FIFTH ANNUAL REPORT 1973

Interdepartmental Committee on Space

Comité Interministériel sur l'Espace

INTERDEPARTMENTAL COMMITTEE ON SPACE

FIFTH ANNUAL REPORT

J. H. CHAPMAN
CHAIRMAN

I. S. McLEISH
SECRETARY

OTTAWA
FEBRUARY, 1974.

TABLE OF CONTENTS.

1. INTRODUCTION.

The purpose of this document is to report on the activities of the Interdepartmental Committee on Space (ICS) for the year 1973. It should be noted however that financial data contained herein necessarily covers the Federal Government's Fiscal Year 1973-74, i.e. 1 March, 1973 to 30 April, 1974.

2. COMMITTEE ACTIVITIES.

During the calendar year 1973 the ICS held three formal meetings which were largely devoted to the problem of developing a space policy for Canada. It also met twice with a Committee representing the Air Industries Association of Canada to discuss industry's preliminary views on this same subject. As a result of these meetings the Committee approved a set of Principles for a Canadian Space Policy, attached as Annex 1, to be used by the Ministry of State for Science and Technology in preparing a definitive Space Policy for Canada.

The ICS Sub-Committee on the International Aspects of Space has continued to be active and to serve in organizing and presenting Canada's position at international space meetings primarily those of the UN Committee on the Peaceful Uses of Outer Space, its Sub-Committees and Working Groups.

The ICS Sub-Committee on Research has also been active. This Sub-Committee has a dual role in that it is also the Associate Committee on Space Research of the NRC. It has been primarily concerned with problems associated with university participation in upper atmosphere rocket experiments and with Canadian university participation in satellite experiments.

Members of the ICS Sub-Committee on Space Vehicles and Propulsion provided advice and assistance to industry relating to the preparation of a SPAR consortium proposal for the development in Canada of an advanced remote manipulator system.

3. CANADIAN SPACE ACTIVITIES.

With the encouragement of the ICS, the National Research Council (NRC) publishes an annual report on Space and Upper Atmosphere Programs in Canada which contains up-to-date data on the space programs of many agencies and

departments of the Federal Government as well as Canadian universities and industry. A copy of the latest report, reference SRFB 080, dated January 1974, is attached as Annex 2, for general information. Specific highlights of the Federal Government departmental activities are given in the following sections.

3.1 International Space Activities.

During 1973 Canada participated in the 16th session of the Committee on the Peaceful Uses of Outer Space as well as in the 10th session of its Scientific and Technical Sub-Committee and the 12th session of its Legal Sub-Committee. In response to questionnaires circulated by the Outer Space Committee, Canada submitted in October 1973 two papers entitled respectively, The Canadian Reply to the U.N. Questionnaire on Remote Sensing of the Environment and Natural Resources from Space, and, Canadian Experience on the Dissemination and Utilization of Remote Sensing Data.

In March 1973, Canada participated in the fourth session of the Working Group on Direct Broadcast Satellites during which Canada, in cooperation with Sweden, submitted a working paper emphasizing the close link between consent and concepts of cooperation and participation in international broadcasting and opposing the tendency to proceed with haste in developing legal rules in binding treaty form.

The Legal Sub-Committee met in 1973 and continued consideration of the draft treaty relating to the moon and the draft convention on the registration of objects launched into outer space.

3.2 Space Communications (Domestic).

With the successful launching and positioning of the second satellite ANIK II on April 20, 1973 and the completion of the 37 earth stations, the initial Telesat space communication system is now in place and operational.

3.3 Space Communications (International).

The Canadian Overseas Telecommunication Corporation has recently extended service from its west coast station located near Lake Cowichan on Vancouver Island. This station can now communicate directly with Australia, Japan, Hong Kong, the Philippines and China via an Intelsat IV satellite stationed over the Pacific Ocean.

3.4 Communication Technology Satellite (CTS).

The CTS is a cooperative Canada-USA-ESRO project having as a general objective the advancement of the state-of-the-art in spacecraft and associated ground-based technologies relating to future communications and other satellite application systems. During 1973, design was completed on all CTS spacecraft subsystems and the program in general was advanced from the design into the assembly and test stage.

To date 41 experimenters have submitted proposals for experiments to be carried on the CTS and these proposals are now being assessed by an Evaluation Committee.

3.5 International Aeronautical Satellite (AEROSAT).

Activity continued during 1973 to further define AEROSAT system requirements and help resolve some international problems relating to the development of such a satellite. The cooperative study program, jointly undertaken by MOT and DOC, in support of the AEROSAT concept was continued and plans were made to take part in the Application Technology Satellite-F (AFS-F) in 1974 as part of a joint Canada-USA-ESRO program.

3.6 Remote Sensing.

During 1973, the main thrusts of the satellite program of the Canada Centre for Remote Sensing included the upgrading of the ERTS-1 satellite imagery production system from experimental to operational capability, as well as the continued development of applications for remote sensed data. Information from 2000 satellite passes over Canada was processed. Methodologists developed spatial as well as spectral techniques for the analysis of satellite as well as complementary airborne data, especially in the areas of agriculture, environment, and geology. The Satellite Imagery Browse Facility as well as 'RESORS', an automated technical information system, both maintained at the Centre in Ottawa, continued to serve users of remotely sensed data. A "Quick Look" Imagery Facility was established and operated by private industry in Prince Albert, Saskatchewan.

3.7 International Maritimes Satellites (INMARSAT).

The Ministry of Transport and the Department of Communications, in consultation with other Government Departments, have participated in the work of the Panel of Experts on Maritime Satellites established under the aegis of the Inter-Governmental Maritime Consultative Organization (IMCO). Several papers relating to "L" band propagation characteristics and multi-access control techniques were submitted to the Panel.

3.8 Meteorological Satellites.

The Satellite Data Laboratory of the Atmospheric Environment Service (AES) of the Department of the Environment continued to acquire, utilize and apply weather satellite data directly obtained from orbiting meteorological spacecraft in visual and infrared real-time transmission modes. During 1973 information was acquired from the TOS operational spacecraft, ESSA 8, and from NOAA 2 and NOAA 3 of the Improved TOS series. Also monitored were WEFAX transmissions from ATS 1 and ATS 3 Application Technology Satellites.

A picture reproduction unit known as the FH 8100 was put into service to reproduce APT Vidicon camera readouts and to reproduce the Scanning Radiometer output in an expanded scale.

3.9 Canadian Industrial Capability.

The Department of Industry, Trade and Commerce continued during 1973 its support of activities designed to aid, and increase the capabilities of, Canadian space industries. Some highlights of this activity follow:

a) Future Canadian Communication Satellite Requirements.
The Department funded a $100,000 study of Canadian capabilities to meet future Canadian satellite communications requirements. In addition, the Department will be seeking funding for a further study with AIAC concerning optimization of benefits from Space Research. (Estimated cost is between $100-200,000).

b) TDMA Developments.
Discussions took place with DOC/COTC/Telesat on the possibilities of developing Time Division Multiple Access (TDMA) equipment in Canada for use by COTC and Telesat. Because of the long lead time required for development of this system and its importance in meeting future satellite communication requirements, substantial Government funding may be required.

c) Sarsat.
The Department actively promoted a joint development project with the U.S.Navy of a Search and Rescue Satellite System to aid in the detection of crashed aircraft. Negotiations will continue with the U.S. towards the signing of a project agreement in the near future. The Department funded a study on the design considerations and attributes of an extension of this system which would provide adequate coverage of Canada.

d). ERTS.
Marketing and development activities continued with Canadian companies who are attempting to market equipment, developed for the ERTS program, to such countries as Indonesia, Germany and Italy.

e) Aerostat.
Department involvement has led to support for a government funded antenna project at CRC.

4. EXPENDITURES ON SPACE ACTIVITIES.

Details of expenditures on space activities of departments and agencies as provided by the members of the ICS are attached as Annex 3, and are summarized in the following table:

SUMMARY STATEMENT OF FEDERAL GOVERNMENT EXPENDITURES ON SPACE ACTIVITIES FOR FISCAL YEAR 1973-74 AND 1974-75 (FORECAST) ($1000s).

	1973-74	1974-75
DOC	21,270(1)	22,588(2)
EM&R	6,199	6,238
NRC	4,400	4,400
DND/DRB	1,184	1,048
IT&C	1,352	1,654
MOT	211	205
TOTAL	34,616	36,133

Notes: (1) 247 recoverable from DND/DRB not included
(2) 179 recoverable from DND/DRB not included.

From the table it can be seen that total expenditures for space activities are estimated to increase by approximately $1.5 million in Fiscal Year 1974-75.

5. COMMITTEE MEMBERSHIP AND TERMS OF REFERENCE.

The membership of the ICS and its terms of reference are attached as Annex 4 and Annex 5 respectively.

ANNEX I
TO THE FIFTH ANNUAL
REPORT OF THE ICS.

PRINCIPLES FOR A CANADIAN SPACE POLICY AS APPROVED BY THE INTERDEPARTMENTAL COMMITTEE ON SPACE.

1. Canada's interest in space is to use it, whenever necessary or preferable, to further national policies, the themes of which have been defined as seeking to:

   a) foster economic growth;
   b) safeguard sovereignty and independence;
   c) work for peace and security;
   d) promote social justice;
   e) enhance the quality of life; and,
   f) ensure a harmonious natural environment.

2. Canadian space activity is a field of technological applications for use by Departments and Agencies of the Federal Government in support of their individual missions which in turn, contribute to the achievement of national goals.

3. The requirements of departments and agencies for space research, development and production of space hardware should be met to the maximum extent possible by Canadian industry consonant with the present "Make or Buy" policy, and by Canadian Universities.

4. The Space Sector of Canadian Industry should be encouraged to develop and maintain its capability to design, develop and construct space craft and payloads as well as the associated ground systems. Major launch vehicles and associated services will be purchased from foreign sources.

5. Industry should be funded at the continuing floor level necessary to maintain its competence and facilities since domestic requirement tends to generate a peak and valley type of industrial loading.

6. Canadian space research strategy should have as its objectives the maintainance of a capability to understand the properties and potentialities of the space environment as well as the ability (e.g. trained scientists and engineers), to exploit opportunities for application of space technology.

7. Canadian international strategy should ensure that Canadian sovereignty, interests in, and ability to exploit space through application programs, are furthered through international agreements.

ANNEX 2
TO THE FIFTH ANNUAL
REPORT OF THE ICS.

