international markets. This will continue in the immediate future with the upgrading of Canadian ground systems to accept data from the newest generation of satellites. However, there is a significant addition to the Canadian strategy (now being pursued by the federal government) intended to secure access to remote sensing data for resource managers. The Canadian Surveillance Satellite (SURSAT) program, completed in 1980, showed, using data from the US SEASAT program, that ice and ocean monitoring were feasible with a satellite-borne imaging radar. A program, RADARSAT, is now underway to define mission requirements, conduct an R&D program with Canadian industry on space radar technologies, and develop a conceptual design for a Canadian radar satellite primarily to provide Arctic operators with the all-weather ice movement information required for safe and efficient exploitation of energy resources.



SEASAT synthetic aperture radar (SAR) image showing first year and multi-year ice near Peel Point, N.W.T. The image was digitally processed.

Participation in cooperative satellite programs with other nations is also being pursued, particularly with the European Space Agency (ESA) in the development of the ERS-1 remote sensing satellite which will likely include an imaging radar.

Satellite-Aided Navigation

Canadian government vessels use satellite navigation aids in naval and coast guard operations, oceanographic research, fisheries patrol and management, and hydrographic surveys. To improve the safety and accuracy in air and sea navigation, studies of possible uses of satellite systems such as the AEROSAT project and the US NAVSTAR/GPS are in progress.

Interdepartmental Committee on Space

Over the years, each agency that became involved in space activities developed certain areas of expertise related to its individual mission. This led to the present situation in which a number of agencies may each be regarded as the leader in particular areas of space application or research.

To achieve a measure of coordination, the Interdepartmental Committee on Space (ICS) was set up in 1969. It is assisted by three subcommittees dealing with the industrial, international and scientific aspects of space policy. After a number of years of evolution the ICS has recently been made responsible to the Minister of State for Science and Technology. The ICS comprises senior officials representing the Department of Communications (DOC); Department of Energy, Mines and Resources (EM&R); Department of Environment (DOE); Department of

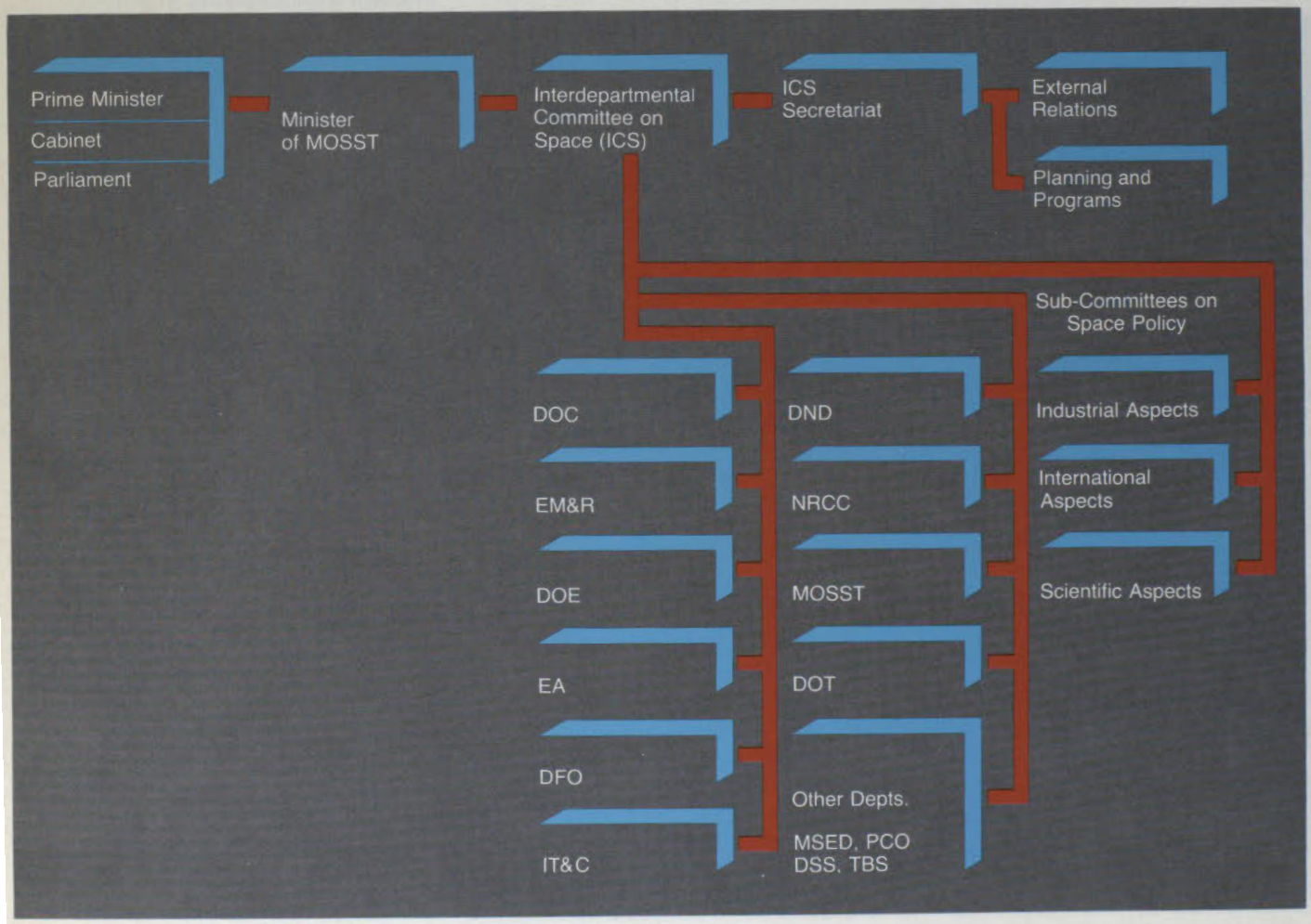


Figure 1
Interdepartmental Committee on Space

External Affairs (EA); Department of Fisheries and Oceans (DFO); Department of Industry, Trade and Commerce (IT&C); Ministry of State for Science and Technology (MOSST); Department of National Defence (DND); National Research Council of Canada (NRCC); and Department of Transport (DOT). Representative from the Ministry of State for Economic Development (MSED), the Privy Council Office (PCO), the Department of Supply and Services (DSS) and the Treasury Board Secretariat (TBS) have observer status on the Committee.

Since early in 1976, the ICS has been supported by a full-time Secretariat. Its function is to provide a base for coordination and liaison between the agencies concerned, the various international space organizations, the Canadian space industry and the space science community at home and abroad. Figure 1 shows the inter-relationship of the committee, agencies, and parliament while Figure 2 shows the committee's terms of reference.

Main Committee

Interdepartmental Committee on Space

- Formulates and recommends policies
- Recommends actions for optimum uses of resources and dissemination of information
- Coordinates space activities to maintain a viable space industry
- Recommends on cooperation with foreign space agencies

Sub-Committees

Industrial Aspects of Space Policy

- Recommends on industrial aspects
- Reviews space activities
- Disseminates information to industry
- Promotes industrial cooperation

International Aspects of Space Policy

- Recommends on legal and international aspects
- Advises on cooperation with foreign space agencies and bodies
- Recommends Canadian positions for UNCOPUOS

Scientific Aspects of Space Policy

- Recommends and advises on scientific aspects and programs
- Advises on scientific cooperation with foreign and international scientific agencies

Figure 2
Committees' Terms of Reference

The federal government expenditures in space have increased over the ten year period 1972-1982 as shown in Figure 3. In addition, the intra-and extra-mural distribution of funds over the same ten-year period, showing an increase in the proportion being spent extra-murally, and a snap-shot of the estimated space budget, broken down by department and agency, for the fiscal year 81-82 is shown.

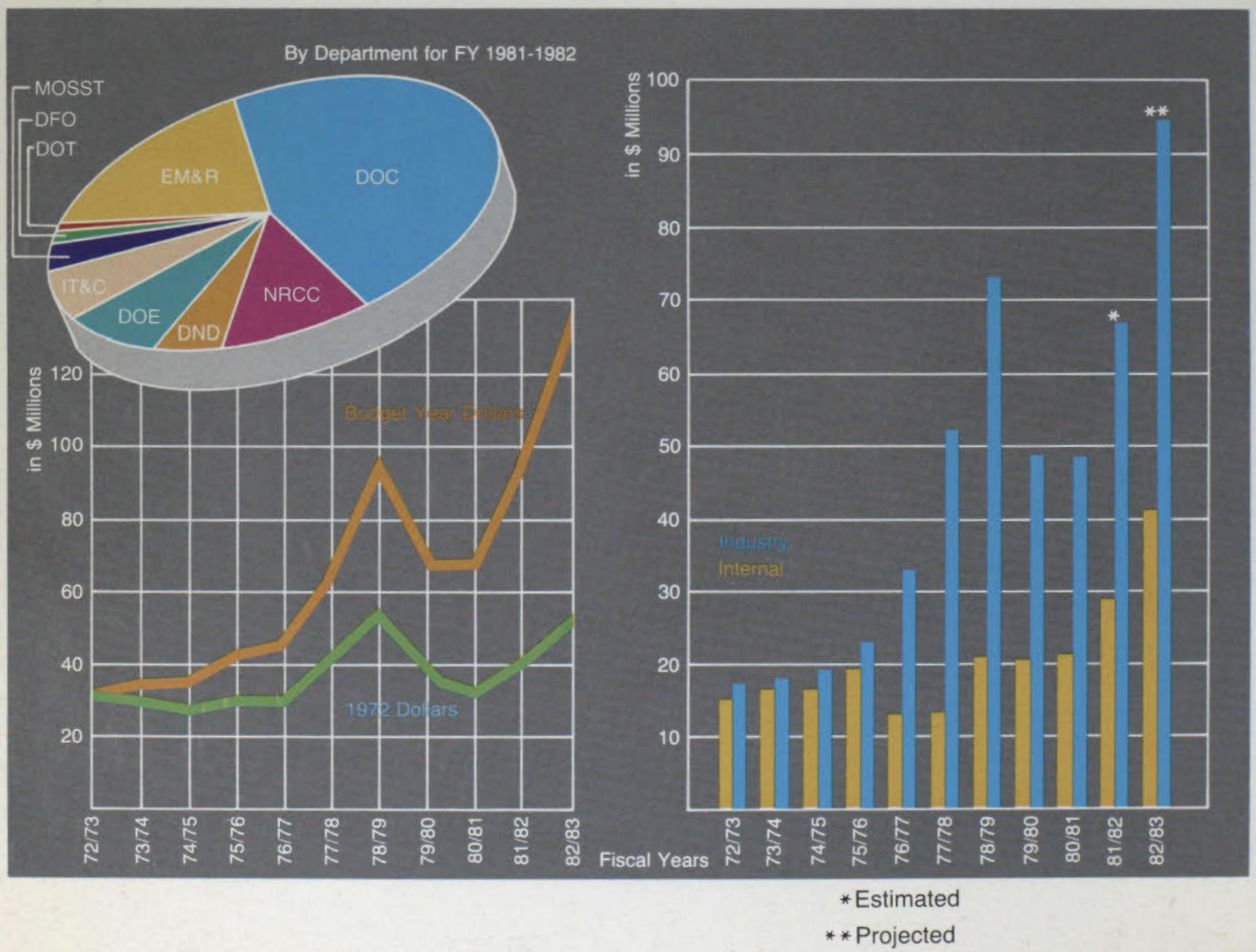


Figure 3
Government Space Expenditures

Organizations Active in Space

Federal Departments and Agencies

This section provides a brief overview of the space activities undertaken by federal departments and agencies within their mandates.

Communications Canada

The role of the Department of Communications is to foster the orderly development and operations of communications for Canada in the domestic and international sphere. As space technology is playing an ever increasing role in the field of communications, the Department has a responsibility for the planning, development, coordination and implementation of policies and programs to meet Canada's needs in space telecommunications and for the development and coordination of plans and procedures to provide for optimum participation by Canadian industry in the design, development, and construction of Canadian satellite systems. In carrying out these activities, the Department supports the development of space communication facilities and services in Canada as well as facilitating the development of new technology and applications through R&D both internally and externally. Federal Government involvement in the development of satellite communications is necessary because of the international character of many of the activities and the need to exploit scarce spectrum and orbit resources in the best public interest.

A critical role of the Department is the planning and management of the use of the radio spectrum. In recent years, increasing attention has also been placed on the planning and management of the use of the geostationary orbit. Priority activities in these areas are evident in international negotiations with the other countries of the Americas concerning the plans to allow the implementation of broadcasting-satellite systems in the 1980's and 1990's, the management of the geostationary orbit for fixed-satellite services, and a mechanism to allow mobile-satellite systems, mobile systems, and broadcasting systems to share the use of the UHF band. It is expected that these activities will expand as increased demands are placed on the use of the spectrum and the geostationary orbit.

The Department has played a lead role in the research and development of a number of major Canadian space programs. Experiments which began with the HERMES satellite, and continued with the ANIK-B system have permitted a wide range of investigations into services such as tele-health, tele-education, public telecommunications and television program delivery. All sectors in Canada including provincial governments, industry, universities and other federal agencies have been involved. Many of these services have proved to be viable and will be transfered to full commercial operation using, for the most part, Telesat's ANIK-C satellite system which is expected to be in operation during 1982. A Mobile Satellite Program (MSAT) is underway aimed at satisfying urgent national needs for improved public and civil government mobile communications to underserved areas of Canada, including resource development activities in remote areas. Other programs that the Department has been involved with are the Franco-German SYMPHONIE satellite experiments for international time intercomparison, International Satellite for Ionospheric Studies operations for obtaining ionospheric data, and the large satellite (L-SAT Program) of the European Space Agency to develop a

large multi-purpose spacecraft for future commercial telecommunications applications.

The Department's in-house program is centered at the Communications Research Centre (CRC). In addition to providing project management for major Departmental space projects, CRC maintains a sufficient level of expertise to be able to provide advice, to keep abreast of international developments in satellite communications and associated technical fields, to carry out studies in support of planning and policy development, and to manage contracts to industry and universities. As a result of this body of specialist expertise on space system design, CRC also supports space applications programs sponsored by other agencies.

The Space Electronics Directorate is concerned with the development and reliability assessment of advanced electronic technology and hardware to meet the future space communications requirements. Some areas of current concern are smaller terminals for TV receive-only and two-way telephone applications; satellite antennas, satellite transponder components, solid state power amplifiers, satellite-switched time-division multiple-access systems and on-board-regeneration systems; and satellite power subsystem components including high reliability battery management systems.

In the area of smaller terminals, DOC has recently funded R&D on a solid state replacement for a TWTA, improved electronics, low cost fabrication techniques for antenna reflectors, and systems design. This work is intended to increase the efficiency and reduce the cost of small terminals.

Spaceborne component R&D deals with a broad range of devices. Studies are continuing on the development of new and advanced spacecraft transponder elements, satellite-switched time-division multiple-access technology components, the application of direct RF modulation/demodulation techniques to communications spacecraft at microwave frequencies, and antenna design. In the area of spacecraft power systems, work is proceeding on a high reliability battery management system utilizing microprocessor control and a high efficiency 250 W DC/DC power converter.

An Emergency Position Indicating Radio Beacon (EPIRB) was designed and fabricated, for SARSAT, in the 406 MHz band, only recently allocated to search and rescue.

The Space Mechanics Directorate is concerned with spacecraft system design, attitude in orbit determination, prediction and control, and mission dynamics. These tasks require a capability in spacecraft thermal materials and mechanical design, control system design, propulsion technology, and analysis of mission dynamics and orbital operations.

The determination, prediction and control of the spacecraft orbit and attitude is vital to the effective and efficient use of advance communications payloads (such as are envisaged for MSAT) and remote sensing payloads (such as for RADARSAT). Advanced orbit determination and prediction programs were developed and demonstrated for use in SARSAT. At the same time, attitude determination and prediction techniques were developed.

Complex spacecraft with high power payloads operating in the harsh space environment require specialized thermal control. Under Space Mechanics initiation and guidance, an integrated heat-pipe system capable of efficient emission and dissipation of large quantities of heat energy has been successfully developed and tested. Development work is in progress on high capacity thermal energy storage systems using phase-change materials.

The development of microprocessor architecture and programs suited uniquely for spacecraft on-board computation is continuing, in preparation for advanced spacecraft such as MSAT and RADARSAT.

The Space Systems Directorate is concerned with concept development and design of communications systems and major sub-systems and with proof-of-concept experiments. It supports applied research and development related to communications processing techniques, including voice codecs, channel modems, and security sub-systems for small terminals and mobile satellite communication systems. The techniques studied are applicable to a variety of systems including ANIK, MSAT and military satellites. In addition, non-satellite applications, such as mobile communications, are served by developments in these studies.

David Florida Laboratory (DFL)

The DFL is a national facility for the environmental testing and integration of satellites and space hardware, which is available for use by agencies of government and by industry on a cost-recoverable basis.

