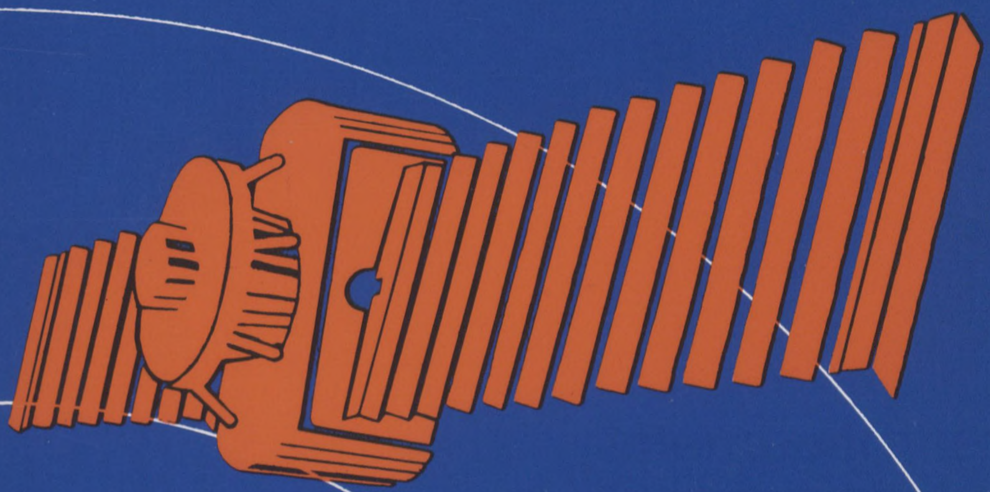
1976 Annual Report

Interdepartmental Committee on Space



INTERDEPARTMENTAL COMMITTEE ON SPACE

8TH ANNUAL REPORT

1976

About the Interdepartmental Committee on Space

The ICS was formed by Cabinet in late 1969, as a committee reporting to the Cabinet Committee on Science Policy and Technology. Its objective was to advise on policy and planning for the Canadian space activities, based on continuing review and assessment, to ensure the coordinated development of government, university and industrial activities, and international cooperation. When the Cabinet Committee on Science Policy and Technology was disbanded in late 1971, the ICS began reporting to the Minister of the newly-formed Ministry of State for Science and Technology. This reporting line and the Terms of Reference of the ICS were reconfirmed in 1974 when Cabinet approved a Space Policy for Canada. Finally, in November 1975, Cabinet directed the ICS to report to the Minister of Communications and on the same occasion gave the ICS the added responsibility of coordinating space procurement activities in Canada, so as to maintain a viable Canadian space industry.

The Committee is composed of senior officials of Departments involved in space activities who are able to speak for their departments on policy matters. At the moment, nine departments or agencies are represented on the Committee with observer status given to two others. The Committee is assisted in its work by three sub-committees which are concerned specifically with the International, Industrial and Scientific Aspects of the space policy.

Finally, to support and service the ICS, a permanent Secretariat was set up in 1976, within the Department of Communications.

This report is in accordance with the Terms of Reference covering the activities of the Interdepartmental Committee on Space

Produced by the ICS Secretariat
November, 1977

ICS ANNUAL REPORT 1976

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PART I - SUMMARY OF THE PRINCIPAL ACTIVITIES OF THE YEAR OF THE ICS

GENERAL

The most newsworthy event of 1976 for the Canadian space program was undoubtedly the launch of the Communications Technology Satellite on 17 January 1976 from the Kennedy Space Center. The CTS, later named HERMES, inspite of some difficulties encountered during its first year in orbit, has performed very satisfactorily. Indeed, plans are now being made to continue operation of HERMES well into its third year. A status report on HERMES is given later in this report.

1976 was also the first year when the ICS was served by a permanent Secretariat. Late in the year, agreement was reached between the ICS and the National Research Council (NRC), whereby NRC's newly-established Space Science Coordination Office (SSCO) would serve as the liaison and coordination point between the space science community and the ICS Secretariat.

A delegation of ICS members, led by the Chairman met with NASA officials in September to review CANADA/USA relations in the area of space. A tangible result of that meeting was that it was agreed that previously bipartite annual Space Science Review meeting between the National Aeronautics and Space Administration (NASA) and the European Space Agency (ESA), would be expanded to a tripartite basis, including Canada.

1976 saw Canada being granted observer status in two of ESA's committees: the ESA Science Program Committee, on which Canada is represented by Dr. P.A. Forsyth, Director of the SSCO; and the ESA Remote Sensing Program Advisory Group (RESPAG), on which Canada is represented by Mr. R. Baker of the Canada Centre for Remote Sensing.

1976 was also a year of re-examination and re-direction of the Canadian space program. A very extensive review of Canada's international relations in the area of space was begun, concurrently with the preparation of a working paper on Canada's long-term plans and priorities. This led to a submission proposing that Canada upgrade its relations with the European Space Agency, while maintaining its association with the USA.

Studies were conducted during the year on the subject of establishing a prime contractor capability in Canada for future Canadian satellites.

Canadian Government expenditures in space for FY 76/77 totalled approximately $47M, somewhat short of the approximate $54M forecast for the year in the last Annual Report. The difference was mainly caused by lower than forecast expenditures in the AEROSAT rogram, resulting from program delays. In FY 76/77, 56% of the total Canadian Government space expenditures (including the subsequent flowthrough to U.S. industry for sub-contracts and components) was spent in Canadian industry, and 12.5% in US industry. The Shuttle Remote Manipulator System was the largest single expenditure item, accounting for roughly 60% of the Canadian Government expenditures in Canadian industry, and for over 70% of the Canadian Government expenditures in US industry.

Outlook for the Future

1977 will see a re-evaluation of Canada's present status in the European Space Agency. It will also likely see decisions taken concerning programs which may be carried out in cooperation with the USA and ESA.

The USA has extended an invitation to Canada to participate in the SEASAT 'A' program. This invitation led Canada to re-examine its coastal and land surveillance requirements for the next decade, and to prepare recommendations regarding Canada's participation in the SEASAT 'A' program, and the possible development of a surveillance satellite in the mid-80s.

Discussions began in 1976 with the USA for the implementation of a cooperative Search and Rescue Satellite program (SARSAT). It is expected that these discussions will be expanded to include other countries such as the USSR and France.

SUB-COMMITTEES

Sub-Committee for the Industrial Aspects of Space Policy

The Sub-Committee held its inaugural and two other meetings during 1976.

A study was initiated of the imbalance of payments with the USA arising from the procurement of space requirements with a view to developing proposals for alleviating this situation. The imbalance, to date, is mainly due to:

a) the placement in the USA of prime contracts for communication satellites by Telesat Canada;

b) the procurement of US launching services for these satellites;

c) the purchase from the USA, for cooperative projects with NASA, of space-rated components and subsystems, and ground-based equipment, for which Canadian sources have not been developed, or for which purchases from Canadian sources would have entailed appreciably greater cost and/or longer delivery times.

The Sub-Committee began a review of the long-term loading of the Canadian space industry, the underlying objective being to promote and schedule new projects so that the resulting level of industrial activity is essentially constant and sufficient to ensure the viability of the industry.

The Sub-Committee reviewed a market evaluation and penetration study of remote manipulator systems by SPAR Aerospace Products Ltd. This study was undertaken to identify space and non-space applications for the technology resulting from the Shuttle Remote Manipulator System, and to formulate strategies for exploiting such applications.

Arrangements were initiated for an annual briefing of the industry on the plans of Government departments and agencies for future space programs.

Sub-Committee for the Scientific Aspects of Space Policy

The Sub-Committee for the Scientific Aspect of Space Policy, which is also the National Research Council's Associate Committee on Space Research, held one meeting during 1976: its 22nd meeting on 16 October 1976. In addition, a space experimenters' meeting was held at the same time as a symposium organized by the Division of Aeronomy and Space Physics of the Canadian Association of Physicists in Calgary on 20 February 1976, and another is planned for London, Ontario in February 1977.

The establishment of the Space Science Coordination Office (SSCO), in response to the recommendations of this Sub-Committee, marks an important development in space science and in the activities of the Sub-Committee itself. The SSCO has stimulated considerable discussion and planning within the space science community and organized the preparation of several reports on matters of importance to the future of this field in Canada. It is felt that the interaction with the Sub-Committee on a regular basis of a small full-time staff committed to the task of planning the future development and coordination of space science, will provide a very important modality for furthering progress in the area of science.

In view of the accelerated pace of planning and the intention of the Sub-Committee to involve itself in all fields of science that could use space techniques, it has been decided that the Sub-Committee should meet twice per year.

One of the challenges facing the Sub-Committee, is to encourage and assist those engaged in astronomy, the life sciences and materials processing, to take advantage of the opportunities offered by the space environment in furthering their field in research. To date, most space research in Canada has emphasized studies of the space environment and the processes that occur in it. While such studies are of considerable interest and importance to Canadians, it is also important that Canada keep abreast of spacecraft technology in all fields of science. The Sub-Committee, in conjunction with the SSCO, can be an important catalyst in stimulating interest and activity in these other areas of science.

Sub-Committee for the International Aspects of Space Policy

During 1976, the Sub-Committee for the International Aspects of Space Policy held seven meetings, its 24th through 28th regular meetings as well as two extraordinary sessions.

The major issues dealt with by the Sub-Committee were developments in the UN Committee on the Peaceful Uses of Outer Space (UNCOPUOS) and its Sub-Committees; a study of Canadian remote sensing policy; the possibility of Canadian participation in the US Large Area Crop Inventory Experiment (LACIE); and the possibility of Canada upgrading its status in the European Space Agency (ESA).

During the year, the Sub-Committee prepared the instructions for the Canadian delegations to the 13th Session of the Scientific and Technical Sub-Committee, the 15th Session of the Legal Sub-Committee, and the 19th Session of UNCOPUOS, the parent committee. Canada played an active and constructive role in these sessions, particularly with respect to those agenda items on the technical and legal questions relating to remote sensing, a possible UN conference on space, and the development of a set of principles to regulate direct broadcasting by satellite. The definition of outer space and the draft moon treaty were considered to be low priority issues for Canada.

A study of Canada's remote sensing policy, in the context of developments in international law and practice, was prepared by Ms. Val. Hood under contract to External Affairs. Besides dealing with political and foreign policy considerations, the study took into account the technical aspects of remote sensing and included a section on LACIE. The study was discussed at a number of Sub-Committee meetings and, while it does not represent official Canadian policy, it has been distributed to members for reference purposes.

At a meeting on 22 March 1976 it was agreed that a Memorandum of Understanding would be drafted which would take into account the aims of Canadian participation in LACIE, and address questions relating to the availability of processed data. Subsequently, a group of officials representing the Departments of Agriculture, Energy, Mines and Resources (CCRS), Industry, Trade and Commerce, and External Affairs held informal discussions in Washington on 28 September with US officials. On the basis of these discussions, the draft Memorandum of Understanding was still being revised at the end of the year.