SRFB 080

SPACE AND UPPER ATMOSPHERE PROGRAMS IN CANADA

1973

A SUMMARY PREPARED BY

WILLIAM H. WATERS

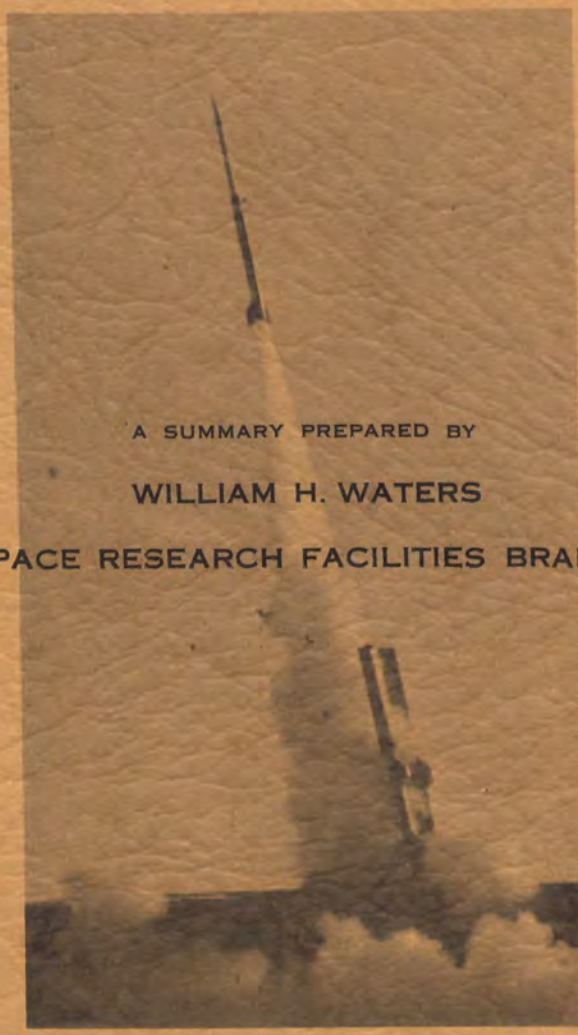
SPACE RESEARCH FACILITIES BRANCH

NATIONAL RESEARCH COUNCIL OF CANADA

JANUARY 1974

SRFB 080

Space And Upper Atmosphere Programs In Canada 1973



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FOREWORD

This report is published annually and is usually brought up-to-date in December of each year. This is the sixth annual edition.

The contents are compiled very largely from material contributed by participating and associated agencies. The aim is to make the publication as complete as possible and readers are invited to assist in this by contributing information about items which are not included.

All previous editions of "Space and Upper Atmosphere Programs in Canada" are out of print except for the May 1972 French edition and the January 1973 English edition. Copies of these and of this current edition may be obtained from the Space Research Facilities Branch, National Research Council of Canada, Ottawa, Ontario K1A 0R6.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

TABLE OF CONTENTS (Cont'd)

TABLE OF CONTENTS (Cont'd)

TABLE OF CONTENTS (Cont'd)

TABLES

INTRODUCTION

Canada, by reason of geography and the interest of her scientists has been able to take an active part in upper atmosphere research. With the assistance of the United States, in an outstanding example of international co-operation, a Canadian designed-and-built satellite was placed in orbit in 1962, and Canada became the third nation to build and operate its own space vehicle.

Balloons were first employed in upper atmospheric research early in this century, and ground-based research was used in the studies of the Aurora Borealis as early as 1867. The use of sounding rockets as tools for upper atmospheric research in Canada commenced in 1957 in connection with the International Geophysical Year (IGY). Satellite research was started in 1958 during the planning stage of Alouette I, shortly after the Space Age was opened by the launching of Sputnik I in October 1957.

Canadian space activities cover a broad range of scientific disciplines in the fields of basic and applied research and in the applications of space technology. The interdepartmental Committee on Space (ICS) in conjunction with the Ministry of State for Science and Technology (MOSST) considers matters affecting space policy. The Associate Committee on Space Research of the National Research Council of Canada contributes scientists' opinions to the ICS and MOSST.

Canada is a member of the United Nations Committee on the Peaceful Uses of Outer Space, and the Canadian National Committee on Space Research is a member of the International Committee on Space Research (COSPAR). Canada is also represented by the Canadian Overseas Telecommunications Corporation on the International Communications Satellite Consortium (Intelsat), which is involved in a global satellite communications system placed in operation in 1965.

INFLATING A BALLOON FOR FLIGHT

BALLOONS

High flying balloons were first used by the Meteorological Branch of the Department of Transport following the First World War. They carried an aneroid-bimetallic device for recording pressure and temperature on a small glass plate. These meteorographs had to be recovered. John Patterson, later Director of the Meteorological Services, did some of the work which was useful in establishing stratosphere heights over Canada.

The next high flying balloon flights in Canada took place from the University of Saskatchewan during the summer of 1939 to measure cosmic ray intensities in the upper atmosphere, in co-operation with R.A. Millikan and V. Neher of the University of Chicago. They carried electroscopes which had to be recovered in order to get the data. Five balloons were spaced along a leader to which the instruments were attached. Four or five successful flights were made. Some early Canadian flights were also made by Professor Demers of the University of Montreal.

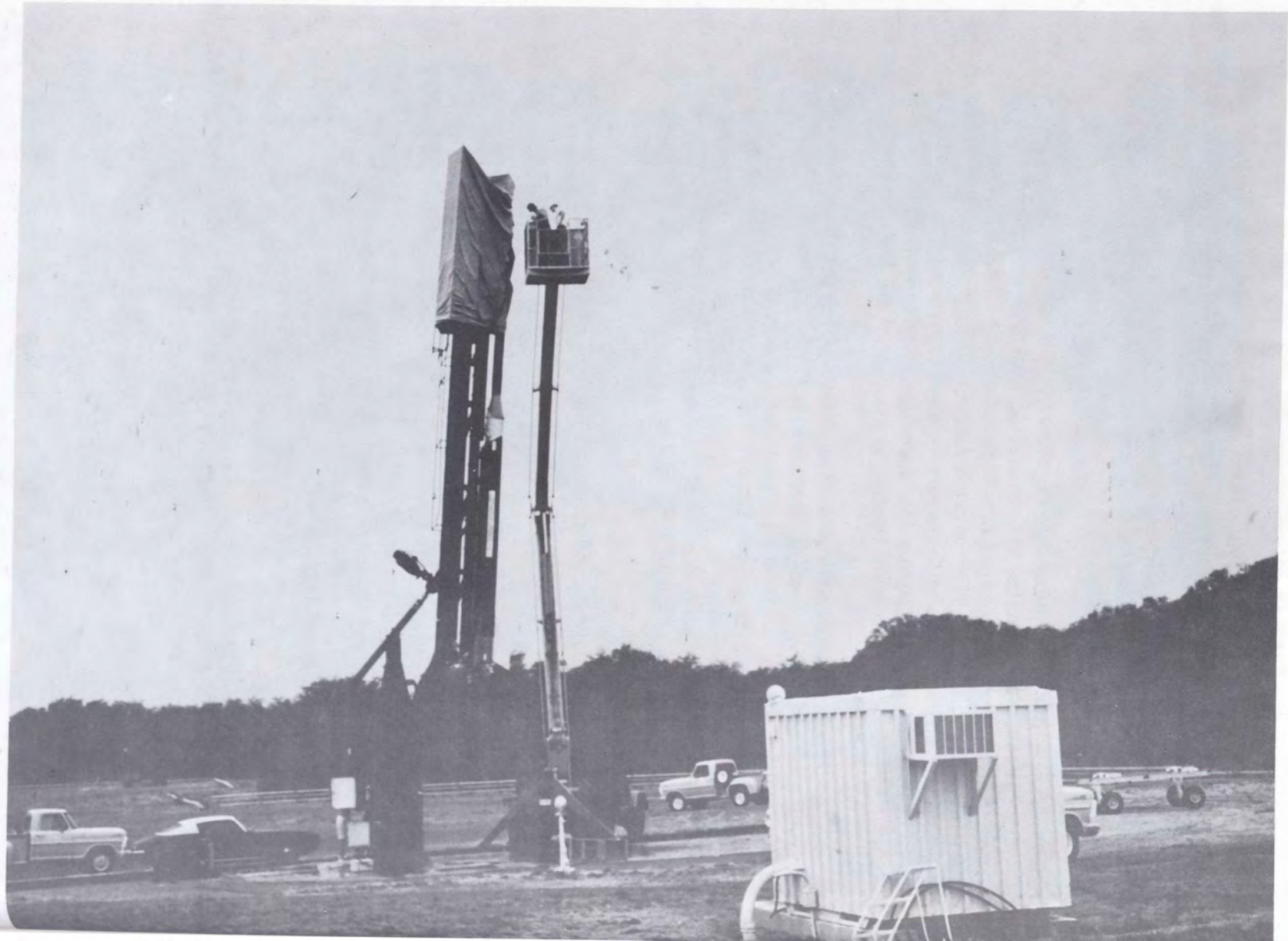
The first large scale Canadian balloon program, however, was that instituted by the Canadian Armament Research and Development Establishment (CARDE), Quebec, during the 1950's. Numerous important spectroscopic and photometric measurements have been made. The CARDE program also involved co-operation with other Canadian scientists, including Drs. H. P. Gush and A. Vallance Jones, and other guest experimenters from the Universities of Saskatchewan and British Columbia. The CARDE program was led by Dr. C. Cumming and J. Hampson.

During the 1950's and the early 1960's, scientists from the United States frequently came to Canada to use balloons from cosmic ray and X-ray observations.

The first Canadian flights for investigation of auroral X-rays were carried out by the University of Calgary in conjunction with the Defence Research Telecommunications Establishment of the Defence Research Board in the spring of 1963. More recently, a program has been instituted by the Universities of Calgary and Saskatchewan. Flights have been carried out at Cold Lake, Alberta, Waldheim, Saskatchewan, and also at Churchill Research Range, Churchill, Manitoba, some in conjunction with rocket launchings.

For the past several years, and with support from Canadian agencies and ground stations, the Office of Naval Research of the Department of the United States Navy has conducted a scientific ballooning program (SKYHOOK) in Canada. The University of Calgary and the Atmospheric Environment Services of the Department of the Environment are participating in this program in 1974.

FINAL PAYLOAD CHECKS BEFORE LAUNCHING A BLACK BRANT IV ROCKET FROM HAWAII



ROCKETS

Beginning with the International Geophysical Year (IGY) in 1957, rockets were first used by the Canadian Armament Research and Development Establishment (CARDE), now the Defence Research Establishment Valcartier (DREV), and later by the Defence Research Telecommunications Establishment (DRTE) now the Communications Research Centre (CRC) of the Department of Communications (DOC), to investigate spectroscopic and ionic characteristics of the upper atmosphere.

At DREV, direct high-altitude measurements began in 1957-1958 with rocket-borne measurements of the sodium airglow and hydroxyl profiles. More recent rocket flights were used to release nitric oxide into the atmosphere in order that ground-based observations of the resulting luminescence could be used to study the reaction of the nitric oxide with atmospheric atomic oxygen. This program produced a better understanding of the atmosphere and the possible role that catalytic chemical processes may play in adjusting the energy balance and composition of the atmosphere. Following these activities, vehicle development begun at DREV led to the production of the Black Brant I and II type rockets.

At CRC, this work was directed towards understanding the physics of the ionosphere with a view to improving communications. To this end, many ground-based measurements using radio wavelengths from a few millimeters to many kilometers were made in conjunction with rocket and satellite measurements.