These facilities, located at Shirley Bay just west of Ottawa, are part of the Communications Research Centre of the Department of Communications. Originally built in the early 1970s to support the integration and testing of the Communications Technology Satellite (HERMES), they have since been expanded (tripled in size) to provide all necessary equipment and assembly areas to perform integration and environmental testing of either small or Delta class spacecraft such as ANIK-B, ANIK-C and ANIK-D or large spacecraft such as L-SAT, INTELSAT V and SYNCOM-4. The facilities were designed to accommodate spacecraft capable of being launched by the U.S. Space Transportation System (STS or Shuttle) or expendable launchers.

The functional units of the DFL are:

- Two high-bay spacecraft assembly areas, with appropriate dust and contamination control, for assembly and integration of aerospace components and systems. This is sufficient space to integrate and assemble up to five Delta class spacecraft at one time;

- An RF test facility comprising two anechoic chambers, two screened rooms, an antenna range with fixed (400m inclined 7°) and movable antenna tower and EMC/RFI equipment for testing to Mil. Specs., together with associated control and data acquisition capability;

- Vibration facility including three separate vibration machines with a capability of 27 kN, 53 kN and 178 kN force respectively, with associated control and measurement instrumentation for launch vibration simulation;

- Five thermal vacuum chambers to simulate thermal and vacuum conditions of outer space: one large 7m × 10m chamber suitable for all-up spacecraft tests; four other chambers, 3m × 9m, 2.5m × 2.5m, 1.25m × 2.5m, 1m × 1m, for testing spacecraft subsystems and components;

- Data reduction facilities used to display, record, store, and analyze vital thermal vacuum test data.

The spacecraft spin balance facility includes a spin balance machine with remote operational capability for use in soft vacuum.

In addition, the facilities include specialized ground support handling and test hardware, together with software packages developed through many years of spacecraft testing.

Energy, Mines and Resources Canada

The Department of Energy, Mines and Resources is tasked with responsibility to manage the natural resources of Canada's vast land and ocean territories in a manner beneficial to Canadians. As numerous studies showed that remote sensing from satellites and aircraft was a cost-effective way to obtain much of the required data, the Canada Centre for Remote Sensing (CCRS) was established in 1972 to develop remote sensing technology, to transfer that technology to industry, and to facilitate the acquisition and dissemination of remotely-sensed data and derived information. CCRS accomplishes its objectives through close cooperation with private industry and coordination, on a national level, of remote sensing through the working group of the Canadian Advisory Committee on Remote Sensing. This committee includes representation from industry, universities, and provincial and territorial governments.

To carry out its mandate, CCRS has two earth receiving stations, one in Prince Albert, Saskatchewan, and the other in Shoe Cove, Newfoundland, both capable of receiving, recording, generating and distributing LANDSAT and NOAA satellite data to Canadian users. The stations provide "quick-look" black and white imagery of Multispectral Scanner (MSS) data, near real-time data through facsimile transmission, computer compatible tapes, and microfiche. The Prince Albert station also provides high resolution black and white or colour imagery and Return Beam Vidicon imagery from LANDSAT.

CCRS maintains four aircraft equiped with state-of-the-art remote sensing instruments. A Falcon jet aircraft, which can fly at an altitude of 11 km, is used to simulate data from future satellite sensors such as those on the USA's LANDSAT-D and France's SPOT, as well as to supplement the visual and infrared data from existing LANDSAT sensors. A Convair 580, with a range of 4,000 km, is equipped with a Synthetic Aperture Radar (SAR) which is now engaged in experiments related to the requirements for future Canadian involvement in remote sensing radar satellite systems. Two DC-3's are engaged in low-level remote sensing operations and in testing new sensors and support systems. These aircraft can be leased for commercial use.

There are extensive computer-based facilities in Ottawa for R&D and production activities in data processing and image analysis. These are used for generating special products as well as for providing users with image analysis facilities. The Digital Image Correction System became operational in 1980 and is now used for routine production of precision LANDSAT imagery which can be overlayed with standard topographic maps. A new colour image recorder, also became operational in 1980 for high volume production of high resolution colour imagery. A new production system to generate digital imaging radar (SAR) imagery is being installed to allow users timely access to this new type of remote sensing data.

Two digital image analysis systems are available to assist users in the interpretation of remotely sensed data. One, known as the CCRS Image Analysis System, allows a user

with minimal knowledge of computer techniques to perform sophisticated analyses of resource management problems. While the System has well-documented processing routines and instructions, an operator is available to assist the user. A second system, the Timesharing Research Image Analysis and Display (TRIAD), is available to the relatively sophisticated researchers who are able to develop their own software. CCRS does not provide operator or training support for the TRIAD system.

CCRS offers an on-line information retrieval system called RESORS which provides bibliographic information on applications and techniques for remote sensing.

To guarantee the future availability of resource management data from space, Canadian ground stations are being upgraded to receive data from the next generation of visual and infrared sensor satellites such as the USA's LANDSAT-D scheduled for launch in 1982. That satellite will include a new sensor, the Thematic Mapper (TM), which will generate much higher resolution imagery with more spectral information than can be derived from the MSS sensors on satellites now in orbit. Due to changes in the data transmission parameters and the orbital characteristics, extensive additions and modifications will be required to the Canadian facilities. These upgrades and the development of a new image analysis sytem to handle higher data rates will be carried out by Canadian industry, world leaders in the ground segments of remote sensing satellite systems.

Following recommendations from the Canadian Surveillance Satellite (SURSAT) Program in 1980, the Department is pursuing options to guarantee access to real-time imaging radar data over Canada, particularly for all-weather support of energy exploration and shipping activities in ice-infested waters. An interdepartmental program, RADARSAT, is now underway in cooperation with industry to define mission requirements for a radar satellite system and to establish Canadian technological competence in the space and ground segments of such a system.

Environment Canada

The main objectives of the Department of the Environment are to preserve and enhance the quality of the natural environment and safeguard man's health and property. These commitments are realized by the Departments constituent Services through environmental monitoring and scientific research, enforcement of regulations, resource management and conservation, safeguarding natural and cultural heritages, and the provision of information and technical services, particularly in meteorology (weather, ice and sea state).

To support the fulfillment of its mandate, the Department has taken a lead role in the development and demonstration of space techniques for the collection, processing and analysis of hydrological and meteorological data, inventories of forest, water and land resources, and studies of the stratosphere and the ozone layer. A considerable portion of this work is done in co-operation with the space industry, provincial governments, federal agencies (e.g. the Canada Centre for Remote Sensing) and Canadian universities.

The Atmospheric Environment Service (AES) has been receiving satellite imagery from space since 1963. Today, AES receives and processes satellite data from two polar orbiting satellites (NOAA) and two Geostationary Operational Environmental Satellites (GOES), all operated by the USA. The purpose of the reception and processing systems is to produce information in formats suitable for rapid and easy assimilation into various operational forecast systems which are tailored to various types of applications. In addition, data are also supplied for input into special applications such as snow cover, and lake and sea surface temperature analyses, and for large scale (1.1 km resolution) ice information.

Advanced Very High Resolution Radiometer (AVHRR) readout stations are located at Toronto, Edmonton and Sondre Stromfjord, Greenland (in cooperation with Denmark). In each of the AVHRR systems, data from the receiver are fed into a synchronizer which reduces data from 10 to 8 bit resolution. Further data processing removes most of the distortion introduced by the earth's curvature.

Visible-Infrared Spin Scan Radiometer (VISSR) stations are operated in Vancouver and Toronto. The Toronto system is built around a minicomputer, while the Vancouver system uses a number of microprocessors to store and process data and transmit images over a landline.

Virtually all imagery produced by AES readout systems is specially enhanced, e.g. grey scale manipulation, to ensure that features of interest are clearly discernible. As well as imagery, computer-compatible data tapes are produced for R&D and special applications.

In addition to operational satellite systems, AES is actively involved in R&D. While systems development continues for data archiving, handling and display, research projects are also underway to link ground-based radar with satellite information (RAINSAT) for cost-effective improvements in short range precipitation forecasting, to effectively obtain

humidity and temperature profiles from satellite-borne sensors for regional scale forecasting, to develop techniques for generating ice information using precision remapping and objective image analysis/classification schemes for ice type, ice thickness, snow cover, cloud presence and cloud type, and to investigate the use of microwave data in support of meteorology in Canada. Within microwave research, an algorithm for using scanning multifrequency microwave radiometer brightness temperatures for ice analysis has been developed, scatterometer data for determining ocean surface winds have been found very useful for improving weather analyses, and active radar (SAR) for the provision of sea-ice information (RADARSAT) is being carefully examined as a possible cost-effective way of gathering information necessary for year-round navigation in ice-infested waters. Each microwave project requires considerable research on the various surface phenomena in terms of their characteristic signatures.

The Environmental Conservation Service and the AES use data collection platforms (DCP's) to transmit data from remote locations via geostationary or polar orbiting satellites to various data collection points. Canadian industry manufactures several generations of land- and buoy-based DCP's.

AES is also upgrading the Canadian meteorological data communications network with a system that has, as its back-bone, the broadcasting of all data across Canada via domestic communications satellite.

The Canadian Forestry Service remote sensing expertise includes the production of forest statistics, forest classification, forest fire management information regarding fuel type, and the detection of clear cut, regeneration and various types of damage to the forests. This work is aided by the Applied Resource Image Exploitation System (ARIES) which has been used extensively by remote sensing scientists across Canada. A complementary system, the Geographic Environmental Monitoring System 300, has also been used. These two systems have led to a new breed of compact image analysis hardware now available from the private sector.

The Environmental Protection Service has developed techniques for the use of NOAA and LANDSAT data in detecting oil spills, in particular, oil on ice. An oil spill contingency plan utilizing this technique will soon be implemented.

AES is actively involved in the global problem of monitoring the protective stratospheric ozone layer using stratospheric balloon probes and ground based remote sensing as "ground truthing". Industry is heavily involved in this program through such activities as manufacturing and exporting the new Brewer spectrophotometer, carrying out balloon payload engineering support activities, developing its expertise in such areas as telemetry and data transmission, and building specialized hardware such as Michelson interferometers and rocket radiometers.

External Affairs Canada

The Department of External Affairs is responsible for the formulation and implementation of Canada's foreign policy and for the supervision of all international relationships and activities. With respect to space, this function includes Canada's relations with multilateral organizations such as the United Nations Committee on the Peaceful Uses of Outer Space and the European Space Agency, as well as with various bilateral partners. The Department provides the Chairman of the ICS Sub-Committee on International Aspects of Space Policy. The Department is also responsible for promoting foreign sales of Canadian space technology and products and has a variety of programs and activities to support this function.

Fisheries and Oceans

The Department of Fisheries and Oceans is the federal agency responsible for the conservation, development and general regulation of the nation's coastal and fresh water fisheries. It has a broad range of responsibilities which encompass fisheries resources management, biological and oceanographic research, hydrographic surveying and charting, small craft harbours maintenance, impact studies and international agreement-negotiation relating to fisheries management and marine environmental quality. The Department looks to space-borne remote sensing and communications to assist in carrying out these responsibilities.

In the area of remote sensing, the Department is pursuing studies related to ocean circulation, wave measurement, ocean climate, ocean productivity and coastal fish habitat. While much of this work relates to sensors carried on previous experimental or present-day operational satellites (coastal zone scanners, infrared imagery, microwave scatterometers and synthetic aperture radar), the studies on ocean productivity are leading to the development of a new instrument. Following an international ocean optics experiment to measure and correlate water productivity measurement with satellite and airborne sensors, an imaging instrument is being developed for measuring the concentrations of chlorophyll-A in the oceans. This is a 3-year project to develop an airborne sensor and then to evaluate its capability to measure chlorophyll-A by detecting the chlorophyll-A's fluororescence under natural radiation conditions. If this proves successful, a satellite sensor would be the next step.

In the area of in situ monitoring and telemetry, the Department has been active in the development of ocean data buoys, which rely on data retransmission to existing satellite systems, to provide a cost-effective source of oceanic data in near real time to users. The Department took the Canadian lead in this area for the first Global Atmospheric Research Program in 1979. Since that time, there has been a continuous program to develop sensors to measure various oceanographic parameters from both moored and drifting buoy systems. The latter type, with its considerably lower cost and easier deployment, is particularly important now that data buoy locations can be determined by the satellites.

In the future, the Department will continue its evaluation of the use of remote sensing and communications through participation in such Canadian satellite programs as MSAT and RADARSAT, and internationally through the ESA remote sensing advisory group for the ERS-1 development.

Industry, Trade and Commerce

The Department of Industry, trade and Commerce is responsible for promoting the establishment, sound development and productivity of manufacturing industries in Canada, and also for promoting foreign sales of Canadian space technology and products.

In consonance with these responsibilities, the Department supports the development of a viable Canadian space industry by providing financial assistance to companies in the space industry for the development of new or improved ground-based and spaceborne products, and for the acquisition of capital equipment necessary for their manufacture. The Department seeks to optimize the benefits to Canadian industry from the Government's space requirements, including the realization of substantial Canadian content, the acquisition of new technology, expanded export sales and the provision of challenging employment opportunities.

On January 12, 1982 the Prime Minister announced that the industry, small business and tourism components of this Department would be amalgamated with the regional program of the Department of Regional Economic Expansion to form a new Department of Regional Industrial Expansion. The trade side of the Department of Industry, Trade and Commerce will be transferred to the newly-restructured Department of External Affairs, The Department of Consumer and Corporate Affairs, will take over the Metric Commission and the Standards Council of Canada.

National Defence

The Department of National Defence is responsible for the formulation of defence policy and its implementation by the Canadian Armed Forces. It is also responsible for the management and operation of all Canadian military establishments and facilities. In order to carry out these functions as cost-effectively as possible, the Department takes maximum advantage of space systems. In order to do this, a number of space-related R&D projects are pursued, and studies on the use of satellites for such applications as surveillance, communications, navigation, and search and rescue are carried out.

While program control and policy direction are generated from Headquarters, most of the space-related R&D within the Department is carried out at either the Defence Research Establishment Ottawa (DREO), Defence Research Establisment Valcartier (DREV) or the Defence and Civil Institute of Environmental Medicine (DCIEM) in Toronto. DREO is responsible for projects on satellite-aided search and rescue, communications, navigation, and surveillance. DREV concentrates on electro-optics and signal processing. DCIEM emphasizes studies on the physiological effects of space. In addition to this work within the Department, there is a strong association with the Department of Communications, Communications Research Centre, other federal departments, and defence departments in a number of other countries.

DND sponsors R&D on a range of military satellite communication topics such as coding techniques and EHF technology. Of particular interest are mobile terminals, with emphasis presently on those for shipboard use. It is anticipated that current studies on mobile satellite communications will culminate in the procurement and deployment of an operational system, the space segment of which may be either dedicated or developed and shared with a partner.

As the Canadian Government organization with lead responsibility for search and rescue activities, the Department has striven to improve its ability to locate missing aircraft and vessels, and to rescue distressed personnel from disaster sites. To this end, repeaters are being provided for installation on three of the USA's NOAA weather satellites. Other countries will also be involved in providing space hardware for this program. When the system is operational, it is anticipated that Emergency Locator Transmitter signals will be retransmitted from the space vehicle to ground. Each country involved in the program will operate its own ground stations. A joint demonstration and evaluation phase for this project is likely in 1982.

The Department has entered into a bilateral understanding with the USA for the development in Canada of military receiver equipment for the NAVSTAR/GPS satellite-aided navigation system. This system is expected to permit users to determine their three dimensional position to an accuracy of better than 10 metres. It will be operational by 1988.

A Canadian company is under contract to design and develop receivers for use with NAVSTAR/GPS. Prototype receivers are expected to be delivered in the last quarter of 1983. Following extensive testing and evaluation, international marketing of these receivers is anticipated. This will be assisted by the expected widespread use of the system being fostered by a Memorandum of Understanding signed by ten NATO countries to effect standardization and interoperability.

DCIEM is participating in a joint experiment on vestibular physiology. The experiment is to be carried out on Spacelab I aboard a Space Shuttle launched in 1983. Two complete sets of experimental hardware (flight and backup) have been accepted from a Canadian manufacturer and, after integration with other equipment, have undergone acceptance tests.

The Space Detection and Tracking Identification (SPADATS) program is one of the NORAD programs in which DND participates. A station at St. Margaret's, New Brunswick, equipped with optical and microwave sensors for the detection and analysis of light and radio frequency signals reflected by space objects, is part of the North American monitoring network. From this station, the size, shape, rotation and surface characteristics of an object in space can be determined using the scintillation parameters of any non-astronomial source in the sky. Digital sensor output is fed directly to NORAD headquarters.

As well as being involved in R&D, the Department operates the Aerospace Engineering Tests Establishment at the Canadian Forces Bases, Cold Lake, Alberta. This group operates an environmental rocket launching and recording facility at the nearby Primrose Lake Range. Sounding rockets are launched from this range providing temperature and wind data to heights of 50 km and more. Assistance is also provided to rocket launching groups at other sites.