The question of Canadian association with ESA had first been considered by the Sub-Committee in 1974, and intermittently thereafter. As a result of an initiative by DOC, the matter was reconsidered in the ICS and the Sub-Committee secretariat carried out extensive consultations within the Department of External Affairs or the foreign policy implications of this initiative.

In preparation for a meeting of the ICS with NASA and US State Department officials to re-examine the status of Canada/USA cooperation in space, the Sub-Committee met to discuss the agenda and agree on a Canadian statement.

ICS SECRETARIAT

1976 was the first year of operation of the permanent ICS Secretariat. The first part of the year was largely devoted to establishing the Secretariat, defining functions and classifying positions. Very early in the year, contacts were firmly established with all the member departments at both the member and working levels. Throughout the year, effective liaison was established and maintained with foreign space agencies. Meetings were held and information exchanged with NASA's International Branch, ESA's executive at all levels, and France's Centre National d'Etudes Spatiales (CNES), and contacts were established with Japan through the Japanese Embassy in Ottawa. Effective working relationships were also established with the Scientific Counsellors of the Canadian Embassies in Washington, D.C. and Paris, France and as well as with the ESA office in Washington.

The Secretariat, in collaboration with ICS member departments, arranged a number of information briefings, such as a briefing for a large number of Canadian scientists by ESA officials on ESA's present and future programs; a briefing by ESA's Ariane Program Office to Canadian Government scientists, managers and representatives from industry, describing the status and schedule of the Ariane Launcher Program and the potential availability of Ariane to foreign users; and a briefing by ERNO, a European company, on the Spacelab program (organized in collaboration with the NRC and SPAR Aerospace Products Limited). A briefing by NASA officials on the capabilities of the Space Shuttle was also arranged by the ICS Secretariat and DOC.

The Secretariat has been designated as the point of contact for the annual tripartite NASA/ESA/Canada Space Science Review meetings.

The Secretariat has also actively participated in discussions and working groups examining the costs and benefits of upgrading Canada's status with ESA.

Following the NASA/Canada meeting in Washington in September 1976, the Secretariat initiated a survey of Canada/USA trade in the area of space. The results have been turned over to the Sub-Committee for the Industrial Aspects of Space Policy.

A contract was entered into late in the year to produce a first draft of a brochure, to be published in 1977, describing Canada's capabilities in space. Input material was collected by the Secretariat from the member departments, and a number of Canadian space companies and universities, and turned over to a professional writer for consolidation.

In September 1976, the Space Science Coordination Office of NRC assumed the responsibilities for the scientific liaison and coordination functions on behalf of the ICS Secretariat. It was also agreed that DOC's International Branch would assist the ICS Secretariat to perform its functions in international relations. The Secretariat is in the process of staffing another Assistant Secretary's position.

PART II - PROGRAMS

DEVELOPMENT/APPLICATIONS PROGRAMS - SHUTTLE REMOTE MANIPULATOR SYSTEM (RMS)

Following consultation with Canadian industry and negotiations with NASA, in July 1975 the NRC undertook the design, development, flight qualification, and manufacture of the first flight unit of the RMS for the Space Shuttle Orbiter.

The National Aeronautical Establishment (NAE) of NRC is responsible for the program.

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

The design, development and construction of both the RMS and the SIMFAC are being carried out by a Canadian industrial team. SPAR Aerospace Products Limited is the prime contractor and is also responsible for overall program management, with CAE Electronics Limited, Montreal responsible for the display and control subsystem, Spar Technology Limited (STL)*, Montreal is responsible for the electrical subsystem, and Dilworth, Secord, Meagher and Associates, Toronto, engineering consultants are responsible for the design of special test equipment.

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

The current large payloads envisaged for the Orbiter spacecraft include: the Large Space Telescope, a NASA reusable tug, the Interim Upper Stage, and the Long Duration Exposure Facility (LDEF), all of which will be manipulated by the RMS. It is presently envisaged by NASA that most US launches in the 1980's will be carried out by the Shuttle. Overall, the Space Shuttle System is to have the capability of placing in orbit payloads up to 18.3 m long, 4.6 m in diameter and 30,000 kg mass.

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

The high reliability requirement for the RMS makes it necessary to develop means, during the design phase, to simulate the operation of the system under zero-gravity conditions, as the arm itself cannot be effectively tested in a gravity environment. The general purpose manipulator system Simulation Facility (SIMFAC), located at SPAR's facilities in Toronto, uses

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* Spar Technology Limited is the former Government and Commercial Systems Division of RCA Ltd. of Montreal, which was acquired by SPAR Aerospace Products Limited early in 1977.

mathematical modelling techniques and allows testing in two dimensions under simulated zero-gravity conditions. The facility will also be used in the development of RMS systems for non-space applications.

The successful completion of this project should ensure for Canada:

- world pre-eminence in the most advanced tele-operator technology in space, with potential for applications in other environments, and a high visibility for its products;

- an initial contract with the USA for two complete, two-arm systems. As NASA's initial plans are to build five Orbiter spacecrafts, there is potentially a requirement for a further three complete two-arm systems;

- as envisaged in the Government's space policy, the improvement of the ability of Canadian industry to design and build space systems.

DEVELOPMENT/APPLICATIONS PROGRAMS - COMMUNICATIONS

HERMES

The Communications Technology Satellite (CTS) was launched from the Kennedy Space Center on 17 January 1976. After being manoeuvred by NASA into position in geosynchronous orbit at 116^{o} W longitude, it was handed over to the Spacecraft Ground Control Centre at CRC on 29 January 1976. By 8 February, the spacecraft was reoriented, the solar arrays deployed, the on-board three-axis stabilization system activated, and the SHF communications transponder turned on, followed by turn-on of the 200 W Transmitter Experiment Package. A thorough check-out showed that the spacecraft functioned as specified and, on 17 February, the check-out of the SHF ground terminals and preparations for communications experiments began.

Communications experiments operations were officially inaugurated by the Minister of Communications on 20 May 1976, when the spacecraft was named "HERMES". In Canada the inauguration signalled the start of twenty-six different experiments to be carried out by twenty organizations. There are fourteen experiments with a social emphasis and twelve with a technical emphasis. The social experiments are further subdivided into tele-education, tele-medicine, community interaction, and administrative services.

Typical educational experiments include communications between the widely separated campuses of the University of Quebec; the live exchange and sharing of university courses between Ottawa's Carleton University and Stanford University in California; and communications to and among native communities by the Alberta Native Communications Society (ANCS).

In a typical tele-medicine experiment, HERMES enabled a communications link-up between London (Ontario)/Moose Factory/Kasechewan for the purpose of satellite-aided medical examinations and decision-making diagnosis. Electro-cardiograms, x-rays, ultrasonic imagery and other forms of medical data were transmitted during the course of this experiment, enabling the Moose Factory hospital doctor to obtain the advice of specialists at the hospital at the University of Western Ontario in London. Such procedures could lead to a level of health care previously impossible in remote locations.

Technological experiments are also conducted into propagation studies, modulation experiments, system demonstration and testing, and terminal evaluation. As HERMES is the first satellite to have an operational 12-14 GHz transponder and is the most powerful communications satellite in orbit, it provides a unique opportunity to experiment with applications of this technology to many new services.

On 4 March 1976, shortly after the start of the spring eclipse season, a malfunction of a relay damaged a module in the SHF communications power subsystem. To avoid the possibility of a similar malfunction in the back-up relay, the SHF communications subsystem was placed in a standby condition. On 20 April, at the end of the eclipse season, the redundant power subsystem was switched on and the SHF communications subsystems was turned back on.

A number of other spacecraft subsystem problems were experienced, but none were serious enough to prevent the planned program of experiments from being carried out. In particular, the performance of the primary telemetry transmitter has been deteriorating. A back-up transmitter was switched on, but failed on 15 September 1976. The primary transmitter operates normally for part of each day but, at other times, its transmitted power drops to a low value.

The low power signal can be received by NASA STADAN stations, which provide back-up reception daily during extended periods. Operating procedures are being developed for operation with no telemetry, in case of complete failure of this system. A short circuit occurred on the north solar array on 8 June 1976, which resulted in a loss of 15% of the array power capability; this loss was insufficient to hamper experimentation.

Throughout the year the communications, attitude and reaction control, thermal control and command subsystems operated normally. Moreover, the low requirements for fuel of the on-board attitude control system and the almost perfect launch sequence have contributed to a large fuel reserve. Consideration is being given to using some of the fuel for north-south station-keeping in order to hold the orbit inclination below 0.2°. A low inclination is desirable for operation of many low-cost ground terminals and as an aid to operations in cases of poor telemetry.

On 3 August 1976, NASA declared the mission a success. DOC did the same on 22 October since all primary Canadian objectives had been met and good progress was being made on achieving the secondary objectives.

In view of the interest in the use of HERMES for experiments and the satisfactory performance of the satellite in orbit, both Canada and the USA are actively planning a third year of operations to January 1979.

CTS-B

Following meetings between DOC and ESA at the European Space Technology Centre (ESTEC) in the Netherlands, in July 1976 a task team was set up at CRC, supported by inputs from industry, to study the feasibility of modifying the CTS Engineering Model for use as a new European Communications Payload to be launched on the third test launch of the ARIANE Launcher. However, another satellite was chosen by ESA to fly on this mission.

ANIK-B Experimental Program

The success of the HERMES program showed the need for a follow-on program of extensive pilot projects to develop further the more promising of the communication services which were examined in the HERMES program. To this end, Telesat's ANIK-B satellite, due to be launched in November 1978, will carry a transponder with the necessary 12/14 GHz capability to carry out these pilot projects, in addition to its primary role of carrying the 6/4 GHz payload as a replacement for ANIK-A/F-1.

During 1976, DOC negotiated with Telesat the terms and conditions of a lease agreement for this 12/14 GHz service. It was agreed that Telesat will provide for the use of not less than two RF channels on a continuous basis for two years, after which DOC has the option to extend the service period for up to three additional years. More than two channels will frequently be available, with the exact schedule being dependent on the power loading of the 6/4 GHz commercial channels, and on the capabilities of other parts of the satellite.

Arrangements were made for payment for this use of ANIK-B to be made in two pre-payments, one on 1 April 1977 and the other on 1 April 1978, plus a monthly charge to be linked to satellite performance.

Development of a program of pilot projects using the satellite was also initiated in 1976. The definition phase of that program was completed, and detailed planning of the pilot projects was started. The satellite will be used to carry out a number of such projects, with the objective of developing new services from the experimental stage of the HERMES program to the point where they can effectively use fully-operational commercial satellite systems. Pilot projects are being planned in the areas of telemedicine, tele-education, television program distribution, and public telecommunications. As well, a number of technical experiments will be carried out to investigate new satellite access, assignment, and modulation techniques.

Teleglobe

Teleglobe Canada operates three commercial satellite communications earth stations, two on the east coast and one on the west coast of Canada, which communicate with overseas terminals via the INTELSAT IV satellite.