As a result of the rocket research activities at DREV and with the assistance of the government, rocket building technology in Canada became available to civilian industry, and Bristol Aerospace Limited, Winnipeg, Manitoba, became the first Canadian industrial rocket developer and producer. In 1964, with assistance and direction from DREV, a rocket propellant filling plant was established by Bristol at Rockwood, Manitoba.

The Radio and Electrical Engineering Division (REED) of the National Research Council of Canada began its participation in the Canadian rocket program by undertaking the development of telemetry components (antennas, transmitters and transmission line components) for Black Brant rockets in 1960. In January 1961, REED accepted the responsibility for supplying engineering assistance to the projected scientific program of upper atmosphere sounding rocket research at Fort Churchill, Manitoba. From that time until the formation of Space Research Facilities Branch (SRFB) in April 1965, REED performed this task, which consisted primarily of technical, but not scientific co-ordination of the program. Since taking over this engineering responsibility from REED, SRFB has used Canadian industry to develop and fabricate scientific payloads.

TELESAT CANADA'S ANIK SATELLITE

SATELLITES

Alouette I

This was the first satellite to be designed and constructed in Canada. It was launched from the Western Test Range, California, USA, on 29 September 1962 and was the oldest active vehicle in space, when it was turned off in December 1972.

Alouette II

This was the second Canadian designed and constructed space vehicle. It was launched into orbit on 29 November 1965, also from the Western Test Range. Alouette I carried four experiments and Alouette II carried five. On 3 June of this year Alouette II was placed in a stand-by state.

ISIS I

Canada's third space satellite, designated ISIS I for International Satellite for Ionospheric Studies, was launched into its prescribed orbit from the Western Test Range at 0646 GMT (0146 Ottawa time), 30 January 1969. This vehicle is instrumented with ten experiments to measure most of the important ionospheric parameters at the same time and in the same place. All experiments, with the exception of the ion mass spectrometer are performing as planned.

ISIS II

The fourth Canadian satellite ISIS II was launched from the Western Test Range, at 0257 GMT on 1 April 1971. This satellite is instrumented with 12 experiments including two to observe optical phenomena. All experiments to date are functioning as designed.

ANIK I

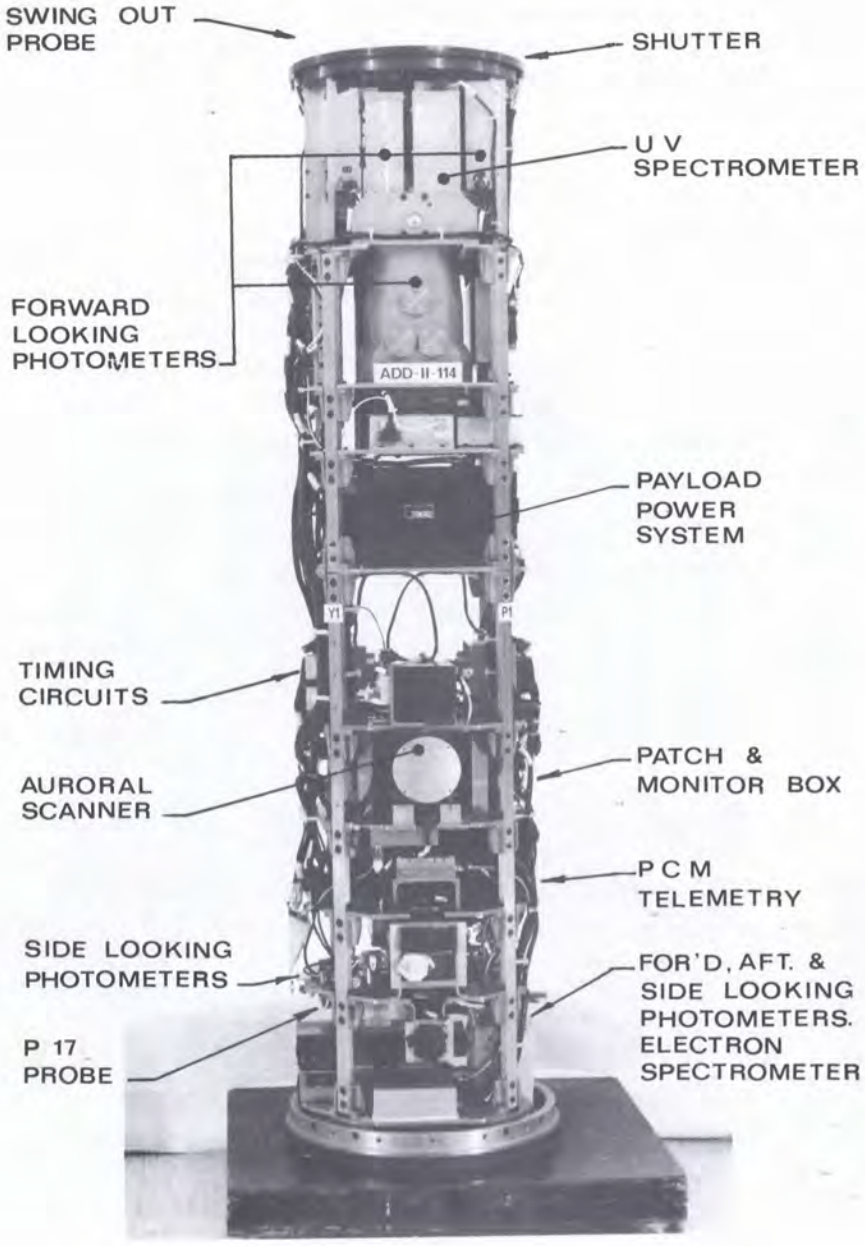
Canada's first domestic communication satellite, ANIK I was launched from Cape Kennedy on 9 November 1972. It was joined in space on 20 April 1973 by ANIK II. Both satellites are currently in service.

Further Details

Further details of these satellites will be found under the ISIS Satellite Program, Telesat Canada and Activities in Industry.

ISIS I and II continue to be tracked and commanded by Canadian telemetry/tracking stations and the United States STADAN network. ANIK I and II are tracked and commanded by Telesat's main earth station at Allan Park, Ontario, with auxilliary services provided by the Lake Cowichan, B.C., station.

THIS REFURBISHED PAYLOAD CONTAINING
22 EXPERIMENTS PREVIOUSLY FLOWN IN BLACK BRANT ROCKETS
II-114 AND 127 WILL BE FLOWN AGAIN IN BLACK BRANT II-128 EARLY IN 1974



HIGH ALTITUDE SOUNDING ROCKET PROGRAM

Scientific instrumentation for the Canadian high altitude sounding rocket program is provided by groups from many universities and several government departments. Vehicles currently employed are in the Black Brant series, designed and manufactured in Canada. In addition, the British Skua II and the United States' Boosted ARCAS II rockets are used on occasion to supplement the program.

The Black Brant family of vehicles now consists of nine different types which are manufactured by Bristol Aerospace Limited, Winnipeg, Manitoba. At the present time, Black Brant rockets are both single and two-stage solid propellant vehicles, with lifting capabilities of 50 to 145 kg to heights ranging between 165 to 1150 km. During 1973 the recently developed Black Brant VI was successfully flown. This rocket is capable of lifting a payload of 5 kg to a height of 84 km. A vehicle designed to lift heavier payloads, which could be used as a satellite booster, has been considered, using clusters of Black Brant motors. Further details of the capabilities of these rockets will be found under Activities in Industry - Bristol Aerospace Limited.

The British Skua II rocket is a 12.7 cm diameter, solid propellant vehicle, approximately 254 cm in length. It is capable of carrying a payload weighing approximately 9 kg to a height of 80 km.

The United States' Boosted ARCAS II rocket is an 11.4 cm diameter, solid propellant vehicle with a booster stage, measuring about 405 cm in length. It is capable of lifting payloads of more than 9 kg to heights of over 105 km.

Individual experiments are usually provided by the scientists concerned. The Space Research Facilities Branch of the National Research Council of Canada assumes overall co-ordinating responsibility and provides contract coverage with private industry for the integration of the payloads. The integration of the experiments into vehicle payloads is carried out by Bristol Aerospace Limited, Winnipeg, the SED Systems Limited of the University of Saskatchewan, Saskatoon, and the Institute for Aerospace Studies of the University of Toronto.

By December 1973 the National Research Council of Canada had participated in 133 rocket launchings which carried aloft 906 different experiments. Fourteen of these rockets carried experiments from the United States, Sweden, the Federal Republic of Germany, Czechoslovakia, the United Kingdom and Belgium, in addition to the Canadian experiments. By the end of 1973, Canada had launched more than 201 scientific sounding rockets.

UPPER ATMOSPHERIC ROCKET AND BALLOON RESEARCH IN 1973

Up to January 1973 the Space Research Facilities Branch had arranged for 98 scientific rocket launchings. These vehicles carried a total of 604 experiments from the National Research Council of Canada, the Communications Research Centre of the Department of Communications, and the Universities of British Columbia, Calgary, Saskatchewan, Western Ontario, Toronto, York, Montreal and Simon Fraser. In addition, 27 experiments from other countries were included in 13 of these vehicles.

During 1973, 11 Black Brant and five Skua rockets sponsored by the National Research Council of Canada, carried 73 experiments to heights ranging from 80 to 800 km to make measurements under quiet and disturbed conditions. With the exception of one vehicle from Gillam, Manitoba, and one from Kauai, Hawaii, all launchings took place at Churchill Research Range, Churchill, Manitoba.

The Office of Naval Research of the Department of the United States Navy again conducted "SKYHOOK" scientific balloon launchings in Canada during 1973. During this program, 16 balloons were launched from two sites carrying experiments from seven U. S. and one Canadian university, Cambridge Research Laboratories, Goddard Space Flight Center and the U. S. Naval Research Laboratory. Canadian agencies and ground stations participated in this program.

Canadian Experiments Carried in Canadian Rockets

Since the NRC program was instituted in 1962, the following experiments, provided by the authorities indicated, have been flown:

National Research Council of Canada

Plasma probes to measure ionization density and structures, micrometeoroid, acoustic and ionization detectors and particle collectors, heat transfer and aerodynamic heating panel experiments, photometers, cosmic ray and proton spectrometers, radio aurora and electromagnetic probes, and energetic particle detectors and angle of attack indicators.

Communications Research Centre, Department of Communications

Photometers, soft electron spectrometers, differential absorption and very low frequency experiments to measure ionization, radio frequency propagation studies and measurements of phase and amplitude of very low and low frequency signals.

Atmospheric Environment Services

Water vapour measurements.

University of British Columbia

Cosmic radiation measurements.

University of Calgary

X-ray detectors, neutron detectors, dual wavelength and scanning auroral photometers, magnetometers, proton detectors and cosmic ray collimators.

University of Saskatchewan

Electric and magnetic field measurements, single and two-channel photometers, X-ray and Lyman alpha detectors, acoustic detectors, day and night glow spectrometers, infrared airglow photometers and spectrometers.

Simon Fraser University

X-ray detection measurements.

University of Western Ontario

Ionospheric inhomogeneity detectors, differential doppler and radio wave absorption measurement experiments.