National Research Council of Canada

The National Research Council of Canada undertakes and sponsors scientific and technological research in a broad range of disciplines including aeronautics, astrophysics, biology, chemistry, mechanical engineering, physics and electrical engineering. It provides a national foundation on which the creation, application and use of knowledge derived from the natural sciences and engineering can be built. It also facilitates the use of scientific technical information by the government and the people of Canada.

The space and space-related responsibilities of the Council can be divided into three main areas: research into the space environment, utilizing rockets, balloons, scientific satellites and other space vehicles; research from the space environment, such as astronomical observations; and the development of equipment and instruments for use in the space environment. In carrying out these responsibilities, the Council is aided and advised by its Associate Committee on Space Research. The Council has consolidated the planning, coordination and support of space science in Canada by establishing a Canada Centre for Space Science. The Council draws on scientific and engineering expertise existing in universities, industry, and its Herzberg Institute of Astrophysics, National Aeronautical Establishment, and Centre for Space Science, to implement scientific and technological programs within its purview.

National Aeronautical Establishment (NAE)

The program to design, develop and construct the remote manipulator system known as CANADARM for use on the USA Space Shuttle was successfully undertaken by NAE. The work was carried out by a Canadian industrial team comprising a prime contractor and sub-contractors.

CANADARM will be used to deploy payloads, satellites and other space devices from the cargo bay of the Space Shuttle Orbiter vehicle and to retrieve recoverable payloads. It is attached to the orbiter and is remotely controlled by a member of the shuttle crew. The arm has seven degrees of freedom and is capable of manipulating a 29,500 kg object occupying a volume of 18.3 m long by 4.6 m in diameter, with extreme accuracy and flexibility.

A general purpose manipulator system simulation facility (SIMFAC) using mathematical modelling techniques is used to verify CANADARM's operability in a zero gravity environment. SIMFAC is also used to train astronauts to operate CANADARM.

This participation in the leading edge of space technology has developed a specialized robotic capability in Canadian industry.

NAE also has an acoustics facility where research and development is carried out related to aerospace acoustics. The laboratory contains two high intensity acoustic noise chambers to examine the integrity of equipment such as satellites and military hardware. The smaller chamber has a volume of 75 m^3 and can generate noise levels up to 165 dB.

This chamber was used for the acoustic development of the CTS (HERMES) spacecraft. The larger chamber has a volume of 540 m^3 and is capable of providing noise levels up to 155 dB. It was designed to accommodate instruments and spacecraft of the type to be carried on the space shuttle. Government departments and industry use the acoustic facility on a contract basis. It works closely with and complements the David Florida Laboratory of the Communications Research Centre of the Department of Communications.

Canada Centre for Space Science (CCSS)

CCSS is responsible for space science coordiation and space research facilities in the Council as well as the development and construction of instruments for international cooperative space science projects. In particular, CCSS is responsible for planning and evaluating future space science activities, funding the major expense items required by the program, providing space engineering expertise to the scientists, and acting as an interface between scientists and Canadian industries who are also major performers in the program. CCSS also operates two national facilities: the Churchill Research Range in northern Manitoba, on the western shores of Hudson Bay and the Mobile Scientific Balloon Launching Facilities based at Gimli Airport, some 90 km north of Winnipeg.

In recent years, the space science program supported by the Council has undergone an evolutionary shift in scientific emphasis. This has resulted in a general reduction in activity at the Churchill Research Range and greater emphasis on rocket and balloon campaigns involving several scientific groups or scientific techniques with a common scientific goal.

In response to this broader scientific objective, CCSS is consolidating its inventory of space science support hardware into one resource centre at Gimli. Rocket and balloon campaigns in various parts of Canada, including the High Arctic, are now staged from Gimli and certain types of balloon flights are conducted from there. During the past five years, 33 scientifically instrumented rockets and 20 large scientific balloons were launched carrying experiments for Canadian scientists. An additional 25 rockets and 15 balloons were launched to meet the needs of foreign scientists.

CCSS is developing a number of facility type instruments as part of an international cooperative program in space science. The instrument work now in progress will result in an energetic ion mass spectrometer, a waves in plasma/high frequency facility, and a wide angle Michelson doppler imaging interferometer for USA Shuttle/Spacelab flights during the mid 1980s. Also, in the mid 1980's, an optical monitor for auroral plasma precipitation will fly on Sweden's scientific satellite, Viking, to obtain u.v. images of the entire auroral oval in support of studies of the earth's magnetosphere.

CCSS is also developing ground-based facilities which will include a network of small observatories as well as a computer-based data processing system. The ground-based observation network will provide simultaneous data complementary to that derived from space-borne instruments.

Herzberg Institute of Astrophysics

The Space Physics section of this Institute engages in basic research of physical processes which occur in the auroral ionosphere, the magnetosphere and the interplanetary medium. Auroral ion source regions and the processes of ion energisation, transport and loss are under study. Investigations on the relationship between auroral arcs, field aligned currents, local electric fields and energetic particle precipitation are being carried out to explore the role of current driven instabilities in the auroral electron acceleration mechanism. Auroral perturbation experiments are being conducted by releasing water vapour in the ionosphere in order to temporarily modify the ionosphere-magnetosphere coupling mechanism by reducing local electron density above an auroral arc. Programmable electron guns will be used to investigate the interaction of the artificial electron beam with the ionosphere's plasma.

Studies of the magnetosphere are done using data from the USA Dynamics explorer satellite and MAGSAT. The emphasis is on high latitude phenomena in order to determine the factors controlling both the global and small scale distributions of the ionospheric and field aligned currents. An ultrasensitive energetic ion mass spectrometer will be flown in Spacelab. An experiment will also be flown on the International Solar Polar Explorer Mission to measure the isotopic and chemical composition, spectrum, and anisotropy of galactic and solar cosmic rays. The measurements will be made during a unique three year interplanetary flight around Jupiter and over both poles of the sun. The launch is planned for 1986. Modulation of the galactic cosmic ray source by the interplanetery medium is now being studied, using data from the near horizontal muon detector array at the Ottawa laboratory. In addition, cosmic ray monitoring is performed at stations in Deep River, Inuvik, and Goose Bay, as well as Ottawa.

In the Planetary Sciences Section, basic physics research is done in the areas of auroras and meteors. Auroral studies are directed towards the understanding of auroral optical emissions in the infrared, visible and ultraviolet regions of the spectrum, and to unravel the morphology of auroral sub-storms, magnetospheric processes and geomagnetic pulsations. Auroral plasma and the polar ionosphere are investigated for their relationships to optical emissions, magnetic perturbations, productions by energetic articles, and for the plasma instabilities and wave processes which arise. Rocket-borne and ground-based photometers, spectrometers, TV imagers, plasma probes and VHF radars are used in performing studies.

Meteor research is concerned with the physical processes of the meteor-atmosphere interaction, the meteor flux rates, the chemical and physical constitution of meteors, and the cosmic origin of meteors from comets and asteroids. In addition to making observations using spectrographic and TV imaging techniques, meteor rates are recorded visually and by radar. A major direction of current effort is directed towards the cometary origin of motions to establish their associations with known comets and to determine chemical compositions and abundances.

Science and Technology Canada

The Ministry of State for Science and Technology (MOSST) is responsible for formulating policies for the development and use of science and technology in support of national goals and for the coordination of science and technology programs with other policies and programs of the Government of Canada. This Ministry is also responsible for fostering the use of scientific and technological knowledge in the formulation and development of public policy.

The Prime Minister has assigned MOSST the leadership role in the government with respect to space policy and development. The Ministry is charged with the responsibility for space research and development policy and for the coordination of space activities among government departments and agencies.

MOSST's coordination function is carried out through the Interdepartmental Committee on Space (ICS) which is responsible to the Minister of State for Science and Technology. The Ministry provides both the Chairman and the permanent secretariat of the ICS, and also administers the Cooperative Agreement signed between Canada and the European Space Agency.

The Canadian policy for space approved by Cabinet states that Canada's interest in space is to use it for applications that contribute directly to the achievement of national goals and, in so doing, to establish a viable research, development and manufacturing capability in Canadian industry. The policy also states that Canada's ability to use space should be furthered by participating in international activities for the use of space. To facilitate implementation of the policy, MOSST, in concert with the civilian operational departments and agencies, develops and maintains an up-to-date medium-term space plan for consideration by Cabinet. All new space program initiatives receive approval and are allocated resources as a result of Cabinet decisions on these space plan submissions.

Transport Canada

The Department of Transport is responsible for the formulation and implementation of federal policy for all forms of land, sea and air transportation. As the safety and efficiency of air and marine operations are critical parts of this policy, any aspect of space services which could have an effect on these is of interest to the Department.

On February 1, 1982 the International Maritime Satellite Organization commissioned a fully operational satellite communication system for marine users. The Department has actively participated in this organization in order to ensure that Canadian maritime users have the opportunity to utilize the improved safety and public communications expected from this system.

Other systems which are being actively pursued include the international AEROSAT program which will evaluate the uses of satellites for air traffic control; the NAVSTAR/GPS which, although being developed by the USA military for satellite-aided navigation, is also being considered for civilian use where particular value can be gained in northern latitudes; SARSAT (Search and Rescue Satellite) which is intended to provide improved alerting and location for both air and marine accidents; the MSAT project being developed in Canada for mobile satellite-aided communications; and the RADARSAT project being proposed to facilitate safe passage of shipping in Canadian ice-infested waters.

Operating Entities

This section provides information on Teleglobe Canada and Telesat Canada.

Teleglobe Canada

By Act of Parliament, the "Canadian Overseas Telecommunication Corporation" was established in 1950. In 1975, its name was changed to "Teleglobe Canada".

Teleglobe Canada provides the Canadian public with international telecommunication services. To this end, the Corporation negotiates the necessary agreements with foreign administrations and domestic carriers in order to connect Canadian users with their foreign couterparts through the jointly operated international network.

The Canadian network and Teleglobe Canada facilities are linked to the facilities of their overseas counterparts by means of submarine cables and satellites.

In 1964, the International Telecommunications Satellite Organization (INTELSAT) was established to own and operate a global commercial satellite system. Teleglobe Canada, on behalf of Canada, was one of eleven original Signatories to the INTELSAT Operating Agreement.

In 1979, the Canadian government signed the International Convention establishing the International Maritime Satellite Organization (INMARSAT). The same year, Teleglobe Canada signed the INMARSAT operating agreement, and will be responsible for providing Canada's maritime satellite communication services.

Teleglobe Canada owns and operates four satellite earth stations: two at Mill Village in Nova Scotia, one on Vancouver Island at Lake Cowichan in British Columbia, and one at Weir in the Laurentians north of Montreal.

The Mill Village No. 1 earth station provides telephone service to the following countries: Barbados, Brazil, France, Germany, Haiti, Jamaica, Trinidad, and the United Kingdom. The station is capable of transmitting 3 FM multi-destination carriers in the 5.925 to 6.425 GHz band and receiving 15 telephony carriers within the 3.7 to 4.2 GHz band. The station was upgraded to an INTELSAT standard A station in 1973/74 and, since then, is capable of providing 11 services normally offered by INTELSAT, including video and ground signals for television.

The Mill Village No. 2 earth station became operational in February 1969. It provides telephone service to Scandinavia, Israel, Germany, Switzerland, Italy, Mainland Spain, United Kingdom, Belgium, Greece, the Netherlands, Yugoslavia, Venezuela, Portugal, Argentina, Chile, French West Indies, Peru, South Africa, Lebanon, and U.S.S.R., and television links with over 50 countries.

The Lake Cowichan earth station on Vancouver Island became operational on September 26, 1972. The station operates to Australia, Hong Kong, Japan, Philippines, New Zealand, Singapore, China, Hawaii, Fiji, Korea, Malaysia, and China (Taipei).

The station is capable of transmitting 3 FM multi-destination carriers in the 5.925 to 6.425 GHz band and receiving 15 telephony carriers within the 3.7 to 4.2 GHz band. The station also has the capacity for the transmission and reception of one television and associated sound channel.

The Laurentides earth station, at Weir, Quebec, was officially inaugurated on September 7, 1979. The station operates with countries in Europe, Africa, and the Caribbean. The station is capable of transmitting 3 FM multi-destination carriers in the 5.925 to 6.425 GHz band and receiving 14 telephony carriers within the 3.7 to 4.2 GHz band. The station has the capability for the transmission and reception of one television and associated sound channel and of SCPC voice and data signals.

Teleglobe Canada participates constantly and actively in the meetings and forums of the international bodies which provide telecommunications facilities, such as the Commonwealth Telecommunications Organization, INTELSAT and INMARSAT. Likewise, the Corporation participates in national and international regulatory or advisory bodies, such as the International Telecommunications Union, the Inter-American Telecommunications Committee, and the Canadian Telecommunications Carriers Association, which are responsible for resolving issues of common interest to telecommunications carriers.

Telesat Canada

Telesat Canada was 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. 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 ANIK-A satellites, with twelve 36 MHz channels (10 plus 2 spare), was launched. Canada then became the first country in the world to have a nationwide domestic telecommunications system using geostationary synchronous satellites. Two more ANIK-A satellites have since been successfully launched and are in operation, and a fourth satellite, ANIK-B, was launched in December 1978. Commercial operations began in January 1973 with one satellite and four earth stations; today, services are provided in the 6/4 GHz band by four satellites, and more than 125 earth stations covering the length and breadth of the country (from 42° to 80°N and 52° to 141°W). Two of the aging ANIK-A satellites have recently been collocated in space so that their useable transponders appear to be on one satellite. This operation was a world first.

A wide variety of earth stations is in service from large permanent, multipurpose, earth stations to transportable message terminals. These latter can be airlifted in small aircraft to the most remote locations and be in service within a few hours of their arrival. The basic traffic now carried includes FM television programming with one or two radio programs in one satellite channel. Message traffic is carried by FM/FDMA, PCM/TDMA and digital SCPC techniques. Recently, several new services have been added:

- A mobile television uplink is available and has been used across Canada (23 locations in one month).
- A daily newspaper is transmitted from one city centre direct to printing plants in four other cities.
- Data have been carried from remote sensing platforms to a central computer.
- Special TV programs have been transmitted to television receive only terminals at cable operators' head ends in cities across Canada.

For future business needs, Light Route TDMA earth stations are being developed for trials in 1982. These will offer a variety of services and be computer controlled.

To replace the ANIK-A satellites, two ANIK-D spacecraft are being built, one for launch in 1982. These have frequency reuse (linear orthogonal polarization) and 24 channels — 12 primary, 8 standby and 4 backup — with full coverage of Canada.

The 6/4 GHz frequency band is also used by terrestrial microwave relay systems and interference often makes it necessary to locate earth stations some distance from urban centres. The 14/12 GHz frequency band has fewer such restrictions on its use. For this reason, the ANIK-B satellite carries, in addition to its 6/4 GHz channels, four 14/12 GHz channels intended for experimental use. Following successful trials at this frequency, the ANIK-C series satellites, which will have 16 channels (14 plus 2 spare), 54 MHz wide, at 14/12 GHz with frequency reuse, were ordered. The antenna on these spacecraft provide four spot beams covering Canada south of 60°N. will be launched in 1982 on the first commercial flight of the USA Space Transportation System.

To operate with these satellites, earth stations have been built on customers' premises, mostly on buildings, in downtown areas. Two of these stations are already transmitting television programs through ANIK-B. The stations will also carry digital message streams between major cities. A mobile 14/12 GHz television uplink is planned for service in 1982. Studies have been made of using an ANIK-C satellite for direct broadcasting to homes and community antennas.

All the ANIK satellites are controlled closely, in attitude and position, by a satellite control system using mini computers and Telesat's own software sytem.

Since the successful inauguration of its system in 1973, Telesat has been approached by governments and private organizations around the world for assistance in the development of plans and specifications for satellite communication systems.

Canadian Universities

This section provides information on some of the activities of Canadian universities in the space field.

The University of Alberta

Edmonton, Alberta T6G 2E5

The Institute of Earth and Planetary Physics is directing its efforts towards the analysis of ground based magnetometer array data (supplemented by selected spacecraft data) with an aim toward understanding how energy from the solar wind penetrates into the interior of the earth's magnetosphere and how that energy is eventually dissipated in the earth's upper atmosphere.

The other major activity undertaken by university scientists is the study of ULF magnetic pulsations, particularly those associated with the onset of magnetospheric substorms. The study of such short-lived impulsive bursts has necessitated the development of relatively sophisticated analysis methods in order to deal with the unpredictable mixture of random noise and polarized signals detected by arrays of multichannel detectors.

An interdepartmental program is also currently involved in classroom applications of LANDSAT imagery. It is called project Omega and is the first such project in any faculty of education to deal with the implications of remote sensing.