The east coast earth stations are located near Mill Village, Nova Scotia, and consist of two antennae with the associated communication equipment which are designated as Mill Village No. 1 and Mill Village No. 2 earth stations. The west coast earth station, located near Lake Cowichan on Vancouver Island, is shared jointly by Telesat Canada and Teleglobe Canada, with each having separate antennae and control facilities.

The major event of 1976 for Teleglobe Canada was unquestionably the Olympic games in Montreal, which became the most widely-viewed event in history as a result of record use by Teleglobe Canada of the INTELSAT Global Satellite System for distribution of television coverage. During the games, Teleglobe Canada transmitted approximately 800 hours of television programs via satellite to Asia, Europe, Latin America and Africa. On some days, more than 60 programs were transmitted. During peak periods, as many as five programs were transmitted simultaneously across the Atlantic Ocean via INTELSAT satellites. A transportable earth station at Montreal, installed especially for the games and also operated by Teleglobe Canada, had a capacity of two simultaneous television channels.

In anticipation of the utilization of the 12/14 GHz frequency band in the INTELSAT network, Teleglobe Canada is conducting a study from locations in Quebec and Ontario on the propagation characteristics of the earth-to-space path in this band. The study consists in collecting and analysing experimental propagation data derived from space diversity radiometric measurements and in investigating of signal degradation resulting from precipitation. It is expected that the study will extend into 1978/79.

DEVELOPMENT/APPLICATIONS PROGRAMS - REMOTE SENSING

Department of Energy, Mines and Resources

The Department of Energy, Mines and Resources' Canada Centre for Remote Sensing (CCRS) is the nucleus of a national program in remote sensing, introducing this new technology into the established resource management and environmental monitoring agencies in Canada. Under the guidance of the Inter

Agency Committee on Remote Sensing (IACRS), made up of representatives of the concerned Federal Government departments, the Centre serves federal and provincial departments and agencies, universities, industry and the general public. It coordinates the national effort in conjunction with the working group of the Canadian Advisory Committee on Remote Sensing (CACRS).

The activities of the Centre are concentrated on the Earth Resources Satellite Program, the Airborne Remote Sensing Program and the Applications Program.

In the area of satellite systems, 1976 saw the establishment of an interdepartmental Task Force, which examined the feasibility of a Canadian all-weather earth-observation system to assist in the management and support of maritime activities off the coasts of Canada including the Arctic. The work of the Task Force formed the basis of a December 1976 recommendation that Canada move towards the utilization of all-weather (radar) satellite systems to meet its requirements in the area of management and support of maritime activities off the coasts and in the Arctic in the 1980-2000 time-frame. It was also recommended that experience be gained in this area by participating in the United States SEASAT-A program, a proof-of-concept satellite including an L-band imaging radar.

Recording and processing of data from the LANDSAT and NOAA series of satellites continued throughout the year. The Prince Albert station records LANDSAT multispectral scanner (MSS) data and NOAA very high resolution radiometer (VHRR) data. Regular tracking with a 26-metre antenna of NOAA orbits covering the Arctic, Hudson Bay and the East coast areas, continued on a non-interference basis with LANDSAT. Routine production of LANDSAT black and white quality imagery was transferred to the firm ISIS Limited of Prince Albert, which will also be responsible for the distribution of imagery from the earth receiving station at Shoe Cove, Newfoundland.

LANDSAT and NOAA images continued to be sent in near real time from Prince Albert to Ice Forecast Central in Ottawa. The images are used to prepare ice-forecast charts that are then relayed by HF radio to shipping.

A portable satellite ground station for receiving and processing LANDSAT and NOAA data, designed and constructed by MacDonald, Dettwiler and Associates of Vancouver, B.C. was delivered to Shoe Cove, Newfoundland in November 1976. It will begin routine production of quick-look images and computer tapes from LANDSAT MSS and NOAA VHRR data beginning early in 1977. The station was tested experimentally in Vancouver prior to shipment to Newfoundland.

Department of Fisheries and the Environment

The Department of Fisheries and the Environment (DFE) continued its programs to develop interpretation methods and applications for data from LANDSAT and meteorological satellites. Major industrial activities in support of these programs included development of hardware and software for research into methods applicable specifically to the Boreal Forest Region, design and installation of a facility for decoding and distributing data from Data Collection Systems using LANDSAT and GOES satellites, a design study for a system of small satellites for fisheries surveillance and data collection, and construction of a meteorological satellite reception station based on the design of the portable ground station developed for reception of LANDSAT data. The Atmospheric Environment Service operated three weather satellite ground read-out stations to acquire daily coverage on an operational routine basis and to provide data for research.

DEVELOPMENT/APPLICATIONS PROGRAMS - NAVIGATION

AEROSAT

Canada is participating with the United States and ESA in the AEROSAT program, which is intended to evaluate the use of satellite for Oceanic Air Traffic Control. The objective of the program is to establish the criteria for an aeronautical satellite system which would be fully operational by the mid-1980's. DOT is the Canadian agency responsible for the ground and airborne segment, and DOC for the space segment.

The AEROSAT Council, which is the chief body responsible to the signatories for the execution of the Joint Aerosat Evaluation Program, met twice during 1976. The first meeting was in April in Washington and the second was in Quebec City in November. The major items considered by the Council during the year were: the contract for the satellites; the possible participation of other countries, such as Japan and Australia, in the AEROSAT program; and the working relationships between the AEROSAT Coordination Office (ACO) and the Space Program Office (SPO). At the November session of the Council, the US representatives announced that they were encountering difficulties in obtaining funding authority for the AEROSAT Program.

AEROSAT Space Segment

The request for proposals for the provision of the AEROSAT spacecraft was released by potential bidders on 1 March 1976. Proposals were submitted by the RCA-STAR, TRW-MESH and General Electric - COSMOS consortia on the due date of 15 June 1976, and evaluated by an international Proposal Evaluation Board (PEB). The PEB recommendation of 8 September 1976 to the AEROSAT Space Board that negotiations be opened with General Electric was accepted and subsequent negotiations with the company were carried out by the Space Segment Program Office (SPO). Throughout the negotiations, policy guidance was provided by a Space Board Contract Negotiations Committee, on which Canada was represented by DOC.

The meeting of the Contract Negotiations Committee on 27-28 October was overshadowed by the disclosure that the US FAA could not proceed with the AEROSAT Program until new financial authority was provided by Congress.

The impact of the FAA's funding problems was considered at length on 15 November 1976, at the ninth meeting of the AEROSAT Space Board. For planning purposes, it was decided to assume a Congressional decision by 31 March 1977, with a General Electric start work date on 1 April 1977 on the spacecraft contract. The contract, which was planned to be ready for Space Board approval by 30 December 1976, would contain a notice-to-proceed clause. Accordingly, the contract negotiating team was directed to continue to negotiate with General Electric for a firm fixed price for a 15 January 1977 start work date, and thereafter a price increase for program slippage for each month until 15 September 1977.

AEROSAT Ground Segment

DOT, which maintains and operates the air traffic controls for all international flights using the North Atlantic routes, is developing a ground-communication centre, which will be built in Canada, to provide switching, control, data processing, and computations. The centre, which will be transportable, will be moved to different locations during the course of the program. DOT is also responsible for one half of an aeronautical services earth terminal (½ASET), to be built in Canada; this transportable facility will be of modular design, providing sufficient capacity to make full use of one satellite. A number of transportable electronic test sets, also to be built in Canada, will be used to test and calibrate communication channels, and to monitor the satellite's forward-channel transmissions.

A considerable amount of progress was made during 1976 toward the consolidation of the AEROSAT Common System Configuration requirements, on the Data Link Design, in reviewing the Frequency Registration Document, and in developing the specification for an ASET. All of this involved a considerable amount of work at international meetings.

Contracts were issued late in the year, and will be issued early in 1977 to SED Systems Limited for AEROSAT Voice/Data Modem Development, and to Digital Equipment Limited for computer subsystem equipment.

Some simulation activities were carried out at the DOT Air Traffic Control Simulation Centre, concerning data exchange between the Centre and avionics packages.

AEROSAT Avionics

Progress was made during the year on the functional description of AEROSAT Avionics Subsystem. Canadian Marconi undertook preliminary work on the AEROSAT Avionics Program funded by the Department of Industry, Trade and Commerce.

INMARSAT

In September 1976, a delegation from Canada participated in an international conference of Governments which adopted a Convention and Operating Agreement on the International Maritime Satellite Organization (INMARSAT). It is expected that the signature and ratification process will take 2-3 years. This organization will come into effect 60 days after the date on which states representing 95% of the initial investment shares have become parties to the convention.

The purpose of the organization is to deploy and operate satellites for improving maritime communications, thereby assisting in improving the communications for distress and safety of life at sea, efficiency and management of ships, maritime public correspondence services, and radio location capabilities. The organization will seek to serve all areas of maritime communications.

Canada has signified its intention to initiate domestic procedures which would permit its membership in the INMARSAT Organization. It is participating in the work of an interim Preparatory Committee, set up to perform studies and make preparations which will facilitate the establishment of the maritime satellite system when the organization comes into effect.

The first meeting of the Preparatory Committee, to be held in London, England in early January 1977, will be attended by a Canadian delegation headed by the Department of Transport (DOT). The principal objectives of this meeting are the formation of technical, organizational and economic panels which will consider various criteria for the establishment of the INMARSAT Organization and the space segment. Canada intends to be represented on all these panels which will meet in May and June 1977 and report back to the next Preparatory Committee meeting scheduled for October 1977.

The Interdepartmental Committee on Maritime Satellites (ICMS) considers all matters concerning Maritime satellites, including Canada's participation in the INMARSAT Organization. The ICMS approves all instructions for the delegations attending the Preparatory Committee and Panel Meetings.

Cabinet approval for Canada to participate in INMARSAT will be sought in the near future.

NAVSTAR/GPS

The US Department of Defense has initiated a $750 million research and development program on the Global Positioning System (GPS), often referred to as NAVSTAR/GPS, to satisfy the navigational requirements of the US Armed Services. R&D, to date, promises accuracies to the user that surpass anything currently available, along with high resistance to jamming. Initial operation is scheduled for 1979, and full operation by 1984.

GPS will be a world-wide navigation system based on 24 satellites continuously broadcasting time and satellite location data to users. Derived position accuracies better than ± 10 m in a protected, jam-resistant mode, and ± 45 m in an unprotected mode will be available to users. This system represents the next generation of navigation systems and is expected to eventually render many current systems obsolete or redundant.

The possibility and economic feasibility of Canadian industrial participation in the development and procurement of the NAVSTAR user equipments have been explored in response to the Canadian Defence Management Committee direction. Discussions have taken place with staff of the project office of the USAF Space and Missile Systems Organization (SAMSO), Los Angeles, and most of the early system and equipment specification have been provided by SAMSO.

A Memorandum of Understanding has been drafted to cover cooperative R&D and the exchange of technical information. Canadian elements of R&D would include designing and developing one or more user equipments, investigating propagation anomalies in the auroral zone, user equipment antennae design, and the application of strapdown inertial techniques. Presently, funding has been allocated by DND for a general study and the design and construction of systems developmental prototype equipment.