University of Toronto

Pressure and density gauges, ionization probes, photometers, rotational temperature apparatus, photomultiplier lunar aspect sensors, micrometeoroid detectors, atmospheric temperature and partial density, molecular oxygen and nitrogen and atomic oxygen measurements, atmospheric composition and temperature detectors.

York University

Infrared 1.27 micron photometers, single channel photometers and auroral spectroscopes, vacuum ultraviolet and oxygen atom probe experiments.

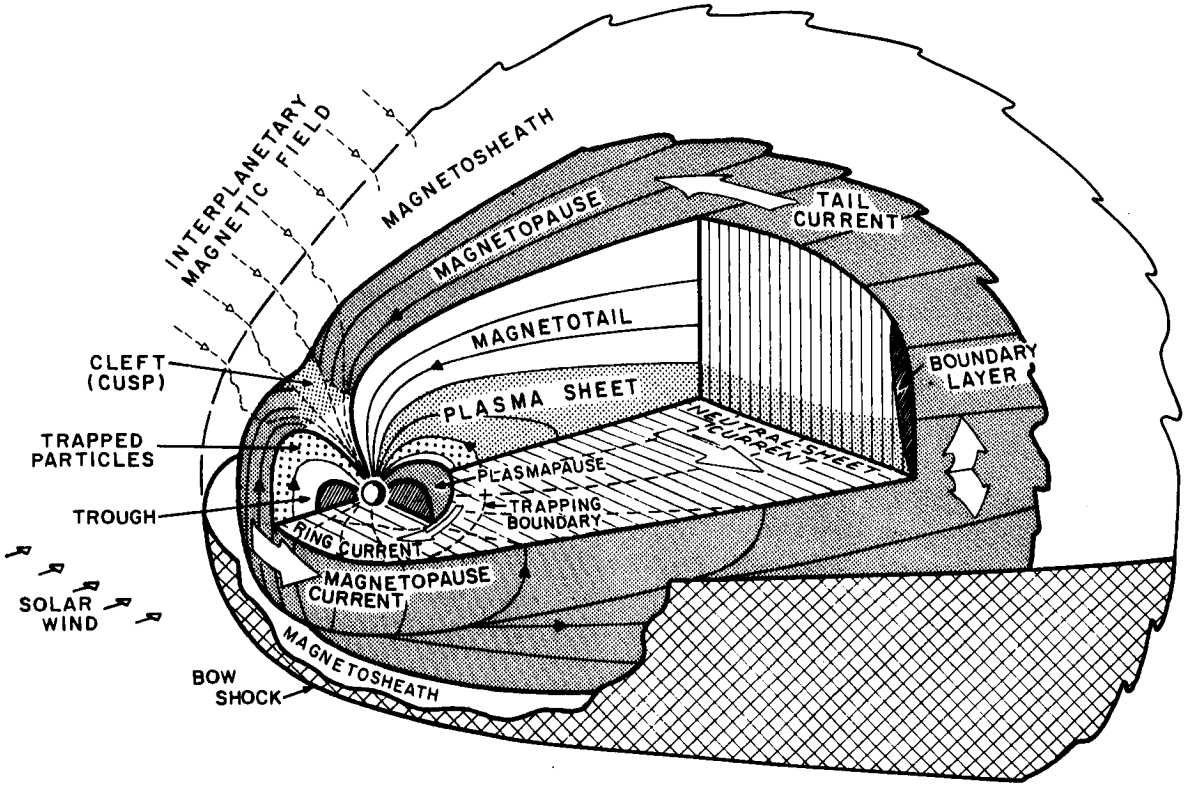
University of Montreal

Thermal electron measurements and multi-grid velocity analyzers.

Experiments Carried for Other Countries in Canadian Rockets

In addition, electric field and electrostatic ballistic probes, micro-meteoroid detectors, OH dayglow instruments, barium cloud, ozone measuring instruments (above 55 km), solar X-ray, Lyman alpha, spectrometer and photometer experiments were carried in 14 of the above rockets for the United States, Sweden, Federal Republic of Germany, Czechoslovakia, the United Kingdom and Belgium. Some of these experiments were ejected from rockets during flights, while others remained with the parent vehicles.

MAGNETOSPHERIC FIELD AND PLASMA ENVIRONMENT



COURTESY OF W. HEIKKILA

ACTIVITIES IN UNIVERSITIES

UNIVERSITY OF ALBERTA

Institute of Earth and Planetary Physics

The Killam Earth Sciences group is continuing to analyze the data it has obtained from the meridian line of magnetometer stations which it operated over the interval 1969-72 through western Canada. Most of the line is presently shut down, and the instruments are being prepared for the experimental program planned for the upcoming International Magnetospheric Study. A few instruments are still operative in the N.W.T. in a cooperative study with the University of Alaska.

Studies of the development of magnetospheric substorms have indicated that the substorm intensified electrojet develops in a series of impulsive intensifications of current elements each to the north and west of the preceding one. The behaviour of the poleward border of the electrojet is, therefore, very dynamic while the main electrojet formed during the early stages of the expansive phase is rather more stable. Studies of polar cap equivalent current flow for very quiet and for more active times have been completed, and it is found that polar cap variations result from contributions from several different current systems which behave in different fashions.

Studies continue using ISIS satellite data to correlate ionospheric parameters with the structure of current flow across the auroral electrojet and with the location of oscillating L-shell regimes thought to be responsible for the generation of Pc4, 5 micropulsation activity. An investigation of pi 2 micropulsations has been completed in which the spectral character of the pulsations was used to evaluate the use of pi 2's as a signature of electrojet development.

Cooperative studies with several satellite groups are now underway, including correlation of station line data with ATS-5, S^3 and TRIAD data.

A strong effort within the Geophysics group in the Department of Physics continue on the effects of induction in the Earth due to upper atmospheric and magnetospheric current systems. Arrays of magnetometers are now being prepared for Arctic studies, to determine the subsurface conductivity structure in that region. Theoretical studies continue on the perturbation patterns associated with discontinuities in conductivity, and an experimental magnetotellurics program studying subsurface conductivity in the region of the Black Hills anomaly is underway.

S^3 - Small Scientific Satellite

TRIAD - Navigational Satellite

UNIVERSITY OF BRITISH COLUMBIA

Department of Physics

A flight of a helium cooled interferometer to measure the spectrum of the cosmic background radiation in the wavelength region 2 mm to 0.2 mm took place in December 1972. The apparatus functioned properly throughout the flight and the bolometer temperature was kept at 0.37°K. The interferograms have been analyzed and reveal that radiation from the earth is being scattered into the instrument from the rocket skin. A new apparatus is being designed to overcome this difficulty.

Department of Geophysics and Astronomy

Aeronomy and Space Plasma Physics

Three research projects were carried on during the year, one on the origin of ionospheric lower hybrid resonance noise and the other two relating to geomagnetic micropulsations.

A possible mechanism of exciting lower hybrid resonance noise has been considered by R.N. Michkofsky and T. Watanabe: whistler-mode waves induce polarization electric fields within ionospheric irregularities which may become resonantly strong near the hybrid resonance frequencies. The process has been investigated through a mathematical analysis of propagation of electromagnetic waves in a magneto-active plasma which is weakly inhomogeneous in density. Let $\vec{k}_w$ and $\vec{K}_s$ refer to the electromagnetic wave number and the wave number characterizing the inhomogeneity. For $\vec{k}_w$ and $\vec{K}_s$ parallel to each other and perpendicular to $\vec{B}_o$ -- the background magnetic field -- the electric field induced due to the inhomogeneity becomes singular at the hybrid resonant frequencies. The induced electric field can be considered to have a quasi-electrostatic nature if $k_w << K_s$. This induced electric field may well be what has been termed whistler-triggered lower hybrid resonance (abbreviated here-after with LHR) noise. As K_s becomes smaller the electromagnetic nature of the induced fields become apparent. One still observes a resonance at the LHR frequency, but one may observe another resonance at the frequency where K_s equals twice k_w. For a K_s which is reasonable in the upper ionosphere, this resonance occurs at a frequency less than but near the LHR frequency. The effect of temperature on the above two resonances is negligible for ionospheric conditions. However, when T_o is not zero, an additional resonance appears at the proton gyro-frequency. For k_w not perpendicular to $\vec{B}_o$ and for the temperature being zero, the induced electric field has a resonance at two frequencies greater than the LHR frequency. For a given angle between $\vec{k}_w$ and $\vec{B}_o$, the resonance frequencies increase for decreasing K_s. These resonances above the LHR frequency may help explain why the noise band has a lower cutoff frequency at the LHR frequency.

An investigation of the origin of geomagnetic micropulsations in the Pc 3 - 4 range has been in progress. G. Nourry and T. Watanabe have compared micropulsations recorded at a ground-based station, Ralston, Alberta, in 1967-68 with solar wind plasmas and magnetic fields observed by the satellites IMP D and F. The comparison confirmed the finding by Bolshakova and Troitskaya that Pc 3 activity enhances or diminishes as the direction of interplanetary magnetic field (outside the bow shock) projected on the solar ecliptic plane tends to be parallel or perpendicular to the Sun-Earth line. The comparison also revealed that the Bolshakova-Troitskaya's rule is not a side effect of solar wind. It was found that it is observed even under a steady solar wind condition such that there is very little change in pressure as well as direction. It was also ascertained that Pc 3 activity is controlled not only by the azimuth of the interplanetary magnetic field as discovered by Bolshakova and Troitskaya but also by its elevation, the angle with the solar ecliptic plane. It has become clear that Pc 4 activity is also dependent on the azimuth and elevation of the interplanetary magnetic field. However, it was found that Pc 4 is controlled much more strongly by interplanetary field direction than Pc 3. Generally, it remains within an angle of about 30° from the Sun-Earth line when Pc 4 is active. A considerable number of examples indicated that a Pc 3 of Pc 4 hydromagnetic wave outside the bow shock was concurrent with a ground-observed micropulsation activity having a comparable period. Also obtained were several examples of a Pc 4 hydromagnetic wave in the magnetosheath occurring with a micropulsation event observed at Ralston. In each of these events, the elevation of the magnetosheath magnetic field remained negative. An abrupt change in solar wind pressure does not give rise to a continuous micropulsation activity unless the interplanetary magnetic field direction changes into a favourable range. If the field direction remains unfavourable, a sudden pressure change causes a transient oscillation in the geomagnetic field which is somewhat reminiscent of a Pi 2 type micropulsation.

An experiment for observation of geomagnetic micropulsations is under way. A semi-permanent station has been established within the University Research Forest about 30 miles east of Vancouver. The site is free of man-made magnetic noise. H. Ueda and T. Watanabe have been comparing two different types of induction magnetometers, one using an air-core coil as a sensor and the other a high μ-metal core coil. The purpose of this experiment is to resolve the controversy over the reliability of μ-metal core coil sensors. There is a considerably high degree of skepticism about their reliability, because of the non-linear behaviour and temperature characteristics of high μ-metals. The comparison experiment that has been performed so far indicates that the micropulsation signals by the two systems are identical except for periods shorter than several seconds. The discrepancy in the shorter period range appears to be due to a difference in the characteristics of the two amplifiers rather than the sensors. To further the experiment H. Ueda is constructing two identical amplifiers which match either of the sensors.