The University of British Columbia

Vancouver, British Columbia V6T 1W5

University researchers are monitoring optical emission from a layer of atomic lithium which surrounds the Earth at a height of approximately 92 km by means of a photometer telescope directed towards the zenith sky which measures the changes in the airglow intensity at a wavelength of 6708Å during the twilight period as the sun rises or sets. Such observations enable one to follow the daily variations of intensity and to determine the height of the layer.

The Physics Department has completed a 1.5 m Ebert-Fastie type scanning spectrometer which is used primarily for the calibration of low-brightness spectral-line optical sources by comparing the intensity with that of a continuum source, the brightness of which has been determined, as a function of wavelength, against a primary standard source. It also constructed a secondary continuum source during the summer of 1981.

In addition, the University of British Columbia has been cooperating with the B.C. Hydro and Power Authority to find how magnetic field variations affect power transmission systems. It seems that every adverse effect of these is ultimately caused by a geomagnetically induced current, especially in high latitude countries such as Canada where more severe magnetic storms are known to occur compared with areas of other latitudes.

The University of Calgary

Calgary, Alberta T2N 1N4

Scientists and researchers from various departments of the university are involved in theoretical and practical studies covering a wide spectrum of space phenomena.

Research efforts being conducted by the Departments of Astronomy and Astrophysics include the study of:

- auroral x-rays with particular attention to pulsations by means of balloons;
- supernovae remnants using HEAO 1 data;
- an eclipsing solar-type binary system Al Phe using the International Ultra-Violet Explorer Satellite; and
- the structure and chemical evolution of normal galaxies.

Research work is also being performed on the following two planned scientific space missions:

- a Wide Angle Michelson Doppler Imaging Interferometer (WAMDII) instrument for the Space Shuttle, and
- an Ultra-Violet Auroral Imager for the Swedish Viking Satellite.

University scientists have also been conducting theoretical studies of:

- the formation of potential double layers in partially ionised plasmas which have shown that instabilities observed in laboratory positive columns as well as in space plasmas associated with electrostatic double shocks are related to the prediction of an electrostatic instability when the electron drift speed exceeds 5/6 of the electron thermal velocity;
- Wolf Rayet stars that have shown that many of their characteristics can be understood as evolutionary consequences of rapidly rotating massive young stars losing mass due to stellar winds.

Finally, remote sensing is used by the researchers to gather data on wind and turbulence profiles (especially during the Chinooks).

Laval University

Québec, Québec G1K 7P4

Laval University offers undergraduate and post-graduate studies in remote sensing, in image acquisition techniques, in analog and digital processing of images, and in applications of land-based remote sensing to urban centers, to agriculture and to forestry.

Research and development work deals with:

- resource mapping by analog and digital analysis of LANDSAT and Seasat imagery;
- SPOT and LANDSAT imagery simulation; and
- studies of atmospheric transparency.

McGill University

Montreal, Quebec H3A 2T5

McGill University, in conjunction with the Defence and Civil Institute of Environmental Medicine (Toronto) and the Massachusetts Institute of Technology has undertaken a project that will become the first Canadian life science experiment to be conducted in space. It will consist of conducting a series of tests of the balance organ (vestibular) function on the crews of Spacelab missions SL-1, D-1 and SL-4. These experiments, which will assess adaptation of the inner ear to weightlessness and re-adaptation to the 1g environment, are directed at the basic issue of plasticity within the nervous sytem, and the practical problem of understanding space motion sickness. Equipment required for the Canadian component of the project has been designed and built by Canadian industry. It has now completed testing and has been delivered to the USA. Training of the SL-1 crew, who will conduct the in-orbit portion of the study, is at an advanced stage. Detailed experiment protocols have been developed which will provide for maximum data return in the time allocated.

Graduate programs are carried out in remote sensing and its environmental applications. Of particular interest is the study carried out in using high-resolution synthetic-aperture airborne radar to analyse the drainage networks in the forested, south-eastern margin of the Canadian shield. In this study, it was shown that this imagery could provide some of the details required in hydrological analyses of drainage basins in forested shield environments.

The University has also studied the effects of rain on radio propagation between a satellite and its ground reception facility.

Weather satellite data is used for hydrometeorological studies. A serious problem in climatological investigations and weather forecasting is the estimation of rainfall over regions where conventional surface observations are not available. An empirical method has been developed, based on the remotely sensed visible and infrared properties of clouds, which effectively discriminates between clouds that are raining and those that are not, and gives an indication of the rain intensity.

McMaster University

Hamilton, Ontario L8S 4L8

The Department of Chemistry, through its Lunar and Planetary Science Program, is conducting research on lunar soils and anomalies in meteorites. It uses two high precision mass spectrometers, designed and built at McMaster, for sulphur isotope analysis.

Since the beginning of the lunar sample program, sulphur isotope studies of the lunar surface and of meteorites have occurred. The lunar samples, and particularly the lunar soils, show alterations of sulphur content and of sulphur isotopic abundance relative to lunar rocks. In meteorites, sulphur isotope anomalies are proving to be unique indicators of the degree of heterogeneity of primordial solar nebula and of the contributions to its make-up of material from different nucleosynthetic sources.

The University of Manitoba

Winnipeg, Manitoba R3T 2N2

The University is active in balloon-borne measurements of powerline harmonic radiation from the Manitoba Hydro HVDC electric powerline. These measurements are being made at an altitude of 32-37 km. The purpose of the study is to test/calibrate a numerically generated radiation model for a powerline by making quantitative measurements across the controlled HVDC line, adjusted so as to radiate strongly the 6th and 12th harmonics of impressed 60 Hz currents. In close collaboration with international research teams and with the cooperation of Manitoba Hydro, launches of a series of two balloons from the SRF Gimli were made, during the summers of 1979, 1980, 1981.

Several research programs related to Canadian satellite communications are also being undertaken. Examples are:

- studies on the design of a multiple beam antenna system for the Land Mobile Satellite;
- research on techniques to improve side lobe characteristics of small earth terminal reflector antennas; and
- research to design high performance feeds for reflector antennas.

Memorial University of Newfoundland

St. John's, Newfoundland A1C 5S7

The Department of Engineering provides courses in remote sensing to undergraduate and graduate students. It also conducts research on the effect of flooding in various reservoirs of hydro-electric plants in Newfoundland and Labrador and in the mapping of sea surface temperature and sea ice distribution by means of pictorial and digital satellite data.

The Department of Mathematics and Statistics is carrying out theoretical investigations on the solar wind medium, fluid dynamical analysis of plasma near the Jovian satellite Io, and acceleration of particles by shock waves in space and on blast waves in interplanetary space produced by a solar flare.

Finally, since 1976, the university, through its Medicine and its Educational Television Centre has been involved with the HERMES satellite program and subsequently with ANIK-B. The HERMES project consisted of five terminals to provide one-way video and two-way audio programming to several hospitals. ANIK-B facilities were used by the telemedicine group for a wide variety of interactive audio applications.

University of New Brunswick

Fredericton, New Brunswick
E3B 5A3

The Departments of Surveying and Forestry offer courses dealing with applications of remote sensing and other space techniques to their respective fields.

The Department of Surveying carries out research and development in fields such as SAR imagery, the use of NAVSTAR/GPS for hydrographic surveys, the configuration of remote sensing systems, etc.

University of Ottawa

Ottawa, Ontario K1N 6N5

Scientists at the University of Ottawa are active in R&D connected with the latest satellite communications techniques, in particular, new cost-effective digital transmission systems exhibiting high spectral efficiency, and nonlinear amplification techniques yielding improved power efficiency. In this mission-oriented research, the requirements of the Canadian manufacturing and operating companies are emphasized. The work is leading to the design of new hardware prototype models and new system configurations to increase the efficiency of communications facilities.

The individual projects being carried out are all closely related. One is the development of small satellite earth station subsystems for cost-efficient new Single-Channel-per-Carrier satellite systems. Another is a major research program, which will contribute to the production of Canadian built Time Division Multiple Access (TDMA) satellite earth stations compatible with INTELSAT and domestic requirements. A third is the investigation of novel on-board regenerative satellites for more efficient systems. In addition, new power and bandwidth efficient modulation techniques are being introduced, prototypes designed and their performance analyzed in the complex interference environment of terrestrial microwave and satellite systems. The evaluation of all these new subsystems is performed on a 14/12 GHz satellite earth station (4.5 metre antenna), over the ANIK-B satellite and a 2 GHz digital microwave link. The complete earth station and the microwave link, the property of the research team, serve as a test bed.

University of Saskatchewan

Saskatoon, Saskatchewan
S7N 0W0

The Institute of Space and Atmospheric Studies has been involved with most Canadian aeronomers in a major campaign to study pulsating aurora, the findings of which were reported in August 1981 in the Canadian Journal of Physics. Results showed definitively that pulsating aurora were caused by very low energy electrons with the periodic pulsations being produced by an energy increase of the incoming electrons. A second major auroral campaign, to study the dynamics and energetics of dayside aurora, took place between November 18 and December 21, 1981.

Another field project in Western Canada and northern USA was undertaken in August 1981 to study the aspect sensitivity of auroral radar echoes. This involved recording the back-scattered signal from an array of 50 MHz transmitters at various receiver locations.

Ozone measurements in the mesosphere, as part of the International Ozone Rocket Intercomparison experiment, were completed and reported showing a diurnal variation in the ozone profile. Composition measurements are being extended with a planned OASIS rocket flight from the USA. A study has continued of UV solar flux and ozone concentrations in the stratosphere with a 440k m^3 balloon flight from Palestine, Texas, USA, on September 23, 1981.

Studies of electric and magnetic fields in the high latitude ionosphere were continued with a successful flight of a newly designed probe in a FALCONS rocket payload from Ft. Churchill in March, 1981.

Institute members are active participants in on-going Canadian space science programs which include CANOPUS, an auroral network in support of the USA OPEN program, an auroral UV camera experiment for the Swedish 1984 VIKING satellite, and a winds and temperature measuring interferometer for a scheduled space shuttle flight.

University of Sherbrooke

Sherbrooke, Québec J1K 2R1

The University of Sherbrooke has a Remote Sensing Lab used for teaching, research and consultation. Emphasis is given to research and development; operational applications are usually transferred to private companies capable of carrying them out.

The laboratory boasts equipment which allows acquisition, processing and interpretation of remote sensing data. It has a mobile earth station which allows measurement of radiation and thermal flow in the four spectrum bands of the LANDSAT satellite. It is connected with the University's Computer Center, for digital analysis of remote sensing imagery and for analysis of more complex images. Access to other centers in the University and to the Lennoxville Experimental Farm allows it to set up field experiments.

Current research deals with:

- thermal infrared, and its application to water, soil, vegetation, microclimate and energy conservation;
- the visible and near infrared, for simulation of future remote sensing satellites and for analysis of the potential and limitations of new sensors for agriculture; and
- radar images, within the RADARSAT project for non-renewable resources.

University of Toronto

Toronto, Ontario M5S 1A1

The Institute of Aerospace Studies of the University of Toronto is conducting atmospheric composition measurements above altitudes of approximately 90 km. The Institute uses the EBFP (electron beam fluorescence probe) method, in which spectrometry is used to analyse radiation from molecules excited by high energy electrons.

Analytical work in the area of Space Dynamics and Control covers the dynamics and control of large space structures, the modelling of satellite orbit decay processes for the improved prediction of lifetimes in orbit, the determination of orbit parameters and attitude by modern filtering methods, and the dynamics and control of general categories of remote manipulators.

To determine Space Environmental effects on Polymer Matrix Composite Materials, an Experiment will be flown in 1983 aboard the USA's Long Duration Exposure Facility (LDEF). Extensive ground-based space simulation tests have been underway to provide a comparative data base for the same materials included in the experiment; graphite/epoxy, Boron/epoxy, Kevlar/epoxy and glass/epoxy.

Spacecraft in synchronous orbit sometimes behave very strangely. This strange behaviour includes instruments registering non-existent events, receivers being commanded to change gain for no reason, and antennas inexplicably ceasing to be "de-spun" so that instead of pointing

at the earth they rotate rapidly, completely disrupting communications. Data analysis revealed a correlation between magnetic substorms and spacecraft peculiarities which were being referred to as "operational anomalies". Furthermore, instruments revealed that charged particles being detected on scientific satellites had been effected by an apparent negative charge accumulation and that during "eclipse" (with the satellite in the earth's shadow) the spacecraft could charge up to between 10,000 and 20,000 volts negative with respect to the ambient plasma.

University of Victoria

Victoria, British Columbia M5S 1K7

Research efforts in space physics at the University of Victoria have included a study of plasma-wave phenomena in the ionosphere and magnetosphere. These studies have used data from a number of satellites including the Canadian ISIS satellites as well as data from ground-based instruments, particularly induction magnetometers. Another study relates to the determination of the effects of geomagnetic field variations on geomagnetically induced currents in electric power systems. In recent years, collaboration also took place with many foreign universities.

The University of Western Ontario

London, Ontario N6A 3K7

The main thrust of the research effort at the University of Western Ontario lies in investigating the effects of the ionosphere on radio signals propagating through it. The purpose of these investigations is twofold: firstly, to achieve a better and more complete understanding of the physical processes occurring in the ionosphere and high atmosphere; and secondly, to determine the extent to which satellite communication system efficiency can be degraded by the environment. To these ends, both satellite and rocket borne transmitters are utilised, with ground based receiving stations at various locations to measure and record numerous parameters of the incoming signal.

A completely automated receiving station and data handling system which can handle either satellite or rocket transmissions has been built. It is known as a 'differential phase-locked system'. It yields the number of electrons present at various locations and various times in the ionosphere together with a measure of the smoothness of the electron distribution. An important additional piece of information required for a complete description of the physical phenomena is the presence and strength of ionospheric electric fields. Again, a completely automated system has been built to derive electric fields from the motion of the 'shadow' of ionospheric electron density fluctuations on the ground. This system, known as the 'long-line system', utilises signals from either geostationary satellites or radio stars and has been operated at London, Ontario for some months. It is proposed to deploy the long-line system simultaneously with the differential-phase system for most of the high latitude expeditions.

University of Windsor

Windsor, Ontario N9B 3P4

The Department of Geography is making use of space-derived imagery and digital data in its teaching and research activities. A remote sensing analysis and computer mapping capability is being developed which uses LANDSAT data for land use and land cover mapping. Use has also been made of the image analysis facilities of the Canada Centre for Remote Sensing in a study of environmental change in the Canadian Arctic.

A wide range of topics involving electron impact with atoms and molecules of interest to space and astrophysics are also being studied. Particular attention is being paid to problems relevant to the study of planetary atmospheres. For example, dissociative excitation of SO_2 by medium energy electrons is being investigated, the motivation being a better understanding of Jupiter's plasma torus and the Voyager observations of this.

York University

Downsview, Ontario M3J 1P3

The Centre for Research in Experimental Space Science of York University is an interdisciplinary research centre in which faculty members from the departments of Chemistry, Computer Science and Physics, and their post-doctoral fellows, project scientists and research students, perform collaborative research on many topics of contemporary earth and space science.

Spacecraft (Spacelab-Shuttle), satellite (ISIS), rocket, balloon and aircraft based observational programs are supplemented by ground based observations and supporting laboratory and theoretical research on numerous problems in aeronomy and atmospheric chemistry and physics, astronomy and astrophysics, chemical physics, magnetospheric physics, and remote sensing of the terrestrial surface (including oceans and lakes), and the atmosphere. Typical research projects include balloon-based observations on stratospheric chemistry, lidar sounding of the lower atmosphere, rocket spectroscopy of the solar corona, and remote sensing of ocean and lake surfaces.

University scientists are involved in the following projects:

- the Wide Angle Michelson Doppler Image Interferometer experiment to be flown on Spacelab 6 in 1986 to acquire images of upper atmospheric winds from emission features in the aurora and airglow;
- A Wide Angle Michelson Interferometer using a photomultiplier detector without imaging will be used to measure neutral winds;

- the ultraviolet imager to be flown on the Swedish satellite VIKING;
- an interference filter photometer with a CCD array and electronics that sort the pixels into 32 wavelength channels will be flown as part of an atomic oxygen payload in the OASIS program;
- a Magnetospheric Cleft Detector, which will allow detection of the dayside aurora under twilight conditions.

ISIS II operations and data analysis are continuing, and studies are in progress on mid-latitude red arcs, on the seasonal variation of 6300Å emission at mid-latitudes and on 6300Å tropical arcs.

The above projects are also supplemented by strong experimental laboratory programs on spectroscopy of astrophysical and atmospheric molecules and on the chemical kinetics of atmospheric and astrophysical molecules and molecular ions.