The prototype development will be carried out by Canadian industry while the remaining work will be carried out at the Communications Research Centre (CRC) under existing contractual arrangement with DND. The National Aeronautical Establishment (NAE) and possibly the Aeronautical Engineering and Testing Establishment, are to be involved in airborne testing of user equipment.

The inauguration of NAVSTAR/GPS operations is expected to lead to progressive phasing out of older navigation systems. This should lead ultimately to operational savings of money and personnel by DND. Participation in the project will enable Canadian industry to provide user equipments satisfying Canadian Forces specifications.

The Department of Transport is also examining the possible commercial and civil applications of the NAVSTAR/GPS system.

MARISAT

The US MARISAT satellite system consists of three satellites, all launched in 1976, with one each over the Atlantic, Pacific and Indian Oceans. DOT has installed a MARISAT terminal on one of its ice-breakers and undertook some trials with the system while the ship was operating in the eastern Arctic. Voice, telex and facsimile communications via the satellite were tested and found to be operationally satisfactory, and of better quality than can be achieved with the present HF circuits. These trials showed that satellite communications are a great potential benefit to the maritime community.

SCIENTIFIC PROGRAMS

General

In 1976, the National Research Council established the Space Science Coordination Office to plan and coordinate the Canadian Space Science Program. The Space Research Facilities Branch of the NRC operates various science-oriented facilities such as rocket ranges and balloon launching stations. The ISIS satellites are still being used actively in Canada and throughout the world. Space activity associated with these facilities is described in Part III.

Space research has been defined as research *on* space, research *from* space and research *in* space. Canada's main involvement to date has been in the first of these; Canada's participation in the second, remote sensing in the earth and observation of astronomical objects beyond the earth's environment is more recent and there is little Canadian experience, to date, in the third - such as space processing which depends on the unique physical conditions provided by the space vehicle and by the space environment.

There are, at present, approximately seventy projects being carried out in more than 13 Canadian universities. Almost all of these are in the areas of auroral anomalies and upper atmosphere physics. These research activities are described in detail in a publication of the Space Research Facilities Branch of the NRC entitled: *"Space and Upper Atmosphere Programs in Canada 1976"*, copies of which are available from the NRC and the Secretariat of the ICS.

The Herzberg Institute of Astrophysics of the National Research Council of Canada is also carrying out a program of space research, in particular in the area of planetary sciences (auroral phenomena, studies of cosmic dusts, meteor research, meteorite recovery); space physics (auroral particles, magnetospheric studies, cosmic ray studies); and astronomy (long-baseline interferometry by satellite links, daily observations of solar radio flux and optical solar observations). Detailed descriptions of these activities are also contained in the above-cited NRC publication.

SPACELAB

In June 1976, a joint proposal by the Massachusetts Institute of Technology (MIT) and the Canadian Defence and Civil Institute of Environmental Medicine (DCIEM) was presented to NASA to carry out vestibular experiments in SPACELAB I.

Studies have shown that 25% of all aircraft accidents involving fatalities are caused, at least in part, by disorientation. The mechanisms causing disorientation in pilots are understood to some extent and it is known that the vestibular system of the inner ear and brain stem is involved as a prime mover. In the SPACELAB experiments, DCIEM will expand its investigations of the basic mechanism of the vestibular systems, with resulting benefits to flight safety.

No formal definition of responsibilities or division of workloads between the scientific programs for SPACELAB I has been agreed upon between NASA and other participants. However, on the basis of preliminary discussions, it is probable that DCIEM will be responsible for three of the six experiments proposed in the joint MIT/DCIEM proposal. These experiments are designed to assess the perception of linear acceleration, to determine awareness of body image and spatial localization, to study susceptibility to motion sickness, and in collaboration with a McGill University scientist, to investigate muscular activity during a "hopping" experiment. Responsibility for the remaining experiments is divided between MIT and the European Space Agency (ESA).

Scientists will perform the experimental programs on-board SPACELAB. They will be cross-trained to perform experiments in other fields for which a payload specialist is not on-board. Dr. K.E. Money (DCIEM) and Capt. R.C. Malcolm (CF-DCIEM) are the two Canadian candidates astronauts who could be selected by NASA as SPACELAB on-board payload specialists. Final selection of the payload specialists will not be made until 1978 or 1979.

It is considered that the involvement of Canadian scientists in the studies of vestibular physiology aboard SPACELAB will be of considerable benefit to the Canadian Forces and to Canada generally in that useful scientific knowledge will result and will have practical benefits in the fields of flight safety and human performance. In addition, active participation by DCIEM scientists in SPACELAB will provide a basis of experience and knowledge which will be readily available to other Canadian scientists in space projects.

GEOS-3

The GEOS-3 satellite carries a radar altimeter which is capable of measuring, with great precision, the distance from the satellite to the earth's surface. Analysis of the return pulse provides information on wave height.

Canadian experiments using GEOS-3 are aimed at computing tides and mean sea level, computing the ocean geoid in the vicinity of Canada, and testing the ability to measure wave height. Canadian proposals were officially accepted by NASA in December 1975.

Under the agreement with NASA, Canadian scientists are considered Principal Investigators in this program. During 1976 NASA was asked to extend the terms of this agreement to include data dissemination to a FRG scientist who is assisting the Canadian team with measurements of the spacecraft's orbit. The Canadian team of investigators is aiming for a final report in June 1978.

Long Duration Exposure Facility (LDEF)

The Long Duration Exposure Facility (LDEF) is being developed by NASA to accommodate, using the Shuttle, many technology, science and application experiments which require a free-flying exposure to space.

The LDEF is a reusable, unmanned, gravity-gradient stabilized, free-flying structure on which many different experiments can be mounted. It provides an easy and economical means for conducting experiments in space.

The LDEF will be placed in an Earth orbit by the Shuttle, where it will remain for an extended period of time. A subsequent Shuttle flight will retrieve the LDEF and return to Earth, so that experiments can be removed and returned to the experimenters. Experiments for LDEF can be either passive or active. For passive experiments, the data measurements will be made in the laboratory before and after exposure to the space conditions. For active experiments, the data gathering may require some active systems such as power, data storage, etc.

In orbit, the Remote Manipulator System (RMS) of the Shuttle Orbiter will remove the LDEF from the payload bay, and release it according to specified limits of orientation and angular velocity. After the planned exposure of six to nine months in orbit, a subsequent Shuttle flight will capture and restow the LDEF within the payload bay for the return to Earth. Upon landing, LDEF will be removed from the Shuttle payload bay and the experiments will be removed from LDEF and returned to the experimenters for analysis.

To date, an experiment has been proposed to NASA by Prof. R.C. Tennyson of the University of Toronto Institute of Aerospace Study. Although no official response has been received from NASA, it appears that the proposal is rated highly and stands good chance of being accepted.

FUTURE PROGRAMS

Multipurpose UHF Satellite (MUSAT)

Work continued during the past year on the definition of user requirements, consideration of system options, and assessment of the feasibility of a Multipurpose UHF Satellite intended to satisfy a wide range of Canadian Government communications requirements.

A major effort is being devoted to the technical feasibility of the transponder and antenna system which would be required for MUSAT. Due to the nature of the communications traffic and the frequency allocation for the UHF band, UHF satellite transponders are susceptible to interference problems which can seriously degrade this effectiveness. The extent of such problems and possible performance and reliability hazards are the principal subjects of this study.

The study also includes an evaluation of components, and the construction and testing of a "brassboard" model of the transponder. The fabrication of this "brassboard" model was initiated in August 1976 at the conclusion of a systems engineering study which defined the transponder and antenna requirements.

The proposed MUSAT communications system requires a highly portable earth station suitable for use in remote locations. Initial cost and implementation studies identified the difficulty of achieving an adequately portable antenna, as well as the potential scheduling problems due to the long development times associated with some components. As a consequence, an advanced development phase has been initiated. Currently, a study of possible antenna configurations and their implementation is underway. A study of Demand Assignment Controller concepts was recently completed. At the conclusion of the study of present systems engineering considerations of the earth terminal, hardware development of selected earth station subsystems will commence.

Systems engineering activities during the past year include the support of the above activities, engineering related to frequency plan coordination, the development of system models, the prediction of the performance of the proposed system and a design study of a general purpose "bus" (spacecraft) to accommodate the UHF payload. Numerous short studies on topics such as frequency control, small sensor data readout, propagation considerations, and possible modulation techniques, have been performed.

SARSAT

The Canadian Government organization responsible for Search and Rescue (SAR) have striven to improve their ability to locate missing aircrafts and vessels, and to rescue distressed personnel from disaster sites. Canada's vast expanse, with its varied geography and frequently inhospitable weather, places major demands and extreme constraints on such activities. Technological advances in electronics and communication already have provided important aids for these responsibilities, in particular, the relatively inexpensive Emergency Locator Transmitters (ELTs) which are now in widespread use. As of July 1975, DOT requires that all aircraft, except those of large commercial carriers, carry ELTs. Satellites offer the possibility of continuous monitoring for ELT transmissions.

Complete monitoring of Canada by satellite can only be accomplished effectively by utilizing near-polar orbits. The swath of a suitable satellite could cover each point of the earth at least every twelve hours, while two satellites would cover it at least every six hours, and four at least every three hours.

During 1975, DOC/CRC began experiments using the AMSAT (OSCAR) satellite to verify a concept of using derived doppler information to determine the location of an ELT. During the same period, DND and CRC became aware that NASA was conducting studies on the same concept, and began informal discussions for the purpose of examining the possibilities of a joint program.

These discussions with NASA, which continued in 1976, determined that a joint program was technically feasible and should be beneficial to both parties. Subsequently, the matter was reviewed at a meeting of the ICS, where it was decided that Canada should formally suggest to the USA that a technical dialogue be started to explore the possibilities of such a joint program. On 2 November 1976, a letter was sent to NASA suggesting that formal discussions begin between Canada and the USA on a Search and Rescue satellite program. The NASA portions of the program was recently approved by Congress.

While these technical discussions between DND/DOC and NASA are continuing with the aim of developing a basis for a joint Memorandum of Understanding on system development, a submission seeking approval for the program and its funding will be prepared by DND, DOT and DOC.

LANDSAT-C

This US satellite, the third in the LANDSAT series, is scheduled for launch in early 1978. Compared to its LANDSAT-1 and 2 predecessors, its main features are the addition of a fifth channel in the thermal IR band, and a modification of the Return Beam Vidicon (RBV) system designed to provide an improved resolution of approximately 30 meters. The CCRS is currently setting up the necessary equipment in its ground stations to permit reception of LANDSAT-C data.

LANDSAT Follow-On

This is the continuation of the LANDSAT series, with an evolution towards operational systems. One of the main features of the LANDSAT Follow-On series is the addition of a Thematic Mapper, a form of multi-spectral scanner with greatly improved spatial and spectral resolution. The first launch is scheduled for 1981. The main ground station requirements for this satellite include S-band antennae to match its down-link frequency, which will differ from that used for the earlier members of the series, high speed recorders, and improved processing and analysis equipment to handle the increased data rates associated with finer resolution. CCRS is maintaining close contact with NASA regarding this program.