UNIVERSITY OF CALGARY

Department of Physics

ISIS II

The department is still heavily occupied with analysis of data from the scanning auroral photometer on ISIS II. From all indications the instrument continues to work well. Recently the group have been moving away from synoptic observations towards operational programs designed to answer specific questions or provide coordinated observations with ground-based or airborne experiments.

The department now has the capability to superimpose latitude and longitude lines on the pictures and also to reorder the data onto a conventional geographic or corrected geomagnetic grid. This should be of great assistance in analyzing the data - especially for those not experienced with the universities' standard representation.

An initial round of publications based on results from the ISIS instrument have been completed, and the group are now directing efforts toward refinement of these results, correlation with other satellite and ground-based observations, and presentation of some new phenomena which have recently come to light in the data. Current analysis projects are listed below:

Aurora

(1) Study of the Dayside Cusp.

(2) Relation of evening arcs to particle precipitation.

(3) Detailed optical-particle correlations during a pass which crossed the diffuse aurora on December 9, 1971.

(4) Correlations between the auroral electrojet and optical aurora.

(5) A detailed study of the great polar cap auroras during and after the December 18, 1971 storm (in relation to ISIS, interplanetary and ground-based data).

(6) An observation of isolated spots of aurora near the plasmapause on January 16, 1972.

(7) Correlation of the position of the equatorward boundary of the diffuse aurora with interplanetary field quantities.

(8) Polar cap sun-aligned arcs in relation to particle precipitation.

Airglow

(1) Morphology of 5577 airglow. From analysis of the limb data we are studying latitudinal variations of the E Region and F Region components. From the non-limb data the geographical distribution of the total green line intensity is being determined.

(2) Study of the F Region from an analysis of limb profiles.

(3) Twilight 3914. The winter evening enhancement has been observed and analyzed with the aid of a theoretical model.

(4) Search for conjugate effect in the F Region green line.

(5) Comparison with ground based observations. Incoherent scatter and sounder data are being used whenever available to study ionosphere-airglow relationships and in particular to investigate variations in the O_2 density.

Analysis of the rocket scanning photometer data continues. A paper describing the instrument and presenting initial results from rocket VB-127 is available in preprint form and is being submitted to Planetary Space Science. Another launch has been scheduled for early 1974 which, in cooperation with Drs. Whalen and Kavadas, will examine electric field behavior over and at the boundaries of the diffuse auroral belt.

Near Infrared Spectrophotometry of Sky Emissions

Airglow hydroxyl is being examined in the 0.95 - 1.2μ region for diurnal and seasonal variations in the (9-5)/(4-1) intensity ratio. Former data obtained in 1968-1970 is being re-examined along with current observations.

Thermal emission studies in the 2.0 to 8.0μ region are continuing. Spectral resolutions better than 100 Å are possible through the use of averaging techniques. A search is currently being made to detect the pollutant 3.3μ NO_2 and 7.3μ SO_2 bands in the atmosphere over Calgary.

Considerable effort has been expended to establish a routine observing programme for the Ring effect (Fraunhofer line filling-in). While the filling-in has been measured as a function of wavelength between 3850 Å and 4350 Å, experimental difficulties have so far prevented the setting up of a routine programme to observe environmental effect (ground cover, sky condition, angle of observation, etc.). A synthetic filling-in profile based upon rotational Raman scattering and Brillouin scattering is being constructed for comparison with measurements already made.

UNIVERSITY OF MANITOBA

Department of Physics

The study of delayed particles following air showers, using a large area scintillator telescope in conjunction with a 20 m^2 air shower array is continuing. The detector is also sensitive to quarks accompanying air showers, while a slight modification of the detector logic allows that an experimental search for tachyons can also be made. The Manitoba muon megatelescope remains in operation, while the program investigating the intensity of the sea level muon component has been successfully completed.

The Absolute Vertical Intensity of Muons Near Sea Level

Current interest in an absolute measurement of the vertical intensity of muons stimulated the present research. A novel method for the classification of events, and in particular the separation of muons from the soft component, has enabled the determination of a set of relatively precise and reliable measurements. The results so obtained are somewhat lower than the few other recently reported measurements.

Sea Level Search for Leptonic Quarks in Cosmic Rays

A search has been made for relativistic leptonic quarks (charges e/3 and 2e/3) in the cosmic radiation near sea level using a narrow angle scintillation counter telescope. The apparatus was oriented at large zenith angles ($> 75°$) and thus used the atmosphere as an extended filter for hadronic quarks. A null result was obtained, leading to upper limits on such quark intensities of $\sim 1.7 \times 10^{-8}$ cm^{-2} sr^{-1} sec^{-1} at the 90% confidence level.

Department of Electrical Engineering, The Antenna Laboratory

Progress has been made in the microwave radiometer program for airborne applications and covering a wide range of interest extending from remote sensing of soil moisture profiles to detection and classification of ships and downed aircraft during reconnaissance as well as search and rescue operations in Northern Canada.

A second program involving a microwave antenna array for transmitting data to a geostationary satellite has also been initiated. Progress has been made on the design and prototype testing of an antenna array for transmitting environmental data collected in remote locations to a geostationary satellite.

MCMASTER UNIVERSITY

The lunar research program is being conducted by Dr. H.G. Thode (principal investigator), Dr. C.E. Rees and Dr. H. P. Schwarcz. Determinations of sulphur concentrations and isotope abundances in returned lunar samples are continuing. The main emphasis is on lunar dust samples which show $^{34}S/^{32}S$ patterns indicative of a complex history of sulphur loss and isotopic alteration. Experiments are aimed at identifying and separating fractions of the lunar dust with different $^{34}S/^{32}S$ values in order to determine the modes of formation.

UNIVERSITY OF SASKATCHEWAN

Institute of Space and Atmospheric Studies

The studies of the O_2 ($^1\Delta$) and OH Meinel emissions reported in previous newsletters have been continued during the past year.

The OH Meinel emissions in the night airglow have been measured in the $\Delta v=2$ sequence for upper state vibrational levels 3, 4, 5, 6 and 7. The results have indicated that, within the height resolution capability of the four barrel photometer, all bands originate at the same height in the atmosphere. The emission profiles on this occasion may be considered to be a 10 km thick layer centered at 87 km. Although the altitude of the peak emission is significantly different from that previously reported, it is in good agreement with that calculated from atmospheric models. For altitudes below 90 km there is a close similarity between the OH* profiles and that obtained for the $O_2(^1\Delta)$ emission on the same flight. However, there is no indication of a second OH* emission layer in the region of 95 km as observed for the oxygen emission. This two layer form of the $O_2(^1\Delta)$ nightglow emission is again suggested by the data from the miniature $O_2(^1\Delta)$ photometer flown on the vehicle ADD-II-127. This data is presently being carefully analyzed and will be compared with that obtained during quiet night-time conditions (ADD-III-54) and the measurements of Drs. Gattinger and Vallance Jones during aurorally disturbed periods.

A further series of eclipse observations for the $O_2(^1\Delta)$ emission have also been made, on this occasion from Lake Rudolf in Northern Kenya. The measurements indicate that the emission decays rapidly during totality, in agreement with previous aircraft observations of equatorial eclipses, and indicates only a minimal contribution to the total emission from high altitudes. However, the duration of local totality on this occasion was extremely long and subsequent increase in the emission intensity before third contact was observed. It has been suggested that this increase may be related to the nightglow emission mechanism and model calculations for various reaction schemes are being attempted.

The role of the OH* + 0 reaction in the atmosphere is being investigated in an attempt to reconcile published rate constants with those apparently

required to satisfy the airglow Meinel emission. It is hoped to provide further information on this matter with a group of scanning photometers which are currently under development.

* Vibrationally excited.

Atmospheric Dynamics Group

The main themes of the research program include:

(1) The measurement of atmospheric winds (60-110 km) by means of a partial reflection radiowave system.

(2) The analysis of these data to obtain prevailing winds, tides and gravity waves.

(3) The causality of ionospheric irregularities, and their relation to atmospheric dynamics and radiowave scatter.

(4) The effects of particle influx upon the ionization and energetics of the atmosphere below 110 km (including the stratosphere).

The prevailing winds (zonal and meridional) from 60-110 km for Saskatoon (52°N, 107°W) are available from 1969 to 1973, often with a time resolution of one week. These data have been compared with meteorological rocket data (30-60 km), from Cold Lake (Alberta), and the matching of the time cross-sections at 60 km is extremely good. The radiowave data have also been used to form two composite time cross-sections for the four years, which are in excellent agreement with models constructed from a hemispheric grid of wind observations. Data from Saskatoon will be incorporated in improved models of seasonal and latitudinal wind variations.

The new radiowave winds system has facilitated a search for short period waves ($\tau \lesssim 1$ hr) in the internal gravity wave spectrum. Closely spaced atmospheric soundings (~12 per hour) for heights between 51-117 km with 3 km height resolution, were made between August 1972 and September 1973. The median of the wind profiles for a given hour were associated mainly with the prevailing wind, and the irregular components from each profile with gravity waves ($20 < \tau < 60$ minutes, $10 < \lambda_z < 30$ km). In general, the winter amplitudes and shears of the irregular winds were shown to have the largest values. Also, a diurnal variation was found, showing a minimum in amplitude and shear values near noon for all seasons; this was especially noticeable above 90 km. Comparisons of seasonal variations in the prevailing zonal and meridional winds with the amplitudes of the irregular winds, suggest a physical relationship involving critical layers and momentum transfer. Links between tropospheric weather systems and the gravity wave amplitudes are also suggested.

The analysis of data for the quiet and disturbed lower ionosphere (60-100 km) near solar maximum years (1970-71) has been partially completed. Systems included a 5577 Å photometer, a magnetometer, a "partial reflection radio-wave system" (2.2 MHz) and an all-sky camera.

For a given intensity of the green line, the ionospheric disturbance (< 90 km) is largest during the night hours in summer and winter; and after sunrise, largest in winter and fall months. There is good general correspondence between these results, and fluxes of precipitated electrons measured by satellite techniques. The measured values of the intensity of the green line (5577 Å) emission, and of the ambient electron densities, have been compared with theoretical estimates of these two variables. An exponential energy spectrum was used in the calculation, and fluxes of precipitated electrons (>40 keV) and values for the e-folding energies (E_o) thereby became available. Comparisons of mean values with satellite measurements made under similar magnetic conditions, showed good agreement. Calculations were also made for two specific nights, (January 26-28, 1971). Characteristic energies were typically 5 keV during the maximum of the magnetic and photometric disturbances, and increased to values of 10-15 keV near sunrise when the ionospheric disturbance (<90 km) is greatest.

Studies, which include analysis of existing data, and the development of new observational programs, are focussing upon the interaction of various scales of atmospheric motion and enhanced solar and corpuscular radiation below 110 km. Various experiments, e.g. the "angles-of-arrival" and "differential absorption system", are being operated in parallel with the "winds system" to allow study of the sources of atmospheric waves and related advection processes in the mesosphere and lower stratosphere.