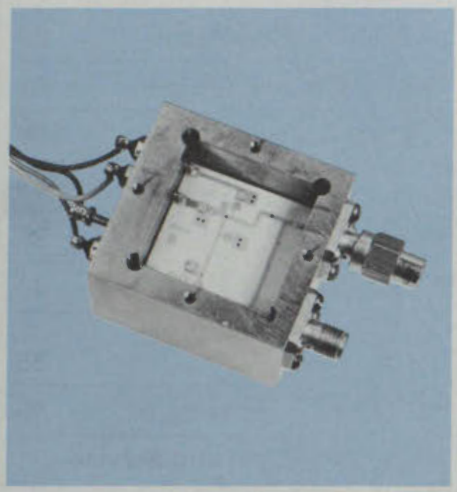
Canadian Space Industry

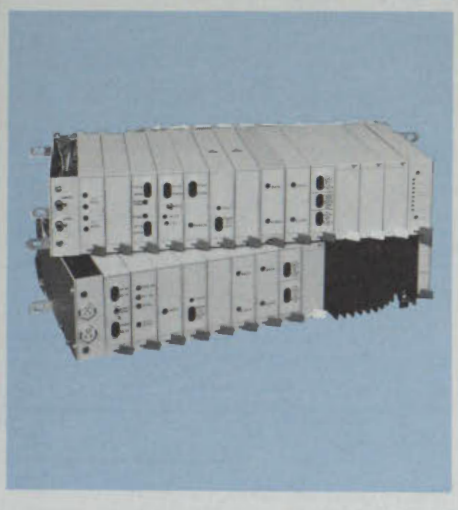
This section provides brief information on Canadian firms which are fully or partly involved in the space industry, including established consultants in the field. Each firm would be pleased to provide more detailed information upon request.

The material contained in this section was assembled under contract from the Department of Communications by Evert Communications Limited and supplemented by the Interdepartmental Committee on Space Secretariat.

AEL Microtel Limited

195-4664 Lougheed Highway
Burnaby, British Columbia
V5C 5T5





Satellite Communications Systems
AEL Microtel Limited is a leading designer and manufacturer of a complete range of telecommunications systems. Its subsidiary, Microtel Pacific Research Limited, is the largest industrial research and development organization in Western Canada.

Main Space Systems, Proprietary Products and Services:

- Complete 14/12 GHz thin route SCPC systems
- VF multiplex equipment for FM/FDM/FDMA earth stations
- Satellite earth station remote monitor and control systems
- Satellite communication system design studies

Other Company Products and Services:

- Research and development
- Microwave radio
- Supervisory and control systems
- Digital and analog multiplex equipment
- Digital PABX systems
- Subscriber equipment
- Telidon terminals
- Video switcher and PC card testers
- Telecommunications consulting
- Systems design and engineering
- Field project management
- Equipment and systems installation
- Specialized training
- Customized manufacturing
- Product representation

Personnel: 3,300

Annual sales: $189 million in 1980

Contact:
Mr. B.W. Granholm
Telephone: (604) 294-0414
TWX: 610-953-4921

Thin Film 1300-1800 MHz Broadband Oscillator for use with earth station receivers

SCPC System Central Control Station Network Interface Equipment (Top)
Remote Terminal Subscriber Interface Equipment (Bottom)

Andrew Antenna Company Ltd.

606 Beech Street
Whitby, Ontario
L1N 5S2

Earth Station Antennas, Transmission Lines and Related Equipment

Andrew Antenna Co. Ltd. was granted a Dominion Charter by the Government of Canada in 1953. Its design and manufacturing efforts have been centred on earth station antennas, transmission lines and related equipment.

Main Space Systems, Proprietary Products and Services:

- 4 and 6 GHz earth station antennas
- 12 and 14 GHz earth station antennas
- Mobile earth station antennas
- TV receive only earth station antennas
- Monopulse tracking feed system
- Portable earth station for MUSAT (Multiple Usage Satellite)

Other Company Products and Services:

- Interfacility links — waveguide and cables
- Earth station accessories — pressurization, de-icing
- Field installation and acceptance testing
- Solar energy collector
- VOR antennas
- Radar antennas
- Field installation and testing
- Coaxial cables, elliptical waveguides and radiating cables
- Microwave terrestrial antennas

Personnel: 175

Annual sales: $12 million in 1980

Contact:
Mr. Alex R. Mackenzie
Sales & Marketing Manager
Telephone: (416) 668-3348
Telex: 069-81269
TWX: 610-384-2754

Andrew Antenna 2.4 m 4 GHz TV receive only earth station antenna at head office in Whitby, Ontario.

Andrew Antenna 8 m 14/12 GHz earth station antenna.

Barringer Research Limited

304 Carlingview Drive
Rexdale, Ontario
M9W 5G2

Electro-optical and Electromagnetic Remote Sensing Equipment
System concepts and prototype development; geophysical and geochemical exploration.

Main Space Systems, Proprietary Products and Services:
- Gas filter correlation spectrometer (GASPEC — space hardened)

Other Company Products and Services:
- Correlation interferometer
- Correlation spectrometer (COSPEC)
- Geomagnetics
- Atmospheric propagation; visible, IR, UV
- Airborne electromagnetics
- Geochemical and analytical chemistry services
- Pollution monitoring
- Magnetometry
- Heavy water concentration monitor for CANDU nuclear reactors

Personnel: 90

Annual sales: $4 million in 1980

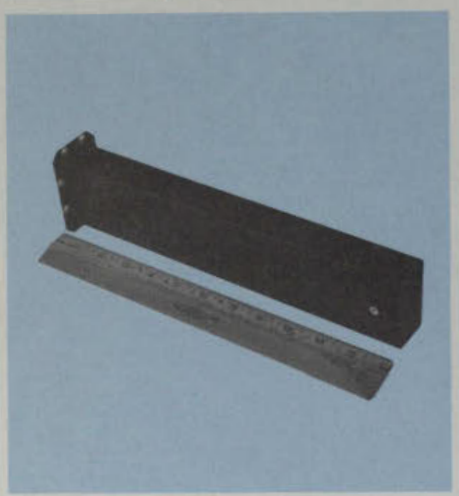
Contact:
Dr. Cameron Cumming
Telephone: (416) 675-3870
Telex: 06-989183

Barringer hand-held Ratioing Radiometer to conduct ground truthing and improve interpretation of LANDSAT or SPOT imagery.

Barringer ultra high vacuum pumping station and calibration cell ground support equipment for HALOE Project.

Boeing of Canada Ltd., Winnipeg Division

99 Murray Park Road
Winnipeg, Manitoba
R3J 3M6



Fibre Re-inforced Composites
The firm was founded in 1969 and has supplied structural and waveguide composites to Canadian and American space programs.

Main Space Systems, Proprietary Products and Services:

- Graphite epoxy
- Waveguide
- Structural composites for satellite systems
- Structural design and analysis

Personnel: 575

Annual sales: $25 million in 1980

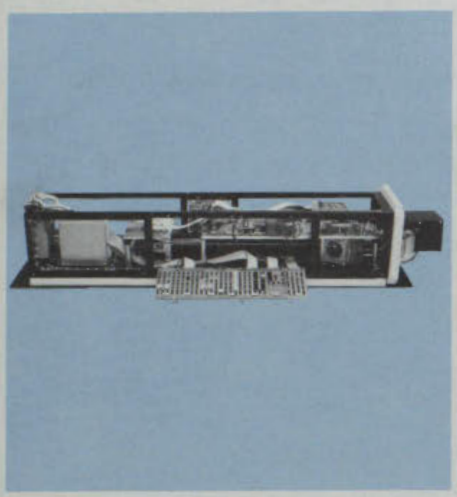
Contact:
Mr. E.M. Sloane
Director
Marketing and Contracts
Telephone: (204) 888-2300
Telex: 07-57309

Lightweight Boeing graphite epoxy and kevlar tower support structure for use on a communications satellite.

Completed Boeing graphite epoxy Chebyshev filter assembly for Anik B and TDRSS communications satellites.

Bomem Inc.

910 Place Dufour
Vanier, Quebec
G1M 3B1



Michelson Interferometers and Related Equipment

Bomem Inc. was founded in 1974 in order to develop special purpose interferometric spectrophotometers, associated data handling equipment and related electro-optical systems. Its main products are a series of high performance Michelson-type interferometer systems for laboratory and remote sensing applications.

Main Space Systems, Proprietary Products and Services

- High-resolution interferometric spectrophotometer systems
- Full data handling facilities
- Visible to far-infrared wavelength coverage
- Aircraft-borne remote sensing systems
- Balloon-borne stratospheric minor constituent measurement sytems
- Satellite-borne remote sensing systems
- Shuttle-borne system to measure atmospheric temperatures and winds

Personel: 30

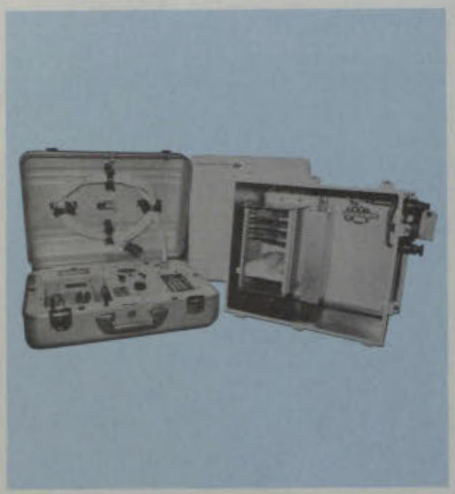
Annual sales: $1.9 million in 1981

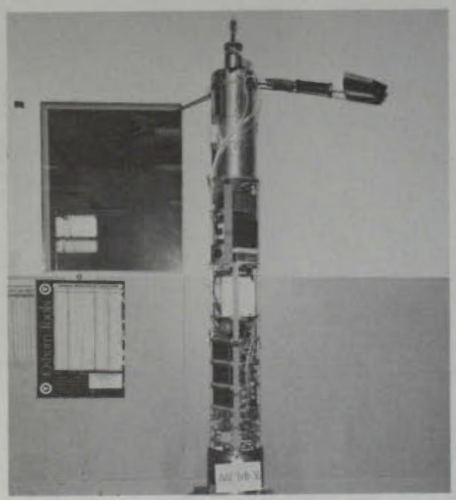
Contact:
Mr. G. Vail
General Manager
Telephone: (418) 683-1707
Telex: 051-3438

Michelson Interferometer System

Bristol Aerospace Limited

P.O. Box 874
Winnipeg, Manitoba
R3C 2S4





Rocket Paylods, Telemetry, Data Collection Platform System
Bristol Aerospace, incorporated in 1930, has been involved in the development, manufacture and flying of instrumented payloads for 17 years. From this experience grew the capability to provide both satellite and ground-based data systems with outstanding reliability under severe environmental conditions.

Main Space Systems, Proprietary Products and Services:
- Instrumented payloads
- Data collection platforms
- Geostationary operational environmental satellite transmitters
- Serial GOES transmitters
- ARGOS transmitters
- Weather stations
- Hydrology stations
- Emergency locator transmitter/ emergency position indicating radio beacon

Other Company Products and Services:
- Jet engine combustion and exhaust components
- Precision weldments of high temp stainless alloys cowlings, etc.
- Aircraft sheet metal assemblies
- Large light alloys aircraft structures
- Aircraft repair modification and overhaul
- Wind power turbine systems
- High altitude research rockets

Personnel: 1400

Annual sales $42 million in 1980

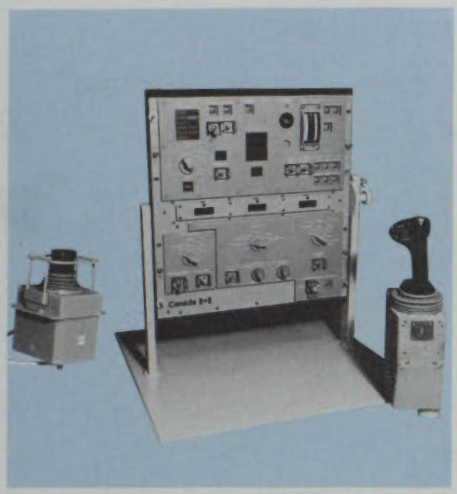
Contact:
Mr. K.F. Burrows
Vice President, Marketing
Telephone: (204) 775-8331
Telex: 07-57774
TWX: 610-671-3598

Bristol satellite data collection platform (right) and test set.

Bristol BBIV payload aboard this AAF-IV-36 launched from Churchill, Man. January, 1981 to obtain data on expansive phase of auroral substorm.

CAE Electronics Ltd.

8585 Cote de Liesse
Saint Laurent, Quebec
H4T 1G6



Remote Manipulation Components
An integrated design and manufacturing company of special purpose real-time computer based systems, airborne and space equipment.

Main Space Systems, Proprietary Products and Services:

- Hand controllers and display panel for the Space Shuttle Remote Manipulator System
- Six-degree-of-freedom hand controllers

Other Company Products and Services:

- Flight and tactical simulators
- Power station simulators
- DACS and SCADA systems for power utilities
- ASW Magnetic Anomaly Detection equipment (MAD)

Personnel: 1,650

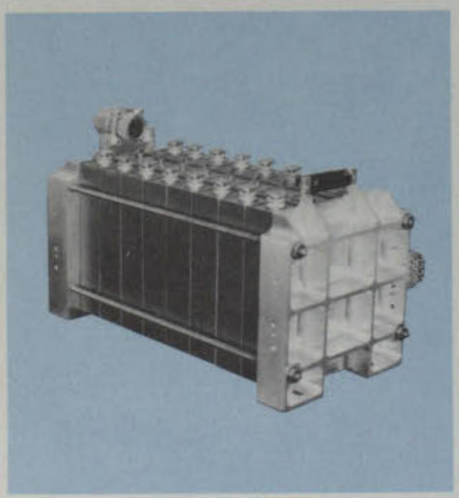
Annual sales: $80 million in 1980

Contact:
Mr. D.R. Tait
Vice President, Technical
Development & Sales
Telephone: (514) 341-6780
Telex: CAE 05-824856
TWX: CAE MTL
610-422-3063

Rotational and translation hand controllers with display and control used on NASA Space Shuttle orbiter to control CANADARM.

Canadian Astronautics Limited

1024 Morrison Drive
Ottawa, Ontario
K2H 8K7



Ground Stations, Support Equipment, System Design
Founded in 1974 to provide space system design and planning services, the firm now has considerably expanded to develop and manufacture a wide range of electronic, computer, microwave and mechanical products.

Main Space Systems, Proprietary Products and Services:
- High-Rel battery management subsystems
- SARSAT ground station (complete system, turn-key responsibility)
- Communications ground station equipment
- UV imager for Swedish Viking mission
- Vibration and thermal vacuum testing
- Mechanical ground support equipment
- System concept definition studies
- Preliminary system design and planning
- Launch and mission operations support

Other Company Products and Services:
- Airborne synthetic aperture radar
- EW radar simulator
- 3-D spectrum analyzer
- Mini and microprocessor systems
- Microwave antenna systems
- Industrial process control

Personnel: 95

Annual sales: $6 million in 1980

Contact:
Mr. J.D. Taylor
President
Telephone (613) 820-8280
Telex: 053-3937

CAL SARSAT ground station.

CAL spacecraft battery pack, part of the firm's high reliability battery management subsystem.

Canadian Marconi Company

2442 Trenton Avenue
Montreal, Quebec
H3P 1Y9

Aerospace Electronic Equipment
Canadian Marconi Co. was incorporated in 1902, and now designs and manufactures electronic equipment for telecommunications, radar, ground and air navigation.

Main Space Systems, Proprietary Products and Services:
- NAVSTAR/GPS user equipment

Other Company Products and Services:
- Antenna navigation systems
- Display systems
- Ground support systems
- Test systems

Personnel: 2250

Annual sales: $113 million in the fiscal year 79/80

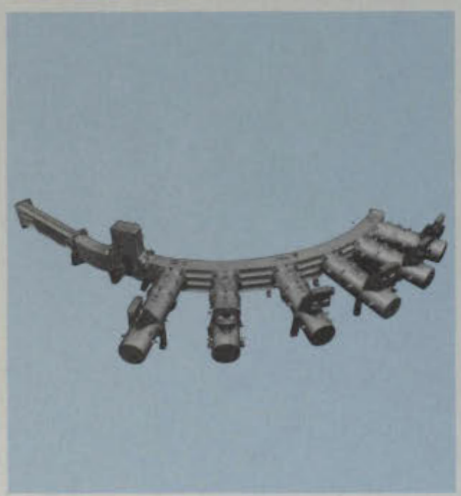
Contact:
Mr. W. Rosebery
Telephone (514) 341-7630
Telex: 05-827822
TWX: 610-421-3564

Typical satellite referenced precision-positioning equipment made by CMC for survey and navigational use.

General view of CMC clean aerospace assembly and test area in Montreal plant.

Com Dev Ltd.

155 Sheldon Drive
Cambridge, Ontario
N1R 7H6



Satellite Communications Microwave Subsystems, Multiplexing Networks

Com Dev Ltd., incorporated in 1971, now houses R&D capability and a space qualified manufacturing facility for microwave subsystems with in-house computer controlled testing, vibration, thermal vacuum, high conductivity plating and N.C. machining. Customers include all major manufacturers of satellite systems.