SEASAT-A

This will be a proof-of-concept NASA satellite, carrying a variety of microwave instruments, including a synthetic aperture radar with 25 m resolution, a radiometer and a scatterometer. Application areas to be studied include all-weather observation of ice, sea-state, sea surface temperature and wind speed, as well as land applications in agriculture, forestry and geology. The satellite is scheduled for launch in May 1978.

The CCRS proposes to readout SEASAT-A at Shoe Cove, Newfoundland, thus covering the north-west Atlantic, Canada's East coast and the Eastern Arctic.

A notable technical challenge is the processing in near real-time of the enormous amount of data generated by the radar, in order to satisfy applications requirements for up-to-date information. An invitation was received from NASA to participate in the SEASAT-A program, and an affirmative reply is being prepared.

European Earth Observation Programs

CCRS maintains close contact with ESA and ESA member-state programs for future earth observation satellites. Programs now being considered in Europe include a synthetic aperture radar satellites and a French proposal for a high performance satellite operating in the visible/infra-red spectrum. It is possible that both payloads will be combined on one vehicle, which might be launched in the period 1983-85.

SPACELAB experiments are also of interest, including the metric camera experiment, a high-resolution high accuracy device intended for cartographic applications.

SURSAT

Recent studies by an Interdepartmental Task Force indicate that an all-weather earth observation satellite system would be of great value to Canada in the areas of maritime applications, ice reconnaissance, and land-based activities. Such a system would be built around satellites mainly carrying a synthetic aperture radar and a high resolution visible/IR multi-spectral scanner. The most economical approach toward the availability of such a system to Canada would be Canadian participation in a global system which might include as initial partners the USA, Europe and Japan. It is a definite possibility that by 1985 there will be a system of approximately four all-weather satellites in orbit.

It is, therefore, important that Canada should participate, within its means, in the development of such a system if the system is to take into account Canadian needs. In addition, financial participation in the development of the system will result in industrial benefits to Canada, as opposed to later forms of participation which could take the form of user fees involving no industrial returns.

In view of the fact that a global system would be assembled from satellites built by different agencies, the main user-oriented features of the satellites such as downlink frequencies and data formats should be standardized. Complementary payloads and orbits should also be conceived. This is a challenging but not impossible task and Canada is well placed to assist in the process, partly because of the acknowledged competence in the field of user-oriented receiving stations, the common denominator between the various types of space systems.

OTHER PROGRAMS

SPADATS (Space Detection And Tracking)

SPADATS (Space Detection And Tracking) is a US Air Force (USAF) program. Canada is involved in SPADATS through NORAD, which has operational responsibilities for the system. There are two NORAD monitoring systems in Canada, one at Cold Lake, Alberta and the other at St. Margarets, New Brunswick. These facilities are equipped with Baker Nunn cameras which were developed by the Smithsonian Institute. As photographs are taken, these cameras move in synchronization with the stars, the latter consequently appearing as points of light on the film. Any non-astronomical source in the sky, such as a satellite, shows up as a streak.

The St. Margaret's, N.B. station was officially opened on 9 November 1976. The Baker Nunn camera with which it is equipped is now operational. The other equipment at this site, the Space Object Identification (SOI) system, an optical and electronic system which is unique to the St. Margaret's station, is expected to be in operation in early 1977. Optical SOI is the analysis of the light reflected from a space object. As for radar return, this signal will vary as the reflection cross-section of the object changes. The scintillation parameters of this signal will be determined by the size, shape and rotation of the reflecting surface. Variation of intensity (or lack thereof in a case of a stable object) is measured by a sensitive photometer placed at the focus of a telescope.

PART III - FACILITIES

THE DAVID FLORIDA LABORATORY

The David Florida Laboratory is maintained by DOC as a national facility for the environmental testing and integration of satellites and space hardware.

The facilities include four thermal vacuum chambers: 3 m dia. x 9 m high; 2.5 m dia. x 2.5 m long; 1.2 m dia. x 2.5 m long; and 1m dia. x 1m long. The vacuum capabilities vary, depending on the chamber and test article outgassing, from 1×10^{-8} torr to 1×10^{-6} torr. Temperatures can be controlled over the range -195°C to +150°C in all chambers. An automated temperature scanning and archival system can monitor up to 160 channels of data. All temperature data is available in digital format for further data reduction subsequent to completion of testing.

The vibration facilities include a 5,450 kg #force sinusoidal, 4,540 kg # force random system and a 2,720 kg #force sinusoidal, 2,400 #force random system, operating over the range of frequencies 2 Hz to 2,000 Hz. Both systems have the capability of monitoring up to 54 accelerometer channels simultaneously. A real-time analyzer is available for data analysis.

A screened room and related equipment are also available for RFI/EMC testing to MIL.STD. 461/462. The RF facilities also include two shielded anechoic chambers; one 4m x 4m x 2m with an average reflection coefficient of -35 dB at X-Band, and another 7m x 7m x 7m with an average reflection coefficient of -50 dB over the frequency range of 1 GHz to 20 GHz. The latter facility is integrated into a 150m antenna range including a 675 kg antenna positioner and appropriate remote controls necessary to achieve efficient economic operation.

A High Bay clean-room integration area, 30m x 12m x 10m high, is utilized for assembly and integration of satellites and space hardware. This facility has a 5 metric ton overhead crane, appropriate air-cleaning equipment necessary ground support facilities, and an interconnecting 2¼ metric tons crane system, facilitating the movement of satellites throughout the environmental and integration areas.

During FY 76/77, environmental testing was performed for the Space Shuttle Remote Manipulator System, ANIK-B Transponder System, and research prototype Rigid Panel Solar Arrays. The RF facilities were heavily used of antenna studies for DOC, DOT and DND.

NATIONAL RESEARCH COUNCIL (NRC)

The Space Research Facilities Branch

The Space Research Facilities Branch (SRFB) of NRC supports Canadian space science by planning and conducting rocket and balloon launching campaigns, as approved by the Canadian Sounding Rocket Planning Group (CSRPG), and by operating permanent research stations.

The Engineering Section of the SRFB implements the sounding rocket program by procuring rocket motors and monitoring the design and fabrication of instrumented rocket payloads by Canadian industry. During 1976, SRFB launched four major sounding rockets as part of the Canadian space science program. A Black Brant IV-B, a Black Brant V-B and a Black Brant VI-B were launched from the Churchill Research Range, and a Black Brant V-B was launched from Woomera, Australia. These rocket launches were carried out for scientists from Canadian Government organizations such as the Herzberg Institute of Astrophysics, and for scientists from Canadian universities.

A successful inaugural test flight of the Nike Black Brant sounding rocket system in December 1975 led to the acceptance of this vehicle of scientific research. It is planned that the Nike Black Brants will be used for three scientific flights during 1977.

Churchill Research Range (CRR)

The Churchill Research Range, Churchill, Manitoba has been operated by the SRFB since 1965. In addition to the regular Canadian scientific rocket launching activities, CRR operates various ground-based instruments on a continuing basis, provides rockets as part of the North American Synoptic Network and provides some services for balloon launches. In addition to the four Canadian rockets launched during 1976, CRR supported eight major US sounding rocket launches on behalf of NASA and the US Air Force Geophysical Laboratories, and one Canadian scientific balloon launch.

Great Whale Geophysical Station

SRFB also operates this geophysical station at Poste de la Baleine, Quebec. The instrumentation comprises of riometers, auroral radar, all-sky cameras, magnetometers and Ultra Low Frequency (ULF) micropulsation instruments.

Scientific Balloon Launching Facility

In response to a need for scientific balloon launching facilities for Canadian scientists, SRFB, with cooperaion and support from the Atmospheric Environment Service of Environment Canada, established a complete mobile facility which became operational in 1976. SED Systems Limited of Saskatoon, is responsible for the operation and maintenance of the facility. The inaugural flight from Churchill in July carried a cosmic-ray telescope for Dr. Bland of the University of Calgary. A major campaign was carried out successfully from Yorkton, Saskatchewan in August. SRFB is planning to launch a balloon in February 1977 from Cold Lake, Alberta. This launch will mark the first winter attempt to launch a large balloon from Canadian territory.

Herzberg Institute of Astrophysics

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

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

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* Dr. G. Herzberg, a scientist on the staff of the NRC, was awarded the Nobel Prize for Chemistry for his work in the field of Molecular Spectroscopy.

CANADA CENTRE FOR REMOTE SENSING (CCRS)

CCRS has two earth receiving stations, one in Prince Albert, Saskatchewan, and the other in Shoe Cove, Newfoundland, both capable of receiving and recording on magnetic tape LANDSAT and NOAA satellite data. The Prince Albert station has the capability to process and distribute high resolution LANDSAT Multispectral Scanner (MSS) black and white images, has a "quick-look" capability for producing near real-time medium resolution imagery, and produces microfilms and microfiche. The Shoe Cove station has the capability of processing and distributing medium resolution black and white images and of producing computer compatible magnetic tapes.

CCRS also features (i) an Image Production System for satellite data capable of generating high resolution black and white film from bulk tapes, of making radiometric and geometric corrections and of generating colour composites; (ii) a General Purpose Data Processing system, exhibiting large scale computing batch processing of remote sensing data, and also capable of providing computer support for remote sensing users inside and outside the Centre; (iii) an application science laboratory dedicated to the development of new techniques for the analysis of remotely-sensed data and to the provision of assistance to resource managers and researchers; (iv) a sensor and systems development laboratory providing for the engineering and of on-board computer and data acquisition systems, sensor interfaces, navigation systems and aircraft modifications. CCRS also possesses four extensively modified aircraft dedicated to experimental remote sensing. These consist of two DC 3 aircraft, one Falcon 20 and one Convair 580.

PART IV - INTERNATIONAL RELATIONS

UNITED STATES OF AMERICA (USA)

In September 1976, a delegation of eight government officials representing the ICS, led by Dr. Chapman, Chairman of the ICS, met with officials from the International Branch of NASA. The purpose of the meeting was to examine ways by which Canada could become more involved in the planning process of NASA programs and to open discussions on the subject of trade flow between Canada and the USA in the area of space. As a result of that meeting, it was agreed that the previously bipartite annual Space Science Review meetings between ESA and NASA would be expanded to a tripartite basis, including Canada. A similar kind of relationship in the area of space applications was not established. The discussions on the subject of trade flow between Canada and the USA were only of a preliminary nature. Data has since been collected by the ICS Secretariat regarding the flow of trade between the USA and Canada in the area of space and has been turned over to the Sub-Committee for Industrial Aspects of Space Policy which is expected to make recommendations to the ICS in 1977.

During 1976, Canada and the USA initiated discussions with the aim of examining the possibility of developing a joint program for a search and rescue satellite. These discussions have led to the point where it is expected that a Memorandum of Understanding will be signed sometime in 1977 covering a joint search and rescue satellite program between the USA and Canada. It is also expected that other countries such as the USSR and France may join in this venture.