Airglow Studies

Several months data of the intensity of helium 10,830 Å twilight emission has been obtained with the use of a Fabry-Perot photometer. This data is now being analyzed. Calculations of the intensities expected are also in progress.

A multi-channel auroral photometer is being built in cooperation with Drs. K. Paulson and D. McEwen. The auroral helium emission will be compared with other auroral emissions.

A search for OI λ7774 emission during twilight has given negative results, resulting in an upper limit being given to this emission.

The decade of measurements of twilight sodium obtained at Saskatoon have been compared with radio meteor counts during the same period to see if there is a connection between the two phenomena. Both times series and epoch techniques were used and showed little connection if any.

SIMON FRASER UNIVERSITY

A program of low energy x-ray astronomy using rocket vehicles was initiated in 1970. Considerable emphasis has been given to the development of new detection techniques to provide both high efficiency of detection, effective energy discrimination and extension to progressively lower energies.

Specifically, new proportional counter gas rejuvenation techniques have been developed, and the ability to program in-flight x-ray efficiency changes has been developed. Large area extremely thin window counters have been constructed and flown, while a glass plate glancing-incidence collector is under development which, with a stabilized rocket platform, should give a soft x-ray instrument with sensitivity and angular and spectral resolution of considerable power.

A detector, incorporating the new gas rejuvenation technique, was included on a rocket flown from Fort Churchill in May 1972. It appears as if electron precipitation at the time of the flight coupled with malfunction of an electrostatic "broom" will limit the astronomical content of data.

A second flight launched from Kauai in June 1973 included a similar detector with programmable in-flight x-ray efficiency, together with a joint experiment (with the University of Calgary). The latter employed a detector with an unusually large response around the relatively unexplored 0.6 Kev region. The first experiment failed due to window rupture at launch; however, the joint experiment functioned well.

A third experiment has been proposed which combines the energy and background discrimination properties of the SFU proportional counter with a glass plate glancing-incidence collector and a stabilized rocket platform. A large number of interesting celestial objects and regions are available for detailed study with such an instrument.

Apart from the use of increasingly sophisticated detectors, a study of transient x-ray phenomena is under way with the re-analysis of historic but unique data. The excellent time discrimination of earlier data, particularly that of a rocket flight which detected a major but apparently transient x-ray source in Cetus, has assumed large significance as a result of the discovery of transient gamma-ray sources in the universe.

UNIVERSITY OF TORONTO

Institute for Aerospace Studies

Atmospheric Composition and Temperature Determination Using Electroluminescence

Spectral analysis of fluorescence induced in an undisturbed sample of gas remote from the rocket is used to determine atmospheric composition, rotational and vibrational temperature from 65 to 200 Km. The fluorescence is generated by a 2.5 Kv 5 mA electron gun carried on board the rocket.

The reduction of flight data to date showed good agreement with the electron beam method and published CIRA values for nitrogen density, atomic oxygen density and kinetic temperature. However, small to significant differences exist when comparison is made with model values for the concentration of atomic oxygen.

The improved version of the instrument will be flown early in 1974. A chopped electron beam and synchronous detection will enable measurements to be carried out to 300 Km. More light has been reserved for the atomic oxygen channels in order to get improved data for this species so that the differences noted previously can be further studied.

*CIRA - International Atmosphere Reference

Aerodynamic Spectrometer

This instrument is designed to measure the density of the major constituents of the atmosphere in the free molecular region (> 90 Km). A miniature linear ion gauge is used to determine the density of the gas behind a slit which samples the gas through which the rocket passes. Mechanical rocking of the apparatus enables various angles of attack to be produced, while chopping of the gas permits rejection of outgassing effects from the vehicle.

A recent computer analysis of the effects of noise on the version of the aerodynamic spectrometer to be flown early in 1974 shows the following parameters may be measured with good accuracy to 150 Km:

(1) Molecular nitrogen and atomic oxygen densities.

(2) Kinetic temperature.

From 150 Km to 200 Km the instrument is expected to yield good data on molecular scale temperature, and the density of the molecular species as well as the total density.

Project Viking Martian Entry Mass Spectrometer

Molecular beam simulation of entry into the Martian upper atmosphere has been used, in a collaborative program with the University of Minnesota to demonstrate the feasibility of an open ion formation region shaped like a cup facing into the flow. The open cup minimizes response time and permits measurement of reactive species such as atomic oxygen. Since the ions are formed from both incoming and surface-reflected molecules, the preliminary investigations included assessment of potential problems such as CO, vibrational excitation by wall collision at 3.8 eV, and atomic oxygen recombination. An optimized design has been selected for the flight, and preparations are complete for performance testing and quantitative calibration of the engineering prototype of the flight instrument.

The results have demonstrated the feasibility of designing an improved source which responds only to the incoming unperturbed gas molecules, thereby eliminating concern due to vehicle induced perturbations such as outgassing. This concept has great potential for future missions involving atmosphere intercepts on other planets and comets[1].

1. To be published, American Geophysical Union, Annual Fall Meeting, 1973.

David Dunlap Observatory

Two proposals from the David Dunlap Observatory have been submitted to NASA for the use of the International Ultraviolet Explorer Satellite. The IUE is scheduled for launch in December 1976. Dr. R. C. Roeder wishes to obtain ultraviolet spectra of some of the brighter low red-shift quasars and other quasar-like objects. His proposal has been accepted for early assignment of time. Dr. R. Garrison will study the ultraviolet spectra of all stars brighter than about the fifth visual magnitude, and others which are fainter visually but bright in the ultraviolet. His aim will be to compare the temperature and pressure classifications from these spectra with those obtained by conventional means. This extensive observational proposal has also been accepted.

A space astronomy sub-committee of the Associate Committee for Astronomy of NRC is concerned with the potential use of vehicles in space or at very high altitudes for observations of astronomical objects.

UNIVERSITY OF VICTORIA

Department of Physics

Twilight Airglow Studies

Results of observations of twilight lithium emissions at Victoria, B. C. during the past five years have shown a seasonal variation much like that for sodium. The integrated emission rate during the summer has a minimum value of about 7 ± 1 rayleighs near the time of the summer solstice and reaches a maximum value of 28 ± 5 rayleighs near the time of the winter solstice. Thus there appears to be a winter/summer seasonal variation of about 4. As has been found for twilight sodium emission there appears to be more variability during the winter months than during the summer months, the upper atmosphere appearing to be more disturbed during the winter. There appears to be no consistent diurnal variation.

Superimposed upon the regular seasonal intensity there appear, at irregular intervals, marked enhancements which last from three to five days. These emissions, which can be a factor of ten or more greater than the expected seasonal value, have in several cases been correlated with rocket releases of lithium vapour into the atmosphere, but not in all cases.

Plasma Wave Studies

Proton cyclotron echoes and spurs are phenomena related to the proton cyclotron frequency which appear on Alouette II, ISIS I, and ISIS II topside sounder ionograms. A study of the phenomena has found that generally proton cyclotron echoes and spurs occur on the ionograms at frequencies below the electron plasma frequency f_N, the echoes predominantly slightly above the electron cyclotron frequency and the spurs just below f_N. Also, they appear most often when a harmonic of the electron cyclotron frequency is approximately equal to one of the other characteristic frequencies of the plasma.

A correlation study of Pi2 micropulsations and ELF emissions in collaboration with Dr. T. Watanabe and Mr. B. P. Smith of the University of British Columbia and Drs. R. E. Barrington and F. H. Palmer of the Communications Research Centre, Ottawa, has shown that the lower-latitude termination of a particular type of ELF emission is located in the vicinity of the inner boundary of the plasma sheet, changing with the inner boundary position.

UNIVERSITY OF WESTERN ONTARIO

Department of Physics, Centre for Radio Science

Radio Aurora

This series of experiments is aimed at determining the role played by ion-acoustic waves in the scattering of radio waves from aurora. A new system is presently under construction to measure the frequency spectrum of the scattered signal to detect the ion-acoustic waves directly. This will employ the bistatic system already available and in order to specify the position of the aurora a phase comparison technique will be used similar to that in the wind motion investigations.

A comparison of incoherent scatter measurements of electron density and ion drift velocity with simultaneous coincident measurements of auroral echoes is being undertaken in cooperation with the Stanford Research Institute.

Wind Motions

Winds are being measured at meteor heights by employing bistatic systems to analyze the signals scattered from meteor trails. A bistatic system has been built involving transmitters in the Ottawa region and receivers in London; additional transmitters are to be installed in Sault Ste. Marie. Meteor echoes are being received for the Ottawa-London system. The complete system will enable the two horizontal components of velocity to be determined.

Ionospheric Irregularities

The Minitrack system has been modified to monitor differential angle of arrival of beacon signals at 150 and 400 MHz from the Transit series of satellites. The differential measurements should greatly increase the sensitivity and allow deductions on the irregularities of the electron distribution during quiet conditions. Portable versions of the two frequency Minitrack system are being constructed to be operated at Churchill and possibly at a site in the West Indies. These will give extended latitude coverage. Both fixed and portable versions will be modified for the ATS satellite to be launched in 1974.

Angle of arrival and Faraday rotation data from four rockets launched in 1968 into separate phases of an auroral substorm have been analyzed. In pre-break-up and break-up phases the electron density distribution correlates well with luminosity measurements. In post-break-up conditions the distribution is consistent with the local formation of plasma instabilities.

Travelling Ionospheric Disturbances

The continuing observations of periodic content fluctuations utilizing the geostationary satellite transmissions have been complemented by simultaneous observations of angle of arrival fluctuations. The combination of both sets of data allows the derivation of the horizontal components of the wave vector at a single observing station and removes the need for triangulation. The data also indicates whether or not the disturbance is in the form of a travelling wave. There is some evidence to suggest that not all periodic disturbances are the result of a travelling atmospheric wave.

H.F. Doppler oblique sounding measurements on the Ottawa-London path have been extended to three frequencies. To assist in interpretation of these observations some simple modelling of the oblique reflection geometry indicates that the expected doppler shifts due to the presence of T.I.D.'s are considerably more complex than in the case of vertical incidence.

Incoherent Scatter

Design and siting studies for a proposed new Incoherent Scatter Radar have been actively pursued for some time. A proposal for a $13 million dollar facility has been formulated by a group of six North American universities. These six institutions, of which U.W.O. is the only Canadian participant, have formed the Upper Atmosphere Research Corporation to further the project and hopefully eventually operate the facility. The earliest operating date for the facility, depending on funding, is early 1975.

Probe Studies

A variety of theoretical models have been studied which result in current fluctuations with spectral densities in the form of a power low at low frequencies. Possible physical models appropriate to the contaminated Langmuir probe and electric field double probe in a range of ionospheric conditions are now under investigation. Preliminary results indicate that, unless the probe contamination is particularly heavy the probe noise in the magnetosphere should be mostly shot noise.

Absorption Studies

The system for absorption measurement uses a matrix of electronically driven attenuators to compare amplitudes of signals scattered at three different frequencies from individual meteor trails. Its performance has been evaluated and results compared with those from the riometer. It appears that the system should be useful for measurements of patchy absorption but should be complemented with data on the location of each meteor trail.