Main Space Systems, Proprietary Products and Services:

- Microwave multiplexing networks
- Variable power dividers and combiners
- High and low power ferrite devices
- Preselect and harmonic filters
- Group delay and amplitude equalizers
- Low loss antenna diplexers
- Antenna phase combiners and dividers
- High power couplers and terminations
- Tx and Rx reject filters

Other Company Products and Services:

- Consultant services for satellite transponder design
- Consultant services for high power segment of earth stations
- Consultant services for microwave signal processing

Personnel: 72

Annual sales: $3.2 million in 1980

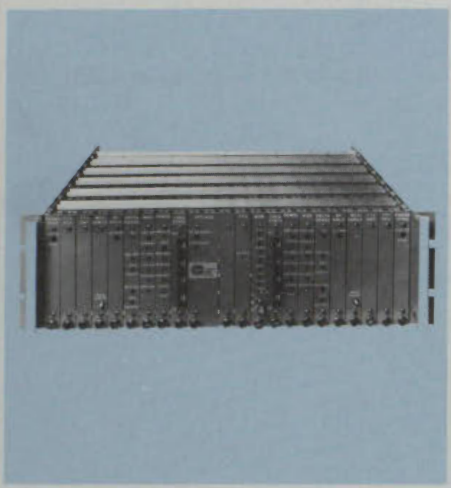
Contact:
Mr. M.V. O'Donovan
President
Telephone: (519) 622-2300
TWX: 610-366-3164

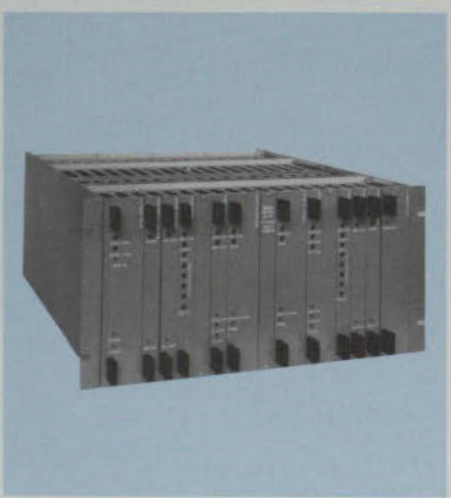
Com Dev six-channel 4 GHz input multiplexer used on RCA SATCOM satellite series

Com Dev six-channel 4 GHz output multiplexing network for communications satellites

Digital Telecommunications Ltd.

1305 Matheson Boulevard
Mississauga, Ontario
L4W 1R1





Earth Stations, Digital Communications Equipment
DTL, incorporated in 1974, designs and manufacturers digital communications equipment. DTL can provide both single modules and turnkey systems.

Main Space Systems, Proprietary Products and Services:
- TDMA earth stations
- Transportable earth stations
- Digital voice encoding (PCM, CVSD)
- Multiplexers
- Voice, data & TTY channel units

Other Company Products and Services:
- Fibre optic equipment
- Digital video codecs
- Data interface

Personnel: 30

Annual sales: $3 million in 1980

Contact:
Mr. W.G. Maillet
Senior Vice President
Telephone: (416) 624-1810
TWX: 610-492-4728

Digital Telecommunications' single channel per carrier receiver.

Digital TV-3 television codec converts standard TV and audio signals to 45 Mb/s streams with frame compatible DSX-3 interface for use in digital satellite link.

Dipix Systems Limited

1785 Woodward Drive
Ottawa, Ontario
K2C 0P9

Digital Image Processing
Dipix is a manufacturer of digital image analysis systems. These systems provide a complete analysis of LANDSAT images, as well as from other remotely sensed data typically obtained from satellite and aircraft sensors.

Main Space Systems, Proprietary Products and Services:
- Digital image analysis systems

Other Company Products and Services:
- Image networking system

Personnel: 40

Annual sales: $3.5 million in 1981 (estimate)

Contact:
Mr. Lou Robert
Marketing Manager
Telephone: (613) 224-5175
Telex: 053-3946

ARIES II Digital Image Analysis System

Fleet Industries, a Division of Ronyx Corporation Ltd.

P.O. Box 400, Gilmore Road
Fort Erie, Ontario
L2A 5N3

Specialized Satellite Structures
Fleet Industries is involved in the production of solar array substrates, equipment shelves for satellites and performs composite technology bonding.

Main Space Systems, Proprietary Products and Services:

- Specialized structures for use aboard satellites

Other Company Products and Services:

- Aircraft component subcontractor

Personnel: 980

Annual sales: $30 million in 1980

Contact:
Mr. H.B. MacRitchie
Sales Manager
Telephone: (416) 871-2100
Telex: 061-5165
TWX: 610-373-0101

Trimming operation of a basic bonded honeycomb structure

Gensat Communications Corporation

809 Wellington St. N.
Kitchener, Ontario
N2G 4J6

Satellite Earth Terminals
Gensat, incorporated in 1981, concentrates its efforts on the international private satellite television earth terminal market through its parents, Electrohome Ltd. and Microdesign Ltd. Electrohome Electronics has strong expertise in video related products while Microdesign specializes in microprocessor-based products for the communications industry.

Main Space Systems, Proprietary Products and Services:
- 12 GHz agile receiver
- 4 GHz microprocessor-controlled agile receiver
- Microprocessor-controlled antenna controller
- Satellite receiver test generator

Other Company Products and Services:
- Video monitors, Telidon terminals
- Custom assembly
- Cable TV videotex systems
- Sub-fractional HP motors
- Deilcraft furniture
- Microprocessor research and development services

Contact:
Electrohome:
Mr. Allan Lodberg
Telephone: (519) 744-7111
Telex: 069-55449

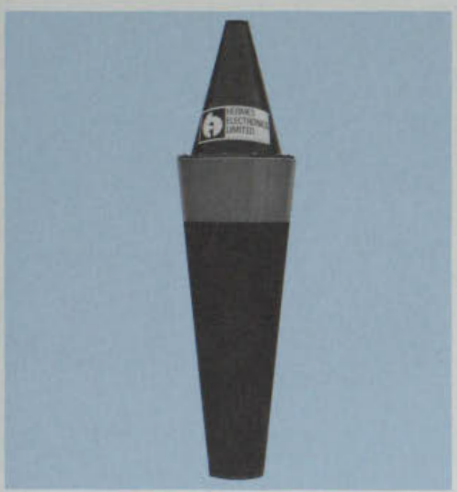
Microdesign:
Dr. Robert Arn
Telephone: (416) 992-4180

Electrohome completely metered 12 GHz manually tuned home receiver.

Microdesign microprocessor-controlled 4 GHz automatic antenna controller with polar and polarization mode. Key pad for use with controller and Electrohome 4 GHz receiver.

Hermes Electronics Ltd.

P.O. Box 1005
40 Atlantic Street
Dartmouth, Nova Scotia
B2Y 4A1



Ocean Data Systems
The company was founded in 1947 and specializes in designing and manufacturing ocean data systems.

Main Space Systems, Proprietary Products and Services
- HT101A TIROS transmitter
- Hexoid data buoys
- Air deployed ice beacons and drifting buoys
- Ice beacons
- Drifting buoys

Other Company Products and Services:
- Ionosphere sounding equipment HF
- Aperiodic loop antennas HF
- Sonobuoys
- Bathythermographs

Personnel: 300

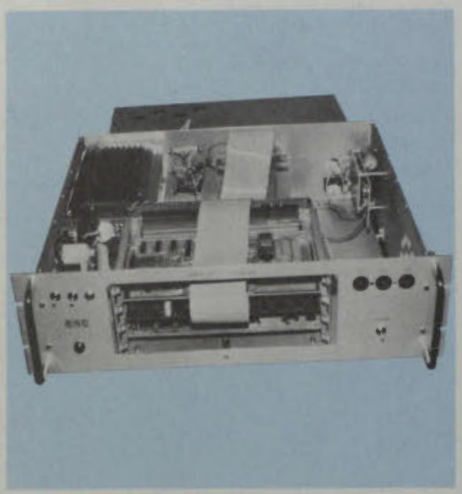
Contact:
Mr. A.S. Logan
Director of Marketing
Telephone (902) 466-7491
Telex: 019-21744

HT101A TIROS Transmitter

Standard Drifting Buoy

HiTech Canada Limited

5th Floor
1390 Prince of Wales Drive
Ottawa, Ontario
K2C 3N6



Communications and Computer Systems Engineering
HiTech incorporated in 1973, is a growing company supplying systems engineering and computer-based products and services. The company established manufacturing capabilities in 1981.

Main Space Systems, Proprietary Products and Services:
- Telemetry and command systems
- Data handling systems (hardware and engineering)

Other Company Products and Services:
- Monitoring and control systems
- Database systems
- Radar systems engineering
- Signal processing
- Optical character recognition

Personnel: 40

Annual sales: $1.5 million in 1980

Contact:
Mr. A.J. Kittridge
Telephone: (613) 820-1200
Telex: 053-3262

Stand-alone HiTech spacecraft telemetry de-commutation system used on board Anik C and Anik D satellites for display of command and control data.

Stand-alone graphics systems contained in HiTech data acquisition systems of up to three real and one non-real time graphs.

Lindsay Specialty Products

50 Mary St. West
Lindsay, Ontario
K9V 4S7

Earth Stations and Accessories
Lindsay Specialty Products was incorporated in 1953 and is actively involved in the TVRO earth station market, supplying earth stations, antennas, receivers and accessories.

Main Space Systems, Proprietary Products and Services:
- TVRO earth stations
- Antennas, receivers, LNAs and accessories

Other Company Products and Services:
- CATV remote cordless converters
- High frequency welding

Personnel: 500

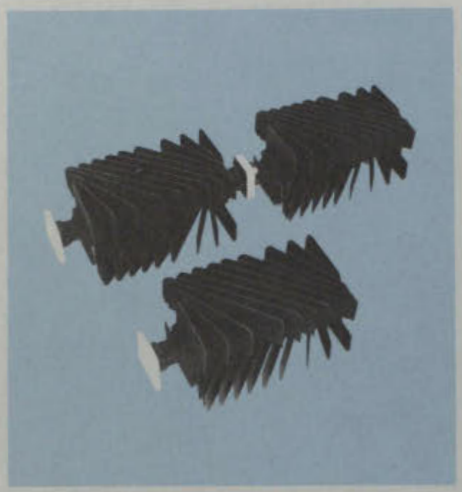
Contact:
Mr. John Thomas
President
Telephone: (705) 324-2196
Telex: 06-962-860

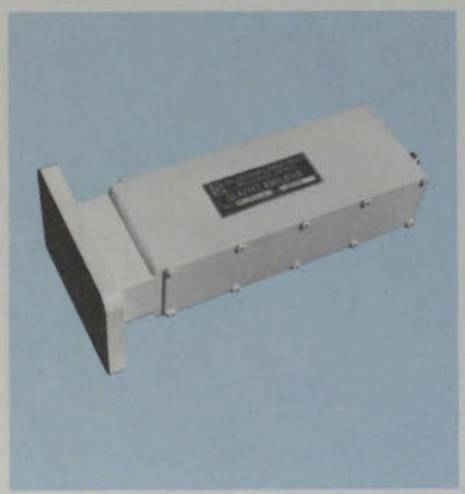
Lindsay 2.6 m TVRO Antenna

Lindsay 4.6 m TVRO Antenna

MA Electronics Canada Limited

3135 Universal Drive
Mississauga, Ontario
L4X 2E7





Microwave Components, Amplifiers and Subsystems
Founded in 1977, MA Electronics now manufactures microwave components for terrestrial communications and satellite earth terminals, with design and manufacturing facilities for all passive and active devices, including low noise amplifiers.

Main Space Systems, Proprietary Products and Services:

- 4 GHz low noise amplifier for TVROs
- 12 GHz low noise amplifier for TVROs
- 14 GHz 1 watt amplifier for telephony uplinks
- 12 GHz redundant LNA subsystems
- 4 GHz LNA downconverters
- High power combining systems
- High power diplexers
- High power terminations
- Power dividers and combiners

Other Company Products and Services:

- Waveguide ferrite devices
- Coaxial ferrite devices
- Waveguide and coax filters
- Transformer, transitions and transducers
- Attenuators (manual and power), terminations
- PIN diode switches and attenuators

Personnel: 51

Annual sales: $1.5 million in 1980

Contact:
Mr. Brian Dinsdale
Sales Manager
Telephone (416) 625-4605
TWX: 610-492-4317

MA Electronics high power terminations and attenuators for 6 and 14 GHz uplink applications.

MA Electronics 3.7-4.2 GHz GaAs low noise amplifier designed for small earth station applications.

MPB Technologies Inc.

P.O. Box 160, 21051 N. Service Road
Ste Anne de Bellevue, Quebec
H9X 3L5

R & D and Specialized Products
The company was founded in 1976 as a R&D activity and has expanded into a number of unique products. It has manufacturing facilities for specialized systems and products.

Main Space Systems, Proprietary Products and Services:

- Electronic design-modems, bit synchronizers
- TDMA analysis and design
- Microprocessor applications
- Signal and data processing and software
- Antenna development
- Propagation analysis: satellite-earth
- Scientific experimenter-hardware interface
- Microwave, mm wave and optical devices and design
- Radar scattering and interaction

Other Company Products and Services:

- Microprocessor controllers
- Electronic graphic and display systems
- Long life CO_2 lasers and instrumentation
- Laser communications systems
- Sea-ice thickness measuring radars
- Microwave instrumentation

Personnel: 30

Annual sales: $1.5 million in 1980

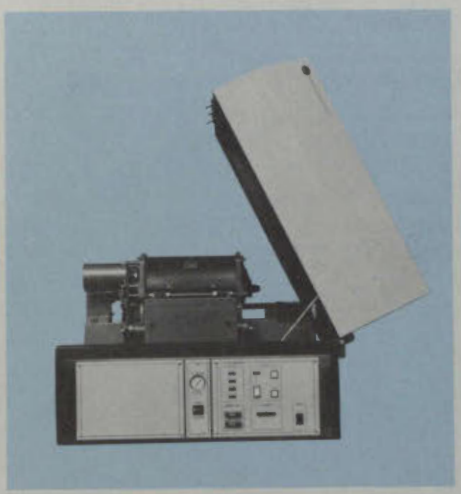
Contact:
Dr. Morrel P. Bachynski
President
Telephone: (514) 457-2035
TWX: CABLE MPBT CAN

An aperture injection-locked atomic iodine laser for use in plasma physics experiments.

A long life CO_2 waveguide laser under development for possible spacecraft-borne laser radar.

MacDonald Dettwiler & Associates Ltd.

3751 Shell Road
Richmond, B.C.
V6X 2Z9



Satellite Processing Systems
MDA Ltd. is a manufacturer of ground stations and equipment for receiving and processing data from earth sensing satellites.

Main Space Systems, Proprietary Products and Services:
- Meteorological satellite ground stations
- LANDSAT ground stations
- Satellite image analysis system
- Synthetic aperture radar processors
- Laser film recorders

Other Company Products and Services:
- Airline flight operations systems
- HF data modem
- Cable TV signal processing
- Airborne SAR processors

Personnel: 200

Annual sales: $12 million in 1980

Contact:
Mr. Marshall Prentice
Telephone: (604) 278-3411
Telex: 04-355599

MDA FIRE-20 laser beam film recorder for processing imagery of sensing satellites.

MDA LANDSAT receiving site located at Alice Springs, Australia, including receiving and processing station.

Microwave Instruments & Components Inc.

6600 Bombardier Street
Montreal, Quebec
H1P 1E4

Waveguide Components
Microwave components for telecommunications applications.

Main Space Systems, Proprietary Products and Services:
- Waveguide components for transmission lines

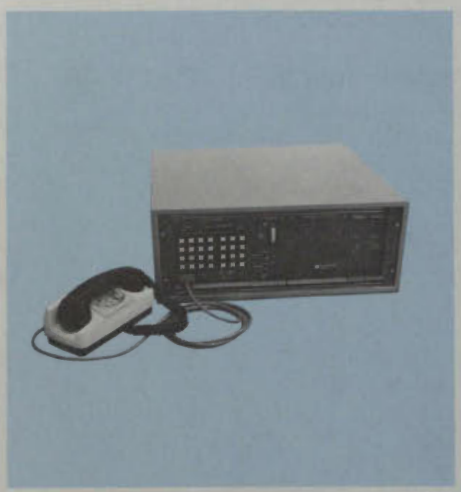
Personnel: 20

Annual sales: $0.7 million in 1980

Contact:
Mr. R. Gentner
President
Telephone: (514) 321-3680
TWX: 610-421-3301

Miller Communications Systems Ltd.

300 Legget Drive
Kanata, Ontario
K2K 1Y5



Satellite Communications Systems Engineering
The firm was founded in 1974 as an engineering company specializing in the planning, design and implementation of a wide range of communications systems and associated automatic testing systems.