The Department of National Defence has also been carrying on discussions with the U.S. Department of Defense which regard to participation in the U.S. NAVSTAR/GPS Program. It is also expected that a Memorandum of Understanding will result sometime in 1977.

EUROPEAN SPACE AGENCY (ESA)

The major event of 1976, concerning Canada's relationship with ESA has undoubtedly been the complete re-assessment of Canada's status with regard to the Agency. This re-assessment was carried out over many months by study groups of the ICS and is expected to lead to exploratory discussions with the European Space Agency with a view to upgrading Canada's relationship with ESA. The Minister of Communications is expected to make a declaration to that effect at the Ministerial Meeting of the ESA Council in Paris in February 1977.

Canada participated, as an observer, in ESA's Science Program Committee (SPC) and in the Remote Sensing Program Advisory Group (RESPAG).

Discussions were held with the Europeans on the possibility of launching the CTS Engineering Model Spacecraft with the European Transponder on one of the test flights of the ARIANE Launcher. Although it was later decided not to resort to this possibility, the many meetings and working groups made up of engineers and scientists from ESA and Canada demonstrated the feasibility of such a project and caused many worthwhile contacts to be established.

FRANCE

DOC participated in the setting up of teleconferences between Quebec and France in December 1976, using the Franco-German Symphonie satellite.

The Department of External Affairs and of Energy, Mines and Resources negotiated an inter-agency agreement with the Centre National d'Etudes Spatiales (CNES) in France, in the areas of remote sensing.

COSPAR

The NRC is the national body in Canada which is a member of COSPAR. The NRC Associate Committee on Space Research (ACSR), which is also the Scientific Sub-Commitee of the ICS, is Canada's national committee for interaction with COSPAR. The present Chairman of the ACSR acts as the Canadian representative to COSPAR and is also the chairman of COSPAR's finance committee. The present secretary of the ACSR is the Canadian national contact for matters relating to COSPAR.

PART V - FINANCES

The financial summary data for the member departments and agencies that reported space expenditures for FY 76/77 and a space budget for FY 77/78 are shown in tabular form in Tables 1(a) and 1(b) and in graphical form in Figures 1 to 5.

It will be noted that the expenditures and budgets are on the one hand divided into In-House (internal), Industry, and University and on the other hand into A-(Space Systems); B-(Ground Stations & Earth Terminals) and C-(Data Processing & Analysis). The In-House expenditures are further separated into Capital, G&S and Salary, while the Industry expenses are divided into Canada, USA, and Others. The division between Canada, USA and Others was done in most cases, at the contract level. Accordingly, subcontracts to foreign firms may appear as Canadian expenditures. (To what extent this occurred cannot be estimated). The A, B and C breakdown was made on the basis of discussions with IT&C and is intended to reflect the different segments of the Canadian space industry. This data does not include expenditures and budgets for space-related procurements by Telesat Canada, Teleglobe Canada and the CBC.

Tables 1(a) and 1(b) show expenditures of approximately \$47M in FY 76/77. This is an increase of 9% over the FY 75/76 space expenditures of \$43M and is also 14% less than what had been forecast in last year's annual report for the same period. This difference is largely the result of under-expenditures caused by delays in the Aerosat program. The tables also show budgeted expenditures of \$65.4M for FY 77/78, an increase of 39% over the current year. This \$65.4M includes \$9M for the DOC share of the ANIK-B satellite transponder.

This is the first time that the information on Canadian Government expenditures in space is broken down as shown in Table 1. As such, it provides a snapshot of where the expenditures were made in FY 76/77 and how they are budgeted for FY 77/78. The sample is too small, however, to conclude on trends which could be inferred by the figures. Any extrapolation would be based on too small a sample size (2 years) to be meaningful.

Figures 1, 2 and 3 show graphically, the proportions between the various expenditure categories used in Tables 1(a) and 1(b). The Canadian space expenditures are shown to be very dependant on one or two major projects. In FY 76/77, the Shuttle RMS expenditures predominates, and in FY 77/78, in addition to the RMS, the contract with Telesat for ANIK B becomes an important portion of the Government-planned expenditures. Throughout the text, these two projects will repeatedly be isolated to show the magnitude of this dependance.

Figures 1(a) and 1(b) show, for both fiscal years, the division of expenditures between In-House, Industry and University. It is evident from these figures, that the bulk of the Canadian Government's expenditures in space is spent in industry: 68% in FY 76/77 and 77% in FY 77/78. Approximately 56% of the total Canadian space expenditures for FY 76/77 and 65% for FY 77/78 is spent or budgeted in Canadian industry versus 13% in FY 76/77 and 11% in FY 77/78 in U.S. industry. In FY 76/77, the Shuttle RMS accounted for 66% of the expenditures in Canadian industry, and for 75% of the expenditures in the USA. In FY 77/78, if one excludes the $9M ANIK-B contract to Telesat, since the work in Canada will be largely completed in 1976, the Shuttle RMS still accounts for 53% of the expenditures in Canadian industry and for 60% of the expenditures in the USA. For both fiscal years, the expenditures in university space research amount to approximately two to three percent of the total Government expenditures in space. The In-House expenditures are budgeted to increase by approximately 4% in FY 77/78 while the industry expenditures are budgeted to increase by 57% and the University expenditures to decrease by 25%. While this 25% reduction is due primarily to the fact that, in FY 76/77, DOC had greatly expanded their University space research program by funding a large proportion of the CTS experiments, it is, in a way, also caused by the fact that the NRC university grants program has remained at essentially the same level for a number of years.

Figures 2(a) and 2(b) give a breakdown of expenditures by type of industrial activity: A-(Space Systems); B-(Ground Stations & Earth Terminals); and C-(Data Processing & Analysis). Figure 2(a) shows that for FY 76/77, close to 70% of the total Government expenditures were expended for space systems, with approximately 20% for ground stations and earth terminals, and only approximately 10% for data processing and analysis. These percentages change to A-(40%); B-(39%); and C-(21%) if one excludes the Shuttle RMS project, which represents the major portion of the space systems expenditures.

For FY 77/78, this pattern is maintained: more than 72% is budgeted to be expended for space systems (A), 19% for ground stations and earth terminals (B), and 10% for data processing and analysis (C), with the major portion of the expenditures still being budgeted for the Shuttle RMS program. Again, excluding the Shuttle RMS program, the percentages become A-(58%); B-(28%); and C-(14%). The space systems expenditures are budgeted to increase by 48% in FY 77/78, the ground stations and earth terminals expenditures by 24% and the data processing and analysis expenditures by 15%. Again, if the $9M for ANIK-B in 77/78 is excluded, the increase for space systems is reduced to 20%.

Figures 3(a) and 3(b) show the breakdown of expenditures by member departments and agencies for both fiscal years. The figures show that in FY 76/77, NRC spent 57% of the total Canadian budget in space and 42% in FY 77/78. Closely following is DOC with 18% in 76/77 and 34% in 77/78. The predominance of NRC is obviously caused by the Shuttle RMS project, since, excluding the RMS project, NRC's expenditures would be only 20% of the total expenditures in 76/77 and 12% in 77/78. Similarly, the large increases in DOC from 76/77 to 77/78 is due primarily to the $9M ANIK-B contract to Telesat Canada.

It is apparent from the previous figures that the Shuttle RMS project is predominant. Although this emphasis is diminishing in FY 77/78 with the emergence of the ANIK-B and of the AEROSAT project expenditures, this overall pattern of emphasis on one single large project is still expected to continue for a few years to come, since the present level of funding cannot support more than one large project at a time.

Figure 4 shows, in bar chart form, the expenditures of member departments and agencies in both FY 76/77 and 77/78, with only the major projects being highlighted. This figure presents differently the same information shown in Figure 3.

Finally, Figure 5 shows the Government's expenditures in space since 1969/70. It is worthwhile to note that while the in-house expenditures have not varied greatly over the years, the industrial expenditures have risen steadily, showing clearly that the Government's policy of transferring high technology work to industry has been applied in the space field.

SUMMARY OF TOTAL SPACE EXPENDITURES INCURRED
BY MEMBER-DEPARTMENTS AND AGENCIES
(in thousands of dollars)

	1976/77				1977/78			
	A	B	C	TOTAL	A	B	C	TOTAL
IN-HOUSE - Capital	1506	1540	543	3589	1143	747	330	2220
G&S	847	1060	970	2877	1250	1579	1292	4121
Salary	2516	2673	1576	6765	2840	2942	1636	7418
Sub-Total	4869	5273	3089	13231	5233	5268	3258	13759
INDUSTRY - Canada	21855	3466	893	26214	34822	5985	1650	42457
USA	4761	710	482	5953	6373	738	350	7461
Others	--	--	--	--	525	10	--	535
Sub-Total	26616	4176	1375	32167	41720	6733	2000	50453
UNIVERSITY	366	268	899	1533	171	87	899	1157
GRAND TOTAL	31851	9717	5363	46931	47124	12088	6157	65369

A - Space Systems   B - Ground Stations & Earth Terminals   C - Data Processing & Analysis

TABLE 1(a)

SPACE EXPENDITURES
BY MEMBER-DEPARTMENTS AND AGENCIES
(in thousands of dollars)

	1976/77				1977/78			
DEPT.	A	B	C	TOTAL	A	B	C	TOTAL
DND	108	2278	532	2918	206	2838	485	3529
DFE	190	546	862	1598	8	326	1456	1790
NRC	25569	--	1245	26814	26390	--	1267	27657
IT&C	1230	974	--	2204	2600	1519	--	4119
DOT	--	627	--	627	25	1175	--	1200
DOC	4754	3202	733	8689	17895	3759	701	22355
EM&R	--	2089	1991	4080	--	2471	2248	4719
TOTAL	31851	9716	5363	46930	47124	12088	6157	65369

A - Space Systems   B - Ground Stations & Earth Terminals   C - Data Processing & Analysis

TABLE 1(b)

INTERDEPARTMENTAL COMMITTEE ON SPACE (ICS)
MEMBERSHIP LIST

Dr. J.H. Chapman (Chairman)	- Department of Communications
Dr. D.I.R. Low (Vice-Chairman)	- Ministry of State for Science and Technology
Mr. R.M. Dohoo	- Department of Communications
Dr. J.G. Chambers (Alternate)	- Department of Communications
Dr. R.E. Barrington	- Department of Communications
Mr. W.A. Cumming	- National Research Council
Mr. F.R. Thurston (Alternate)	- National Research Council
Dr. L.W. Morley	- Department of Energy, Mines and Resources
Mr. H. Douglas	- Department of Industry, Trade and Commerce
Mr. J.H. Crysdale (Alternate)	- Department of Industry, Trade and Commerce
Mr. F.E. Lay	- Department of Transport
Dr. H. Sheffer	- Department of National Defence
Mr. G. Rejhon	- Department of External Affairs
Dr. M.C.B. Hotz	- Department of Fisheries and the Environment
Mr. O. Roy (Observer)	- Treasury Board Secretariat