Meteor Physics

Theoretical work on the reflection of radio waves from ionized meteor trains has been extended, and in particular the influences of these results on radio-derived meteor mass distributions were noted.

Several modifications to the existing low light level television system were made which greatly improved its performance. Extensive sporadic meteor observations were made and analyzed, with a mass distribution index and diurnal rates being calculated. Results indicate close agreement with theoretical mass distributions (with radio data modified to take into account such effects as initial radius) and some previous optical data. Observations are continuing to obtain monthly rates and improve the mass distribution data. A second low light level system is in the process of construction, and it is planned to use triangulation methods to obtain meteor velocities, decelerations, heights, and orbits. Also, studies of light curves of faint meteors and of mass distributions for several of the prominent showers are planned.

YORK UNIVERSITY

Laboratory Astrophysics and Laboratory Aeronomy

New measurements have been made on oscillator strengths of the O_2 Atmospheric Bands and also on the band strengths of the CN Red and Violet Systems.

Wavelength Measurements and Structure Studies on Molecular Spectra

A definitive analysis has been completed of 7700 lines in emission of the O_2 Schumann-Runge system. A unique set of molecular constants which are consistent with all of the lines (to high rotational quantum numbers) has been derived. Nearly 300 pages of tabular computer output relating to this work will be deposited in national libraries. Many previous analyses were found to be in error, particularly for applications to synthetic spectra.

A number of anomalies have been discovered in the analysis of O_2^+ 1st and 2nd Negative Systems.

Identification atlases of molecular spectra; Atlas 10 (NO_2) is currently in press.

The synthetic spectrum programme SPECT III has been further refined to produce realistic emission, absorption and atmospheric transmission profiles.

Theoretical Studies

Line Strength (Honl-London) Factors

Results of research to re-investigate the theory of Honl-London factors and to produce a computer programme which calculates them have now been published or are in press.

R-Centroids

The mathematical basis for the r-centroid approximation has been further extended.

Atmospheric Absorption Coefficients

Studies continue on realistic calculations of atmospheric absorption coefficients. A critical review paper on this topic has been written.

Interpretive Work

The work reported last year on identification of stratospheric NH has been published.

Field Work

Auroral Rocket Spectroscopy

No suitable geophysical conditions existed to justify the launch of York's payload. It has subsequently been made much more sensitive by the incorporation of a Bendix proximity focussed image intensifier.

Solar Eclipse

Payload failure (pointing control) occurred in the Mauritania launch. Data analysis on part of the 1970 Eclipse studies has been completed.

Satellite Studies

The atomic oxygen red line (6300 Å) photometer continues to operate satisfactorily in orbit in the ISIS-II spacecraft, and data collection continues routinely. The receipt of data at York is nevertheless much behind the acquisition,

and is only up to the summer of 1972. Software has been generated for the presentation of the line printer number and shading maps in spin coordinates, with the appropriate geometry. Machine contouring of data, and transformation to other coordinate systems is underway. A catalog system is being developed, and at this stage interested experimenters can telephone the York computer to determine which data have been received and processed. Studies have been carried out on the dayside aurora, the nightside oval, the electrojet, the December 16-21, 1971 event, the August 1972 event, conjugate point photoelectrons, and airglow limb profiles.

Rocket Studies

Photometers were flown in February 1973, BB-II-127, and will be flown again in January 1974, BB-VB-34, February 1974, BB-VB-39, and later in 1974, BB-VA-35. The photometers employ narrow band interference filters and a stepping mask which yields seven spectral elements for each filter. Present objectives are an understanding of the atomic oxygen O^1S excitation process leading to the production of the 5577 Å emission in the aurora, especially its relation to the excitation scheme of N_2.

Ground Based Studies

Ground based measurements using a wide angle Michelson interferometer were made at the University of Alaska in February 1973, in conjunction with the Chatanika radar, and the University of Michigan. The objective was the measurement of neutral winds associated with the aurora. A Fabry-Perot spectrometer is being brought into operation on the York campus for the measurement of airglow neutral winds. Ground based photometer experiments will be made at Cape Parry, N.W.T., in November - December, (70° latitude, 125° E longitude, geographic) with the objective of observing dayside aurora.

Oxygen Atom Probe Measurements

The thin silver film probes for measuring height profiles have been redesigned to permit freedom from surface contamination before deployment. Payloads incorporating four probes in each have been built and flown at Churchill from five SKUA rockets. Results are not yet available.

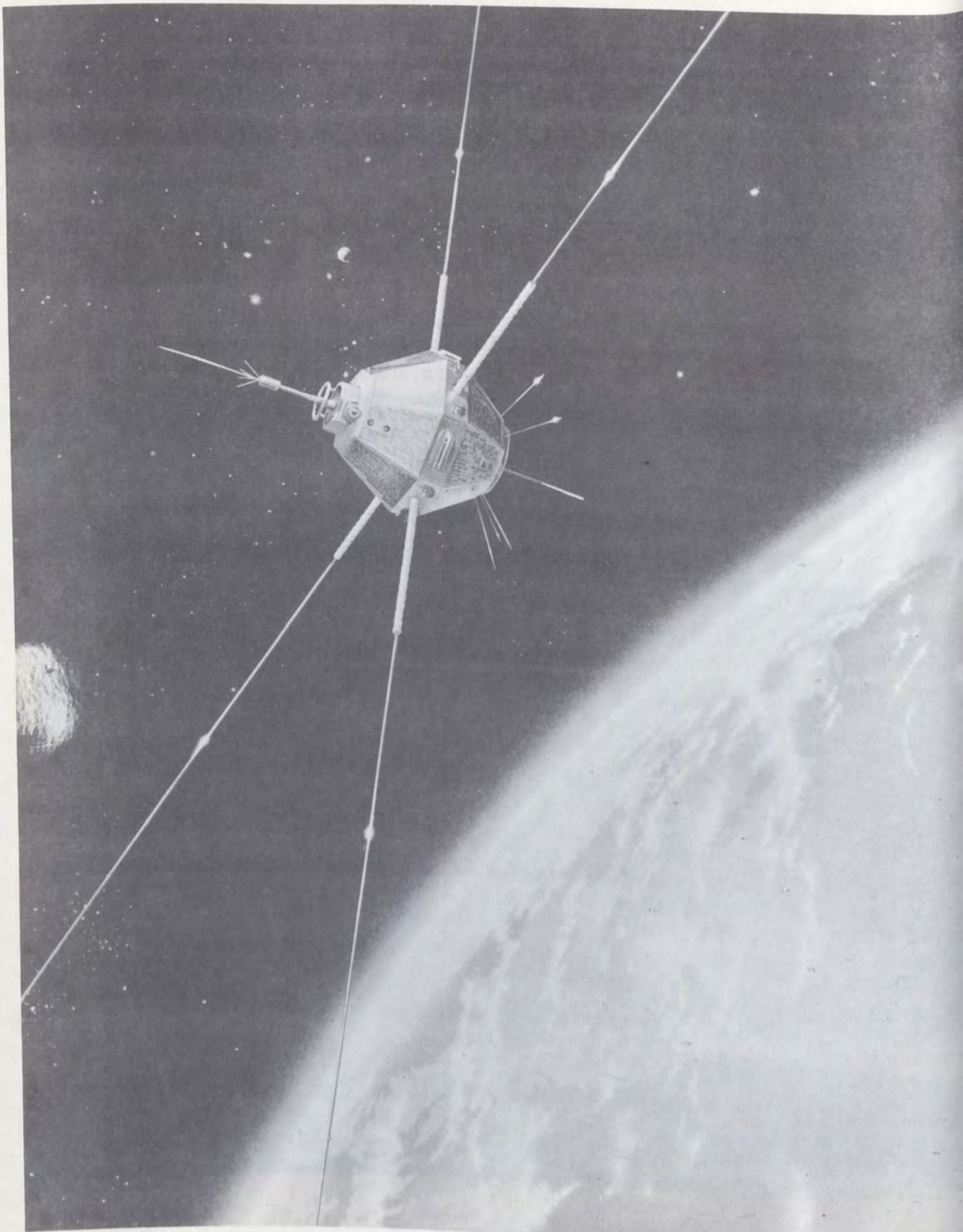
Stratospheric Nitric Oxide Measurements

Recently there has been real world wide concern about the possibility that aircraft flying in the stratosphere might destroy the ozone shield by catalytic destruction from nitric oxide. It was soon realized that the measurement of the NO concentration in the undisturbed stratosphere was of paramount importance. Under

contract to the US Department of Transport, under the Climatic Impact Assessment Program, Drs. B.A. Ridley and H.I. Schiff developed an instrument capable of measuring stratospheric NO with a detectability of two parts in 10^{12}. The principle of the method is the detection of the chemiluminescence produced when O_3 is added to air containing NO. Four instruments were built; two suitable for balloon platforms and the other two for aircraft operation. Four successful balloon flights have been performed in New Mexico, over the altitude range 17 to 30 km. Measurements have been obtained from RB57F aircraft at 20 km from Alaska to Panama. Plans are underway for Canadian flights with this instrument at Churchill during the summer of 1974.

FORT CHURCHILL

ISIS II IN ORBIT



ACTIVITIES IN GOVERNMENT ORGANIZATIONS

DEPARTMENT OF COMMUNICATIONS

Communications Research Centre, Ottawa, Ontario

THE ISIS SATELLITE PROGRAM

The general objective of the ISIS program is to conduct comprehensive studies of the ionosphere. It involves making measurements over a range of heights and latitudes sufficient to determine conditions in the ionosphere and to achieve a full understanding of this region out to the magnetospheric boundary.

For this purpose it was arranged by means of Memoranda of Understanding between the United States and Canada that Alouette I should be followed by up to four satellites, to be built in Canada and launched by the United States.

Alouette I

This spacecraft was launched from California on 29 September 1962. It was the first satellite to be designed and constructed in Canada and was launched by a U.S. Thor-Agena rocket as part of a joint space program between the USA's National Aeronautics and Space Administration (NASA) and Canada's Defence Research Board (DRB). The satellite was designed and constructed by the Defence Research Telecommunications Establishment of the Defence Research Board, now the Communications Research Centre of the Department of Communications.

The satellite is spheroid-shaped, contains four experiments and is in a circular orbit at a height of 1,000 km. Orbital elements are: inclination 80.5°, perigee 994 km, apogee 1030 km.

Routine Alouette I operations ceased on 30 September 1972 and all operations were discontinued on 31 December 1972.

Alouette II

Alouette II was sucessfully launched on 29 November 1965. Orbital parameters are: inclination 79.8°, perigee 502 km, apogee 2,983 km. Although it resembles its predecessor outwardly, Alouette II developed into a substantially

different spacecraft because of the change in orbit and because of further information on the ionosphere gathered by Alouette I. The spacecraft contains the five experiments shown below:

Ionospheric Sounder: The sounder covers the frequency range 0.2 MHz to 13.5 MHz with 300 watts transmitted power. There is also a 100-watt transmitter essentially the same as that in Alouette I. The 300-watt transmitter failed in May 1969; the 100-watt transmitter is still operating.