Main Space Systems, Proprietary Products and Services:
- Light route TDMA terminals
- Network engineering
- Software programs for transmission planning
- Modulation and coding studies
- Communications systems design definition
- Consultants in advanced systems
- Automatic carrier monitoring systems

Other Company Products and Services:
- Demand assignment systems (SCPC)
- Spread spectrum modems
- Digital modems

Personnel: 55

Annual sales: $2 million in 1980

Contact:
Dr. R.G. Lyons
Director of Advanced Systems
Telephone: (613) 592-3020
Telex: 053-4164

Miller developed single-channel-per-carrier channel unit mobile terminal for use with UHF communications satellite to provide field quality voice, and synchronous and asynchronous data transmission resulting from the MUSAT program.

Miller developed carrier monitor system for measurement of carrier amplitude frequency spectral shape and carrier-to-noise ratio for signals ranging from SCPC to video to TDMA.

Mitel Corporation

P.O. Box 13089
350 Legget Drive
Kanata, Ontario
K2K 1X3

Satellite Communications Systems
Mitel, founded in 1971, operates 13 manufacturing facilities on 3 continents. The company rapidly gained world leadership in the field of DTMF technology. In 1976, this capability was augmented by state-of-the-art semiconductor designs which, in turn, led to the production of the highly successful SUPERSWITCH™ line of analog and digital PABXs. Mitel is now the first company to combine telephone/data switching systems technology with earth station technology to offer terminals for both the 6/4 and 14/12 GHz bands. Such terminals have significant "office of the future" applications.

Main Space Systems, Proprietary Products and Services:

- Two way telephony earth stations
- Integrated telephony terminal (SKYSWITCH™)
- Voice and data channel units
- Program channel units
- Business data communications
- Television distribution
- Private networks
- Terrestrial links
- TVRO earth station components

Other Company Products and Services:

- Integrated circuits, LSI and VLSI, in 4/5 micron ISO^2-CMOS™ technology
- Thick film hybrid circuits
- Innovative telephony devices (eg. DTMF receivers)
- A full range of analog PABXs from the SX-2™ home switch to the 208 port SX-200™
- The digital SX-2000™ SUPERSWITCH servicing 150 to 10,000 lines with the world's first true simultaneous voice and data transmission
- The Superset 500™ and Superset 2000™ intelligent voice/data receivers

Personnel: 2,000

Annual sales: $111 million in 1980

Contact: Mr. Les Barton/Ext 1199
Mr. Iain Grant/Ext 1288
Mitel Corporation
Telephone: (613) 592-2122
Telex: 053-4596

Moniteq Ltd.

630 Rivermede Road
Concord, Ontario
L4K 1B6

Remote Sensing Applications and Instrumentation

Moniteq was founded in 1976 to develop new applications in monitoring environmental quality. Electro-optical instrumentation complements interpretive software for oceangraphic and atmospheric applications. It has both hardware and software development facilities.

Main Space Systems, Proprietary Products and Services:

- Image processing software
- Electro-optical sensors for monitoring atmospheric radiation, pollution for remote sensing and in-situ measurement
- Program definitions
- Scientific feasibility studies
- Algorithm development
- Oceanographic imagery analysis
- UV VIS IR remote sensors
- Altimeter studies

Other Company Products and Services:

- Ambient and remote sensors for air quality
- Airborne surveys and software for water quality and depth
- Nerve agents detection device
- Air quality monitoring
- Atmospheric scattering and attenuation measurements
- Image correction and analysis

Personnel: 31

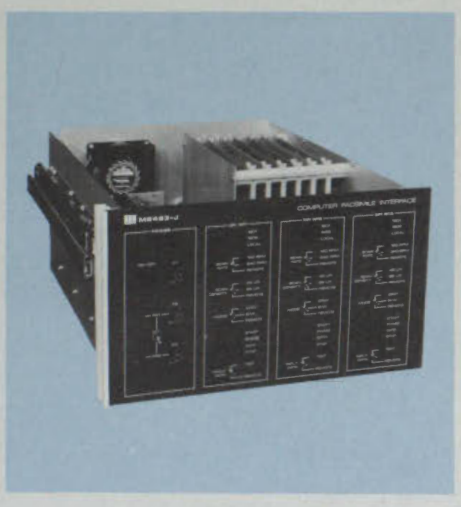
Annual sales: $1 million in 1980

Contact:
Mr. D.A. Whiteman
President
Telephone: (416) 669-5334

Air intake for fast response mobile SO_2 ambient monitor, mounted atop automobile with PLUMETRACKER.

Muirhead Systems Limited

50 Galaxy Blvd. Unit #4
Rexdale, Ontario
M9W 4Y5



Meteorological Satellite Receiving Systems
The company manufacturers a range of products employed in the reception and processing of imagery from meteorological satellites.

Main Space Systems, Proprietary Products and Services:
- Tiros-N APT receiving stations
- Earth station image recorders
- Image processors

Other Company Products and Services:
- Data switching and distribution systems
- Computer facsimile interfaces

Personnel: 20

Annual sales: $2 million in 1980

Contact:
Mr. J.B. Crampton
Telephone (416) 675-7450
Telex: 06-989264

Muirhead satellite signal processor for reception of analog signals for APT from Tiros-N satellite.

Muirhead computer facsimile interface for outputting a processed satellite image for on-site or remote site applications.

Norpak Ltd.

10 Hearst Way
Kanata, Ontario
K2L 2P4

Remote Sensing Display Systems
NORPAK, founded in 1975, develops, engineers and manufacturers a range of colour graphics display terminals and associated digital electronic hardware.

Main Space Systems, Proprietary Products and Services:

- Visual Data Processor (VDP) systems
- Imagery applications devices producing high-spatial resolution
- Display hardware and software
- High-resolution distributed information display systems

Other Company Products and Services:

- Telidon videotex hardware
- Teletext encoder system
- Information provider system

Personnel: 250

Annual sales: $20 million in 1981 (estimate)

Contact:
Mr. Ian Hembery
Vice President
Marketing and Sales
Telephone: (613) 592-4164
telex: 053-4174

NORPAK Visual Data Processor (VDP)

NORPAK Mk3 Telidon Decoder, Keypad and CRT

OVAAC8 International Inc.

4800 Dufferin Street
Toronto, Ontario
M3H 5S9

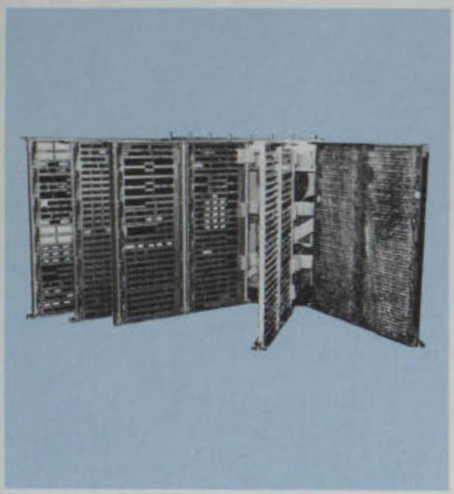


Image Processing and Analysis Systems
OVAAC8 was incorporated in 1972 with a charter to develop, design, manufacture and market sytems for the analysis and processing of remotely-sensed multi-spectral digital data.

Main Space Systems, Proprietary Products and Services:
- Single and multi-class classification of images
- Radiometric and spatial enhancement
- Spatial synthesis
- Scene to scene registration
- Statistical and analytical reporting
- Data base management system
- Software development package
- General device drivers
- Specialized high speed pipeline processor (MP-8)

Personnel: 7

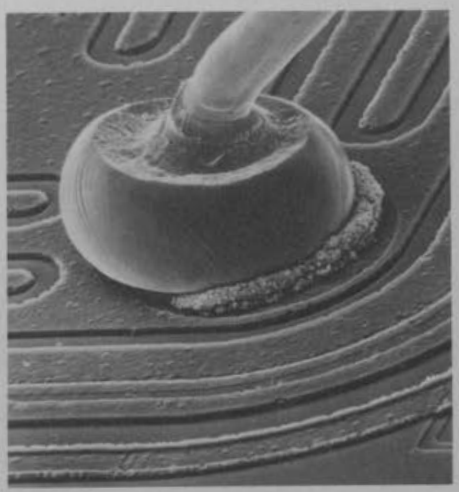
Contact:
Mr. E. Miller
Director of Marketing
Telephone: (416) 661-5088
Telex: 06-217652

Image Processing System

MP-8 Pipeline Processor

QRL Analysis Corporation

19 Grenfell Crescent, Suite 100
Nepean, Ontario
K2G 0G3



Material and Reliability Engineers
The company was founded in 1979 and employs former members of the Canadian government's High Reliability Laboratory to provide materials, reliability and failure analysis of electronic components, including destructive physical analysis.

Main Space Systems, Proprietary Products and Services:
- Reliability studies
- Component analysis
- Failure analysis
- Quality assurance

Other Company Products and Services:
- Materials analysis
- Quality audits
- Electron microscopy

Personnel: 5

Annual sales: $150,000

Contact:
Dr. S.P. Bellier
Telephone: (613) 226-1885

Scanning electron micrograph of intermetallics at gold wire 0.0012 diameter bond of a transistor rejected for use on the NASA space shuttle.

Defective diode after removal of glass seals, Silicon die approximately 1.2 mm per side.

Raytheon Canada Limited

400 Phillip Street, P.O. Box 1619
Waterloo, Ontario
N2J 4K6

Satellite Communications Earth Stations

Raytheon Canada, founded in 1956, is a well established supplier of high technology electronic products, systems and associated services for both Canadian and international markets. Prime activities of the company are in telecommunications systems, including satellite earth stations, and air traffic control.

Main Space Systems, Proprietary Products and Services:

- 14/12 GHz earth stations
- 6/4 GHz earth stations
- Up and down converters
- Video terminal equipment
- Telephony terminal equipment
- Digital (90 Mb/s) terminal equipment
- Engineering studies
- Installation and commissioning services
- Operation and maintenance services

Other Company Products and Services:

- Airport surveillance radars
- Doppler VHF omnirange equipment
- Distant measuring equipment
- Terrestrial radio relay equipment

Personnel: 290

Annual sales: $15 million in 1980

Contact:
Mr. J.E.H. Elvidge
Assistant General Manager
Telephone: (519) 885-0110
Telex: 069-55431
TWX: 610-365-3469

Raytheon Canada 14/12 GHz earth station used by Telesat Canada to receive ANIK C satellite signals.

The Raytheon Canada ASR-8000 series radar comprises a number of advanced L and S band primary radars capable of detecting aircraft in extreme weather and clutter conditions.

SED Systems Inc.

P.O. Box 1464
Saskatoon, Saskatchewan
S7K 3P7

Ground Terminals, Earth Stations, Test Facilities
The company was incorporated in 1972 and specializes in the development and fabrication of ground terminals and satellite components.

Main Space Systems, Proprietary Products and Services:
- Terminals for voice, data, radio telephony and television transmission and reception via satellite
- Microwave components
- Transportable earth stations
- Mobile test facilities
- Design and manufacture of 12 GHz direct broadcast terminals

Other Company Products and Services:
- Remote sensing
- Shuttle and rocket payloads
- Satellite ground control facilities
- Satellite systems test equipment
- Landsat station operations
- Satellite data receiving and processing systems
- Low cost telephony terminal satellite systems
- Research and development studies
- Simulators and trainers

Personnel: 260

Annual sales: $13 million in 1980

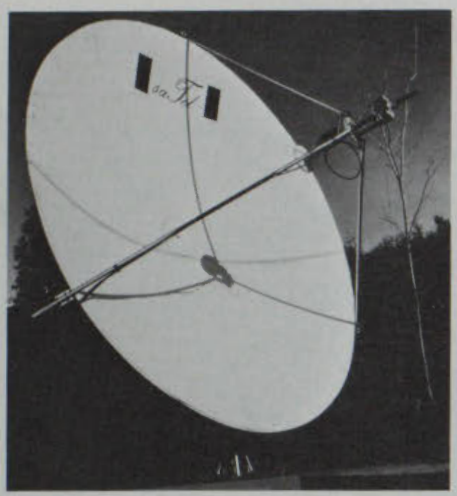
Contact:
Dr. J.D.J. Robar
President
Telephone: (306) 664-1709
Telex: 074-2325
TWX: 610-731-1476

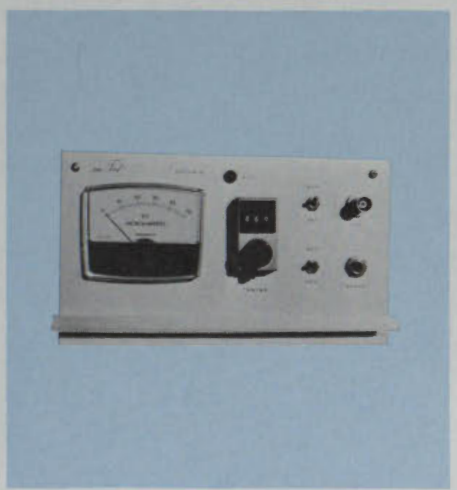
SED small diameter satellite communications direct broadcast 12 GHz terminal.

SED telecommunications electronics workstation at Saskatoon head office

saTel Consultants Limited

1013 Wiseman Crescent
Ottawa, Ontario
K1V 8J3





Earth Stations Telecommunications System & Engineering
Since 1975, saTel has provided systems engineering, manufacturing and turn-key installation for a broad variety of telecommunications, with emphasis on earth stations for radio, TV etc.

Main Space Systems, Proprietary Products and Services:
- TV, radio, etc. earth stations
- Satellite cue/control switchers
- Transportable TV radio earth stations
- RF Interference compatibility analysis and measurement
- Feasibility/definition studies

Other Company Products and Services:
- Wind/alternate energy systems
- Low power broadcast systems
- CRTC, DOC licence applications
- Ground-air navigation/communications systems
- Meteorological data collection and analysis
- MF, VHF communcations systems

Personnel: 7

Annual sales: $0.85 million in 1980

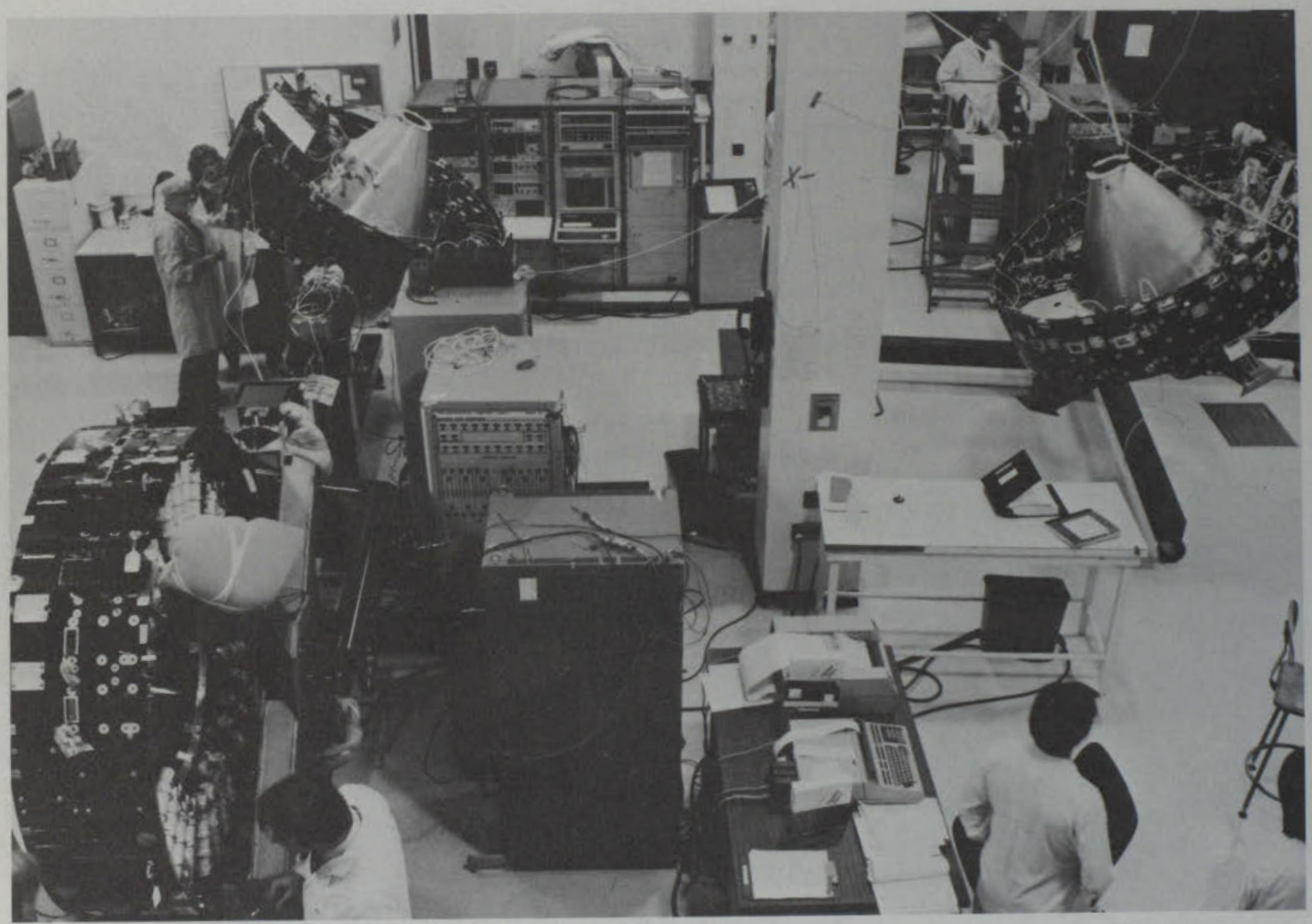
Contact:
Mr. B.F. Murphy
President
Telephone: (613) 733-1878
Telex: 053-4463

saTel TV and radio antenna/low noise amplifier earth station compatible with all 24 satellite channels now in use in Canada.