ICS SECRETARIAT

Dr. R.C. Langille (Secretary, ICS)

Mr. J.T. Marcotte

LIST OF ABBREVIATIONS AND TERMINOLOGY

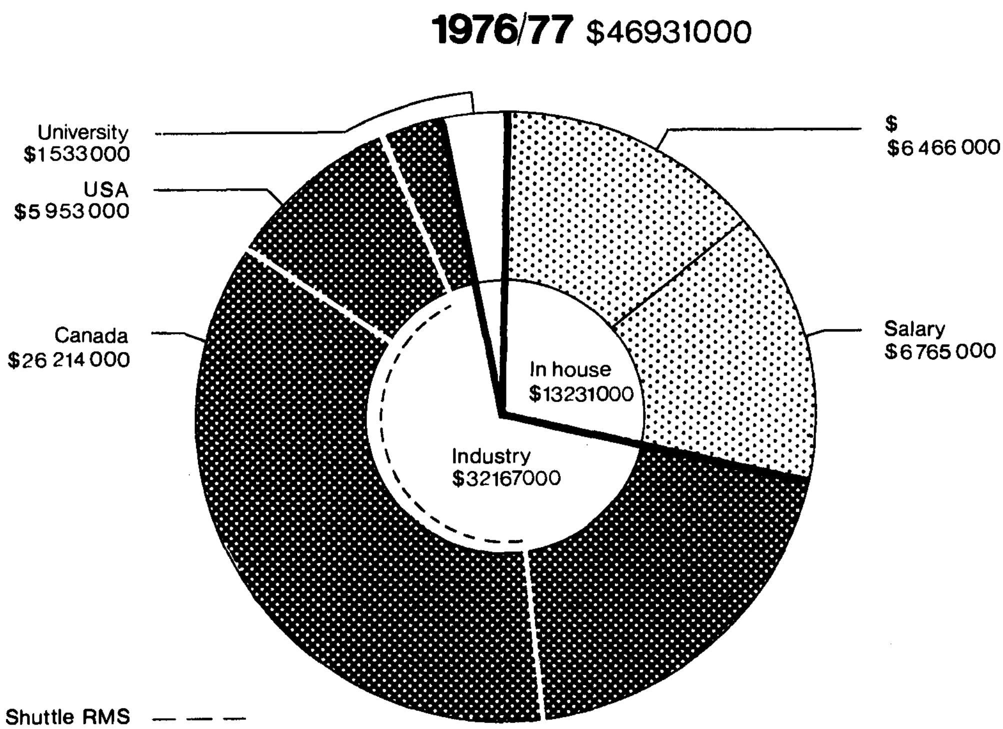
ACO - Aerosat Coordination Office
ACSR - Associate Committee on Space Research
AEROSAT - International (USA/ESA/Canada) Aeronautical Satellite program
ANCS - Alberta Native Communication Society
ANIK - Telesat Canada's satellites are all named ANIK
AMSAT - Amateur Radio Satellite (named Oscar)
ARIANE - ESA's launcher program
ASEA - Aeronautical Services Earth Terminal
Black Brant - Series of scientific rockets
CACRS - Canadian Advisory Committee on Remote Sensing
CCRS - Canada Centre for Remote Sensing (DEM&R)
CNES - Centre National d'Etudes Spatials (France)
COSPAR - International Council of Scientific Unions' Committee on Space Research
CRC - Communications Research Centre (DOC)
CRR - Churchill Research Range (NRC)
CSRPG - Canadian Sounding Rocket Planning Group
CTS - Communications Technology Satellite
DCIEM - Defence and Civil Institute of Environmental Medicine
DEA - Department of External Affairs
DEM&R - Department of Energy, Mines and Resources
DFE - Department of Fisheries and the Environment
DND - Department of National Defence
DOC - Department of Communications
DOD - U.S. Department of Defense
DOT - Department of Transport
ELT - Emergency Locator Transmitter
EMC - Electro Magnetic Compatibility
ESA - European Space Agency

ESTEC	- European Space Technology Centre
FAA	- Federal Aviation Agency (USA)
FY	- Fiscal Year
GEOS	- Geostationary Earth Observation Satellite (ESA)
GHz	- Giga Hertz (one billion Hertz)
GOES	- Geostationary Operational Environmental Satellite (USA)
GPS	- Global Positioning System (USA)
Hz	- Hertz
IACRS	- Inter Agency Committee on Remote Sensing
ICMS	- Interdepartmental Committee on Maritime Satellite
ICS	- Interdepartmental Committee on Space
INMARSAT	- International Maritime Satellite Organization
INTELSAT	- International Telecommunication Satellite Organization
IR	- Infra Red
LACIE	- Large Area Crop Inventory Experiment (USA)
LANDSAT	- Name of earth resources technology satellites (USA)
LDEF	- Long Duration Exposure Facility (USA)
MARISAT	- U.S. Navy Maritime Satellite
Mil.Std.	- Military Standards
MIT	- Massachusetts Institute of Technology
MOSST	- Ministry of State for Science and Technology
MUSAT	- Multipurpose UHF Satellite (Canada)
MSS	- Multi Spectral Scanner
NAE	- National Aeronautics Establishment (NRC)
NASA	- National Aeronautics and Space Administration
NAVSTAR	- Name of GPS program (NAVSTAR/GPS) (USA)
NOAA	- National Oceanic and Atmospheric Administration
NORAD	- North American Air Defense
NRC	- National Research Council
PEB	- Aerosat Proposal Evaluation Board
RBV	- Return Beam Vidicon

R&D	- Research and Development
RESPAG	- ESA's Remote Sensing Program Advisory Group
RF	- Radio Frequency
RFI	- Radio Frequency Interference
RMS	- Remote Manipulator System
SAMSO	- USAF Space and Missile Systems Organization
SARSAT	- Search and Rescue Satellite (USA)
SEASAT	- Sea observation satellite program (USA)
SHF	- Super High Frequency
SIMFAC	- Zero gravity Simulation Facility (Canada)
SOI	- Space Object Identification
SPADATS	- Space Detection and Tracking System (NORAD)
SPC	- ESA's Science Program Committee
SPO	- Aerosat Space Program Office
SRFB	- Space Research Facilities Branch (NRC)
SRMS	- See RMS
SSCO	- Space Science Coordination Office (NRC)
SURSAT	- Earth observation satellite program (Canada)
TBS	- Treasury Board Secretariat
UHF	- Ultra High Frequency
ULF	- Ultra Low Frequency
UNCOPUOS	- United Nation Committee on the Peaceful Uses of Outer Space
USA	- United States of America
USAF	- United States Air Force
USSR	- Union of Soviet Socialist Republics
VHRR	- Very High Resolution Radiometer

FIGURE 1

Canadian Space Expenditures



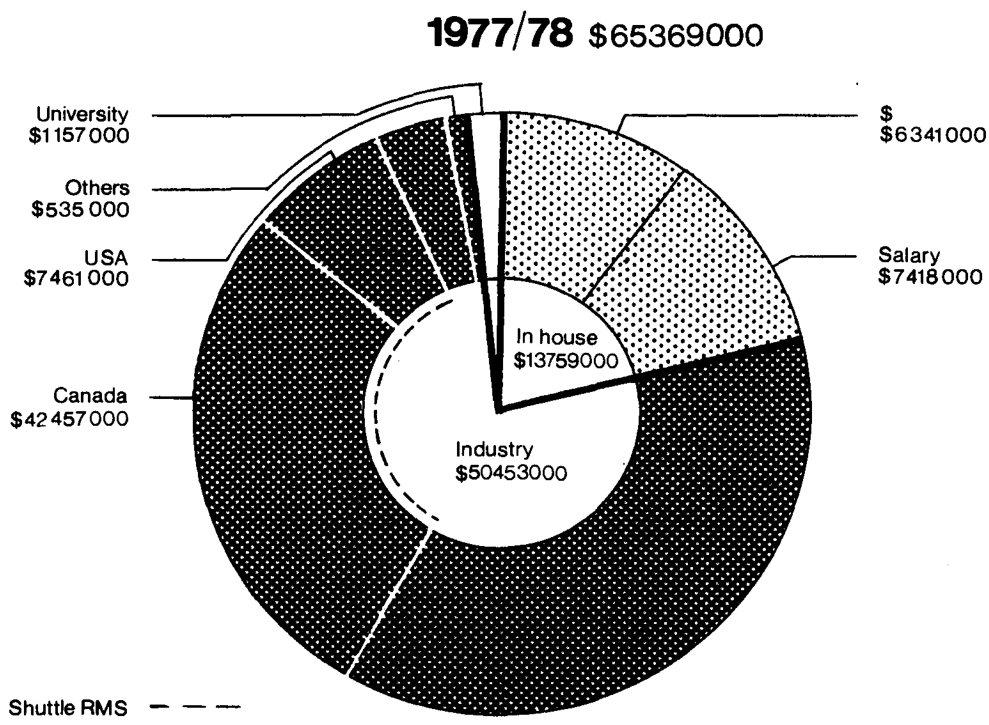
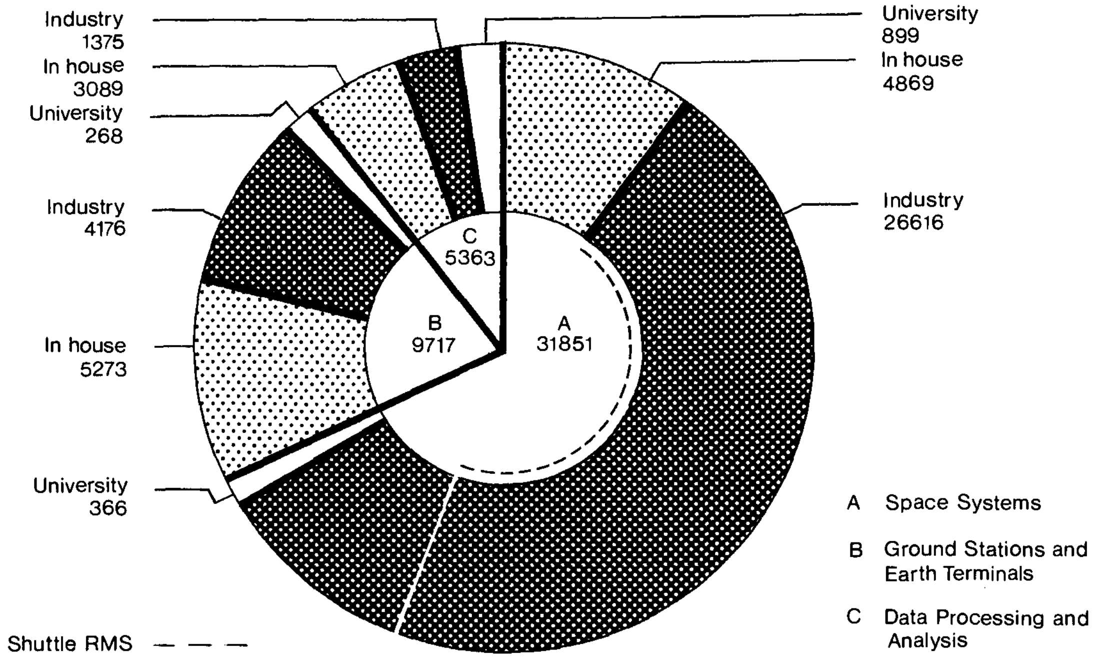


FIGURE 2

Canadian Space Expenditures

1976/77



1977/78

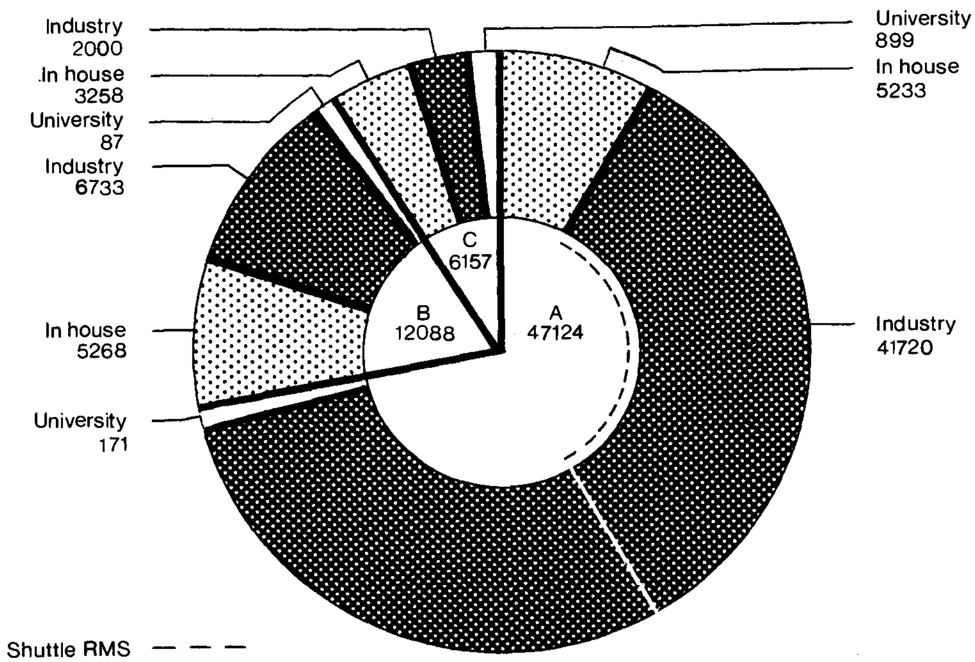
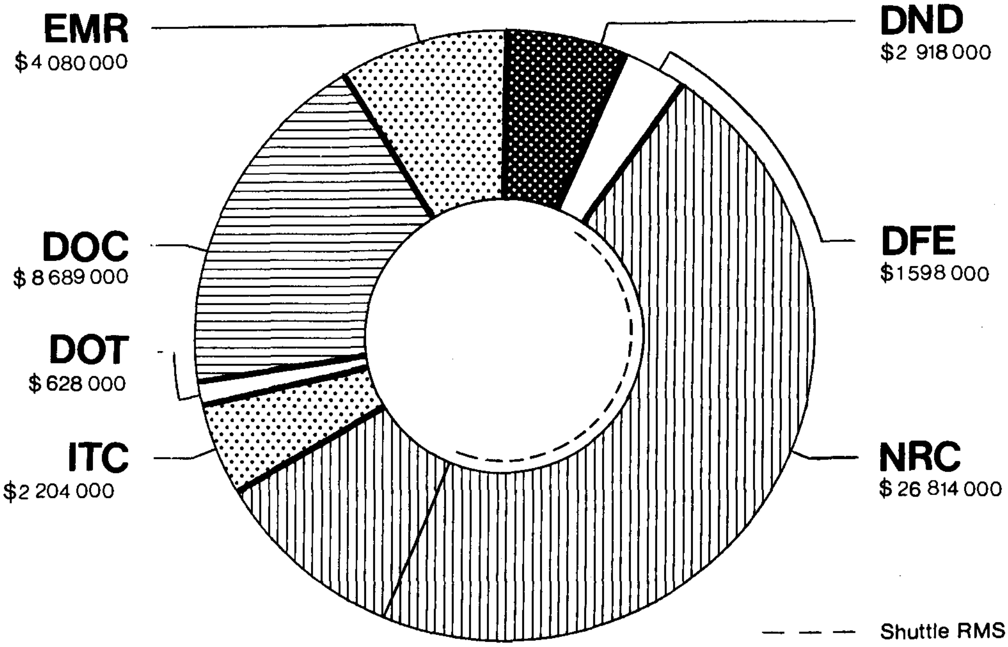


FIGURE 3

Canadian Space Expenditures

1976/77 $46931000



1977/78 $65359000

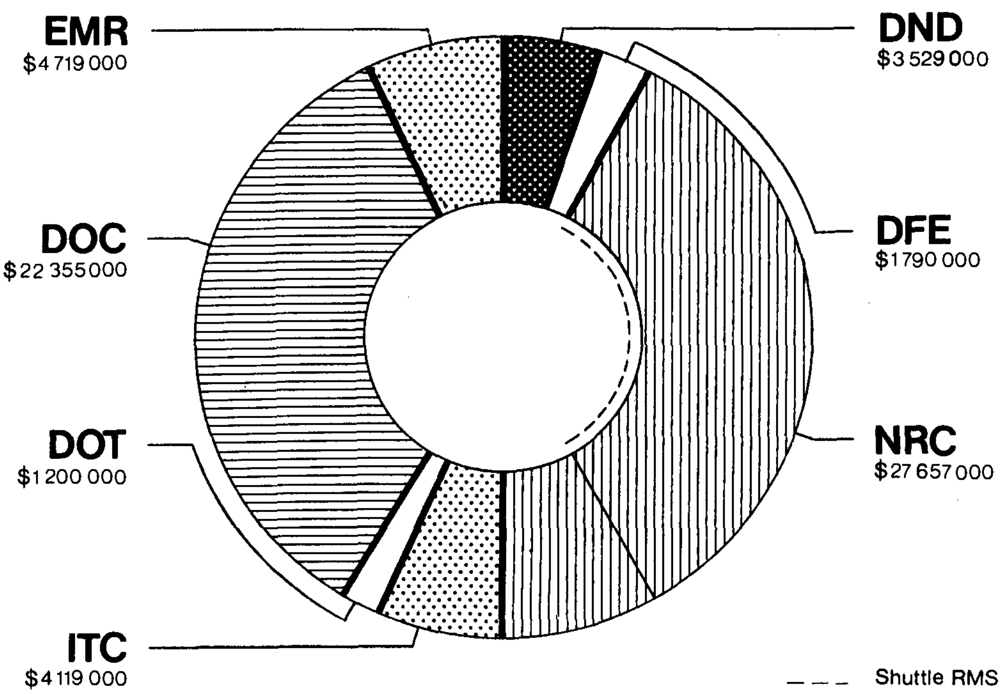


FIGURE 4

Government Space Expenditures (1976/77, 1977/78) by Departments

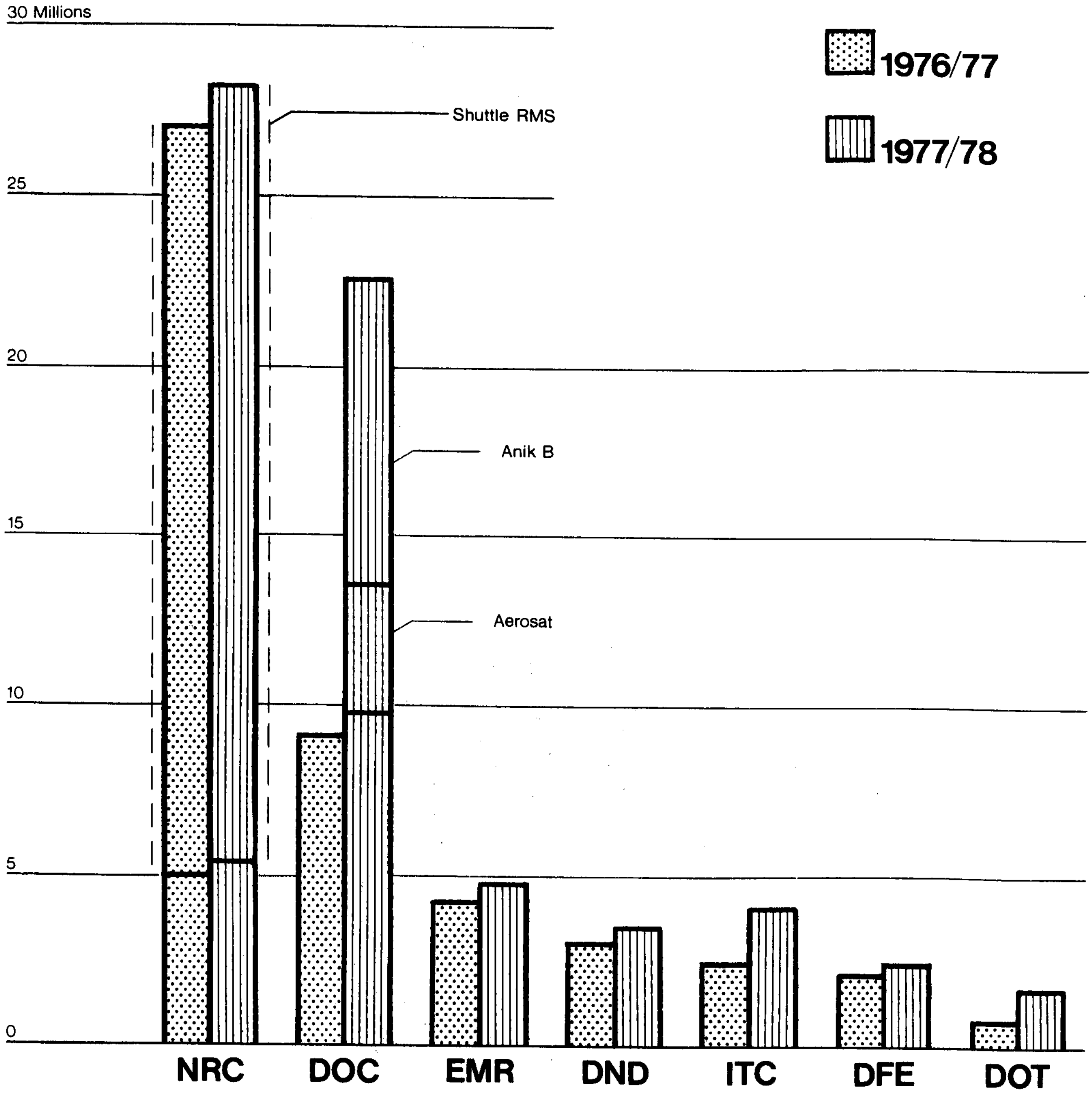


FIGURE 5

Canadian Government Space Expenditures 1969/78