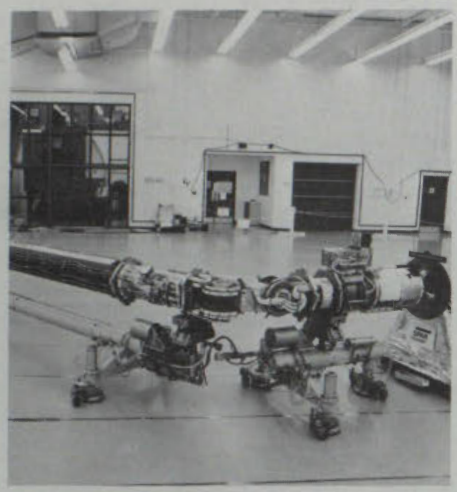
saTel SAT-24D satellite receiver using advanced integrated circuit techniques.

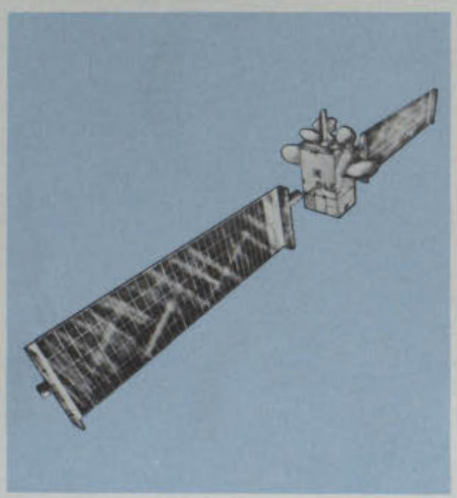
Spar Aerospace Limited

Royal Bank Plaza
Toronto, Ontario
M5J 2J2



Seen at Spar's Ste-Anne plant (clockwise from 8:00) — de-spun components for three satellites: ANIK-D1, ANIK-C2 and ANIK-C3





Complete satellite systems
Spar Aerospace Limited, incorporated in 1968, has acquired space-related assets from The de Havilland Aircraft of Canada Ltd., York Gears Limited, Astro Research Corporation, RCA Limited and Northern Telecom Ltd. In the mid-'70s, the company undertook to develop Canada's prime contractor capability for satellites.

Main Space Systems, Proprietary Products and Services:
- Complete satellites
- Satellite Subsystems, including:
  - — Large solar arrays
  - — Transponders
  - — Antennas and feeds
  - — Satellite deployable structures
  - — Electronics instruments
  - — Remote manipulator systems
  - — Remote sensing surveillance systems
  - — Earth stations

Other Company Products and Services:
- Aerospace gears and transmissions
- Aircraft repair and overhaul
- Terrestrial robotics
- Life-cycle support for military and commercial aircraft and ships
- Mapping systems
- Microwave relay systems

Personnel: 1,950

Annual sales: $128 million in 1980

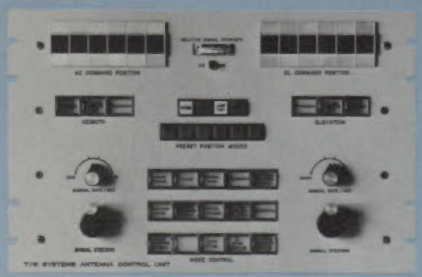
Contact:
Mr. C.M. Hinds
Group Director, Marketing
Telephone: (416) 678-9750
Telex: 069-68923
TWX: 610-491-1503

A remote manipulator system, for use on-board the USA space shuttle Columbia, under testing at a Spar Aerospace plant.

Spar is the solar-arrays subsystem contractor for the ESA L-SAT satellite.

TIW Systems Ltd.

629 Eastern Avenue
Toronto, Ontario
M4M 1E4



Satellite Tracking Systems
Incorporated in 1973, the firm is engaged in design, marketing and construction of satellite tracking antennas.

Main Space Systems, Proprietary Products and Services:
- Satellite tracking antennas
- Antenna support structures
- Surface panels
- Servo drives
- Microprocessors

Other Company Products and Services:
- Design, marketing and electrical component manufacturing facilities.

Personnel: 75

Annual Sales: $8 million in 1980

Contact:
Mr. Donald M. Cameron
Telephone: (416) 416-8111
Telex: 06-2208 (Toronto)

TIW Systems 16.5 TTC & M satellite tracking antenna.

TIW Systems automatic control unit for satellite tracking systems.

Television By Satellite Incorporated

16 Taber Road
Rexdale, Ontario
M9W 3A5

Microwave Antennas
The company was incorporated in 1980 and has developed a line of low cost fiberglass microwave antennas in 3.7 to 4.2 GHz and 12 GHz bands.

Main Space Systems, Proprietary Products and Services:

- High efficiency receive only antenna system in 4 GHz and 12 GHz bands
- Total protection of radio wave reflective surface
- Remotely operated antenna tracking system
- TV/FM receiver-modulators 4 GHz band

Personnel: 6

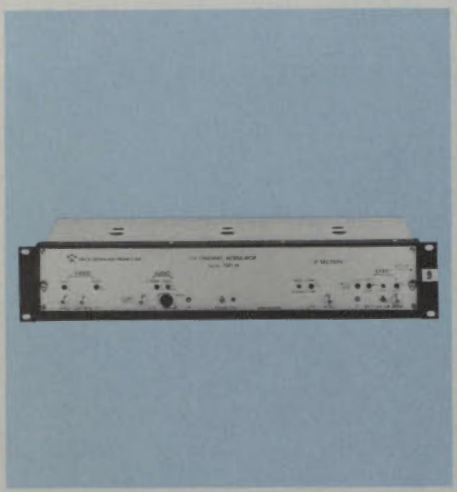
Annual sales: $200,000 in 1981

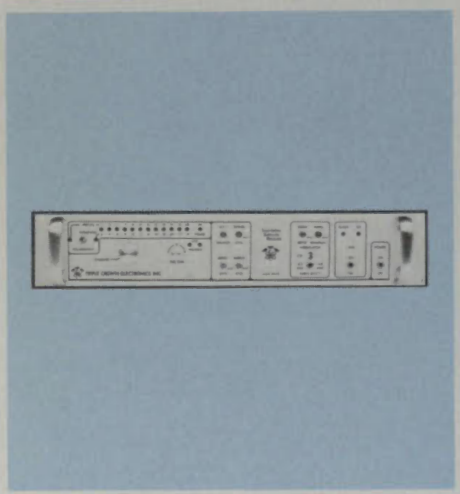
Contact:
Mr. Jan Spisar
President
Telephone: (416) 745-3040

Home user 3.2 m antenna system manufactured by TSI.

Triple Crown Electronics Inc.

42 Racine Road
Rexdale, Ontario
M9W 2Z3





TVRO Satellite Receiver
The firm was founded in 1972 as a CATV (Cable TV) supplier and now markets products ranging from amplifiers to processors to test equipment to TVRO receivers.

Main Space Systems, Proprietary Products and Services:
- TVRO satellite receivers

Other Company Products and Services:
- Amplifiers, broadband
- RF signal processors
- RF test equipment
- Satellite stereo signal processors

Personnel: 80

Annual sales: $3 million in 1980

Contact:
Mr. David Emberson
Telephone: (413) 743-1481
Telex: 06-989292

Triple Crown TV channel modulator model TSP-M which converts IF signal to any TV channel (5-900 MHz) using up-converter section for TVRO application.

Triple Crown television satellite receiver 4000 series for TVRO application which produces 70 MHz IF signal by dual conversion and accepts 3.7 to 4.2 GHz band.

Space Industry Consultants/ Services

ADGA Ltd.
116 Albert Street
Ottawa, Ontario
K1P 5G3

Engineering consultant in RF systems, ground stations and economic modelling

Contact:
Mr. Kester Hamilton
Telephone: (613) 237-3022
Telex: 053-4568

ANCON Space Technology Co.
12 Elmbank Road
Thornhill, Ontario
L4J 2B7

Control systems consulting

Contact:
Dr. Douglas A. Staley
Telephone: (416) 889-0285

Applied Telecommunications Ltd.
976 Kingsmere Avenue
Ottawa, Ontario
K2A 3K4

Consultant services in space systems

Contact:
Dr. I. Paghis
Telephone: (613) 729-7933

Bell Canada — International
1 Nicholas Street
Ottawa, Ontario
K1G 3J4

Engineering consulting services in telecommunications, integration of satellite communications with terrestrial network

Contact:
Mr. P.J. Murphy
Telephone: (613) 563-1811
Telex: 053-4849

Bell-Northern Research Ltd.
P.O. Box 3511, Station 'C'
Ottawa, Ontario
K1Y 4H7

Telecommunications research and development

Contact:
Mr. Ray F. Fortune
Telephone: (613) 596-2304
Telex: 053-3175
TWX: 610-562-1914

Canadian Pacific Consulting Services Ltd.
760-740 Notre Dame West
Montreal, Quebec
H3C 3X6

Consulting, advisory and engineering services in telecommunications related to the transport industry

Contact:
Mr. M. Sugimoto
Telephone: (514) 395-7799
Telex: 055-60147

Cantel Engineering Associated Ltd.
1221 West 23rd Street
North Vancouver, B.C.
V7P 2H5

Satellite consulting engineering services

Contact:
Mr. A.C. Gardiner
Telephone: (604) 980-4911
Telex: 04-507775

DSMA ATCON Ltd.
4195 Dundas Street West
Toronto, Ontario
M8X 1Y4

System engineering and design services

Contact:
Mr. I.J. Billington
Telephone: (416) 239-3011
Telex: 06-967880

Roy M. Dohoo Ltd.
100-56 Sparks Street
Ottawa, Ontario
K1P 5A9

Consulting services for space systems

Contact:
Mr. Roy M. Dohoo
Telephone: (613) 731-1886
Telex: 053-3314

Max T. Friedl Associates
101-56 Sparks Street
Ottawa, Ontario
K1P 5A9

Business consultant in aerospace

Contact:
Mr. M.T. Friedl
Telephone: (613) 238-2385
Telex: 053-3314

Geostudio Consultants Ltd.
525 St. Laurent Blvd. Suite 24
Ottawa, Ontario
K1K 2Z9

Satellite imagery interpretation services

Contact:
Dr. R. Steffensen
Telephone: (613) 746-2950

Intera Environmental Consultants Ltd.
406-7015 McLeod Trail
Calgary, Alberta
T2H 1X9

Remote sensing, meteorological and numerical modelling services

Contact:
Mr. M. Wide
Telephone: (403) 253-8895
Telex: 03-824537

Philip A. Lapp Ltd.
280 Albert Street, Suite 904
Ottawa, Ontario
K1P 5G8

Systems management and policy consultants on space, telecommunications and other applications

Contact:
Dr. Philip A. Lapp
Telephone: (416) 920-1994

Louis Technology Services Ltd.
1843 Kilborn Avenue
Ottawa, Ontario
K1H 6N3

Satellite earth station engineering, technology search and transfer, feasibility studies and marketing

Contact:
Mr. H. Louis
Telephone: (613) 731-7465

Novametric Engineering Inc.
P.O. Box 8163
Saskatoon, Saskatchewan
S7K 6C4

Consulting services in instrumentation

Contact:
Mr. Allan R. Bens
Telephone: (306) 373-4965

Reltek Inc.
302 Leggett Drive
Kanata, Ontario
K2K 1Y5

Space component reliability analysis and screening; Burn-in of components; AC/DC electrical testing; temperature stabilization; PIN-D testing, component radiography; temperature cycling; screening to Mil. Std. 883

Contact:
Mr. Larry O'Brien
Telephone: (613) 592-2411

Remotec Application Inc.
P.O. Box 5547
St. John's, Nfld.
A1C 5W4

Remote sensing services and research and development

Contact:
Mr. Richard D. Worsfold
Telephone: (709) 364-1779
Telex: 016-4939

Telesat Canada
333 River Road
Ottawa, Ontario
K1L 8B9

Satellite telecommunications carrier and consulting services

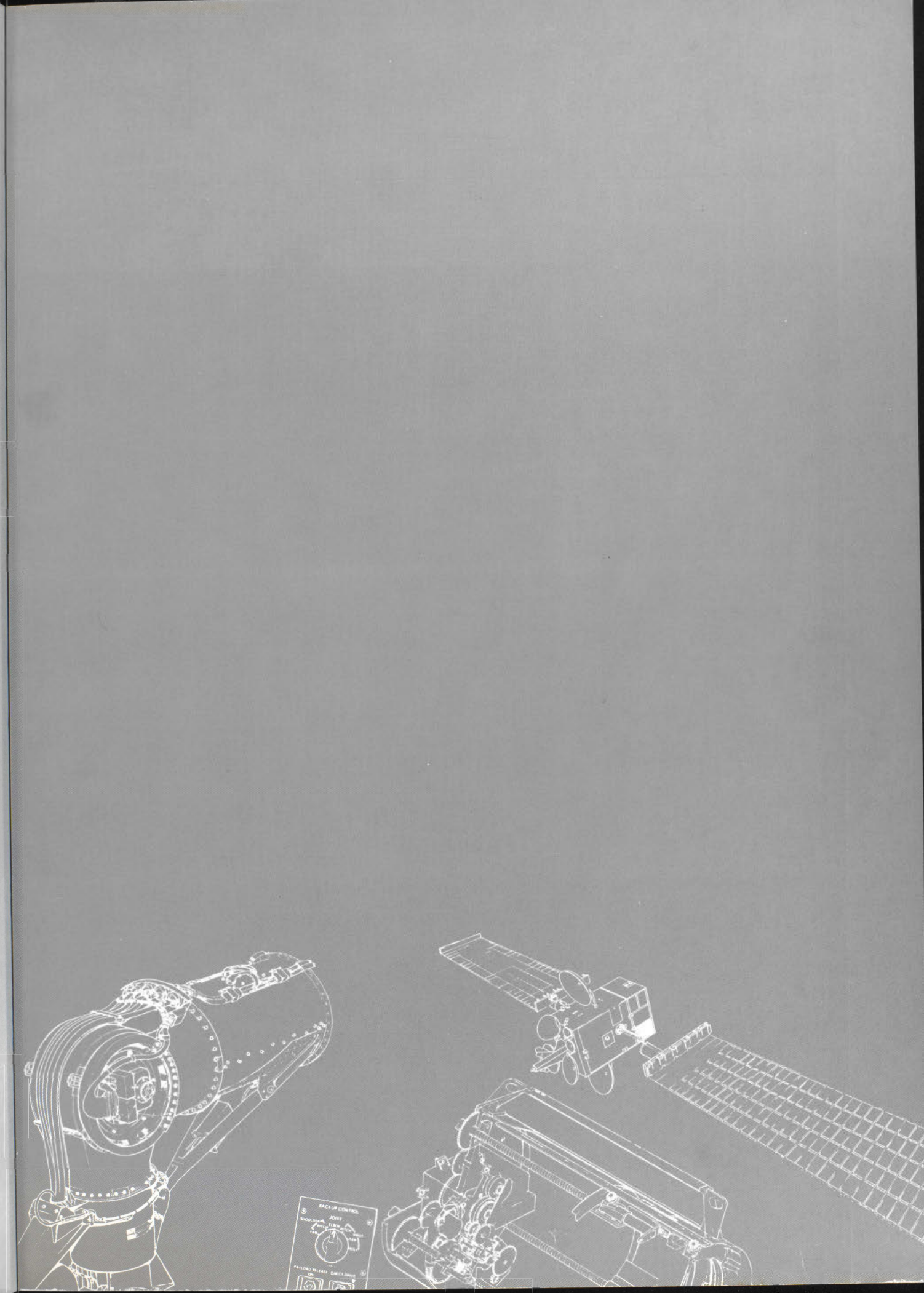
Contact:
Mr. John Almond
Telephone: (613) 746-9852
Telex: 053-3204
TWX: 610-562-1963

Telespace Information Ltd.

28 Flanders Road
Toronto, Ontario
M6C 3K6

Telecommunications, aerospace and information systems consulting

Contact:
Mr. Uriel Domb
Telephone: (416) 667-6308
Telex: 06-986766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