VLF Receiver: The VLF experiment covers the frequency range 50 Hz to 300 kHz.

Cosmic Noise: Since the ionosphere acts as a screen at frequencies below the critical, the receiver works against a background of cosmic noise, and this is measured by monitoring the AGC voltage from the sounder receiver.

Energetic Particle: The energetic particle experiment was supplied by the National Research Council of Canada. Six particle counters are used to record the number of particles within the energy ranges:

a) protons 0.5 to 700 meV
b) electrons 40 keV to 3.9 MeV
c) Alphas 5 MeV to 2.8 BeV.

Langmuir Probe: The experiment measures electron density from 10^3 to 10^6 e/cc and electron temperature from 400° to 5000°K.

Relative to Alouette I, the Alouette II sounder receiver bandwidth was extended at both ends of the range, the sounder transmitter power was increased, the pulse repetition frequency decreased, the frequency sweep rate modified. The VLF receiver was also given an extended bandwidth, and a greater immunity to interference was provided by re-design of the sounder receiver.

All experiments and facilities worked as planned. Results indicate that the capacitive antenna coupling combined with the ion guards have been successful in reducing considerably the effect of the plasma sheath. The bandwidth extension of the VLF experiment has yielded new information, while the re-designed sounder system suffers less interference than did Alouette I. After 40 months in orbit, the 300-watt sounder transmitter became defective. The back-up 100-watt transmitter was then switched on, and much useful data was being obtained during a $2\frac{1}{2}$-hr daily operating schedule until 3 June 1973 when Alouette II was placed in a standby "mothball" state.

ISIS I

ISIS I was launched from the Western Test Range, California, at 0646 GMT, 30 January 1969, into its prescribed orbit. Orbital elements are: inclination 88.4°, perigee 575 km, apogee 3,515 km, period 128.2 minutes. This was the third satellite to be designed and constructed in Canada and is the second in the ISIS (International Satellites for Ionospheric Studies) series. This spacecraft contains the following ten experiments:

Swept Frequency Sounder: This topside ionospheric sounding experiment covers a frequency range of 0.1 to 20.0 MHz.

Fixed-Frequency Sounder: The fixed-frequency radio sounder operates on six crystal-controlled frequencies within the range of the swept-frequency sounder - 0.250, 0.480, 1.000, 1.950, 4.00 and 9.303 MHz.

Mixed-Mode Sounder: This experiment uses a fixed transmitting frequency of 0.833 MHz simultaneous with a receiver which sweeps through the complete frequency range of the topside sounder.

VLF Receiver/Swept-Frequency Exciter: This is basically a low-frequency receiver covering the frequency range of 50 Hz to 30 kHz, which permits experimental studies of the upper ionosphere and exosphere and the complex interactions between the ionized media and low energy particle streams.

Energetic Particle Detector: This package contains two groups of detectors capable of identifying electrons and protons and measuring their angular distributions and energy spectra over the energy range for electrons from 8 keV to greater than 770 keV and for protons from 50 keV to 20 MeV.

Soft Particle Spectrometer: This spectrometer was designed to measure the energy spectrum, angular anisotropy and spatial and temporal variations of both positive and negative particles in the energy range of 10 eV to 10 keV.

Ion Mass Spectrometer: This is an instrument that is capable of analyzing the ionic composition of the ionosphere in the atomic mass range 1 to 20.

Cylindrical Electrostatic Probe: This is an instrument which measures electron temperature and density. The purpose of this experiment is to extend the satellite measurements into the period of solar maximum.

Spherical Electrostatic Analyzer: The objective of this experiment is the measurement of spatial and temporal variations in the concentration and energy distribution of charged particles in the altitude region of the satellite.

136/137 MHz Beacon: This instrument consists of two 100 mw transmitters operating at 136.410 and 137.950 MHz (the former being the tracking beacon) and measuring the scintillation in the total electron content of the ionosphere between the satellite and the ground station.

Cosmic Noise: This experiment measures the background radio noise levels with the sweep-frequency receiver orbiting substantially above the F-layer ionization maximum to obtain information on the galactic radio noise in various regions of the galaxy and the variation of this noise with frequency. In addition, and of particular interest to the ionospheric studies, the data contain information on the enhancements of solar radio noise when the sun is active and on the noise emissions from the ionosphere. Recent studies have yielded information on the direction of propagation and wave polarization of whistler-mode noise in relation to low-energy particle precipitation. The dependence of the noise amplitude on the attitude of the receiving antenna has been studied and information derived about the wave field.

ISIS I operates between five and seven hours per day, and all experiments, with the exception of the ion mass spectrometer and soft particle spectrometer, are performing as planned. As well, by using the onboard clock and programmer and tape recorder, much useful data was obtained on the ionosphere over previously unexplored regions of the globe before clock and tape recorder failure during February 1970.

ISIS II

ISIS II was launched from the Western Test Range, California, at 0257 GMT, 1 April 1971, into near nominal orbit. Orbital parameters are: apogee 1,423 km, perigee 1,356 km, inclination 88.16°, period 113.55 minutes. This was the fourth satellite to be designed and constructed in Canada and is the third in the ISIS (International Satellites for Ionospheric Studies) series. This spacecraft contains the following 12 experiments:

Swept-Frequency Sounder: The objective of the experiment is to determine the electron number density at and below the satellite down to the peak of the F-layer of the ionosphere along the orbit of the satellite. The electron density as a function of distance below the satellite is determined from the delay time of high

frequency radar echoes reflected from the ionosphere as a function of frequency. From repetitive measurements, the heights, latitudinal, longitudinal and diurnal variation of the electron density can be studied. Also, the data yield information about the size and location of irregularities in the ionosphere.

Fixed-Frequency Sounder: The fixed-frequency sounder is designed to provide observation of small-scale irregularities which are too limited in extent to be easily investigated by the swept-frequency sounder and to complement the swept-frequency sounder, particularly where rapid horizontal variations occur. The prime scientific objectives are:

a) The study of irregularities in the high ionosphere;

b) the study of the fine structure of the plasma resonance phenomena;

c) the study of plasma mixing processes by observing the swept-frequency receiver response while the transmitter remains at one of six selectable fixed frequencies.

VLF Experiment: This experiment is basically a low frequency receiver covering the frequency range from . 05 kHz to 30 kHz. Because of the large range in amplitude of naturally occuring VLF signals, the receiver has a dynamic range of about 80 dB, which is achieved by the use of an AGC system. The AGC level is telemetered to the ground along with the broad-band output of the receiver, which directly modulates the telemetry transmitter. Information is provided on:

a) The relative abundance of H^+, H_e^+ and O^+ ions in the vicinity of the spacecraft;

b) the harmonic mean mass of the positive ions in the vicinity of the spacecraft;

c) the propagation of VLF waves of natural origin and from ground-based transmitters;

d) the various ion and hybrid resonances of a plasma that lie in the VLF band;

e) the association between VLF noise or emissions and the intense fluxes of energetic particles that precipitate into the lower ionosphere at high latitudes;

f) VLF noise emitted by the plasma surrounding the spacecraft when it is excited by HF signals from the topside sounder transmitter. The ISIS II spacecraft provides a unique opportunity to study such interactions.

At low frequencies, the behaviour of the sounding antennas of the ISIS spacecraft is profoundly affected by the plasma in which they are enveloped. Even when dealing with field strengths at which the antennas behave as linear devices, the plasma greatly changes their impedance characteristics. Thus if the intensities of VLF signals are to be measured within the ionosphere, it is mandatory that the impedance of the antenna be known. Such impedance measurements are now being made routinely over the frequency range 50 Hz - 15 kHz.

The observation, from the VLF records, that the topside sounder often generates noise at both the lower hybrid resonant frequency and at the proton gyrofrequency of the medium surrounding the spacecraft is of great interest. The characteristics of these signals have been investigated in terms of electron density, sounder transmitter frequency, satellite attitude, etc. It appears, from these results and from previous topside sounder results, that a high-power H. F. transmitter in the ionosphere can simultaneously excite essentially all of the characteristic frequencies of the plasma surrounding the satellite.

Cosmic Noise: This experiment measures the so-called cosmic noise, or more specifically the natural background radio noise level, with a sweep-frequency receiver orbiting substantially above the F-layer ionization maximum. In general the background noise level is determined by galactic noise, and information on its variation with direction in the galaxy and with observing frequency is desired, particularly at frequencies that cannot penetrate through the ionosphere. In addition, there are occasional noise enhancements above the galactic level which are of solar origin. These are associated with the ejection of material from the sun that can drastically affect the earth's upper atmosphere and ionosphere: a monitor of such solar noise emissions at low enough radio frequencies can provide detailed information of the passage of the solar particles through the sun's outer corona and into interplanetary space. Moreover, it appears that study of such noise emissions can lead to quantitative determinations of electron density and temperature in the interplanetary regions.

Yet another contribution to the background noise level comes from radio emissions generated within the ionosphere and such noise, often of exceptionally great magnitude, is commonly observed at high latitudes. A detailed study of this phenomenon as a function of location, frequency, ionospheric parameters is desired, and particularly in a satellite which measures the local ionospheric conditions at the same time. Most of the recent effort has been directed toward understanding the high-latitude ionospheric emissions, and particularly those observed at auroral oval latitudes. The details of particular bands of noise associated with the auroral oval and with the magnetospheric

cleft are being studied, and their relation to other satellite data, particularly the sounder ionograms and the soft particle spectrograms, is being explored as a plasma physics problem in wave-particle interactions.

Retarding Potential Analyzer: The objective is to measure the positive ion density, composition, and temperature in the vicinity of the spacecraft. The secondary objective is to measure the thermal electron density and temperature, and the flux of suprathermal electrons. The effect on the measured quantities of special ionospheric events such as magnetic disturbances, red arcs, etc., will be studied. The long-term dependance of the composition, densities and temperatures upon geophysical parameters such as altitude, latitude, longitude, local time and season will be determined.

Ion Mass Spectrometer: The ion mass spectrometer is a magnetic deflection instrument with two ion detector systems. The instrument scans the mass range 1-64 amu in two sections 1-8 and 8-64, and measures the relative abundance of the ions collected in this mass range from the ambient ionosphere in the vicinity of the satellite.

Soft Particle Spectrometer: Intense fluxes of low energy particles, mainly electrons and protons, are the cause of auroral phenomena and related geophysical disturbances. This experiment is an improved version of the experiment flown on ISIS I which provided good detailed information on the fluxes and energy spectra. The energy resolution has been improved to provide better data on the spectral line width and shape. Particles are detected in two separate beams to provide a check on the variability of the flux on a short time scale.

Energetic Particle Detector: The objective of the energetic particle experiment is to provide data which will aid in the understanding of:

a) The mechanisms responsible for the production and control of the particles which populate the outer radiation zone and which sometimes precipitate into the atmosphere;

b) the related problem of entry into the earth' magnetic field of solar flow particles;

c) the nature of the distortions which occur in the earth's magnetosphere as a result of its interaction with the solar wind.

The experiment is designed to measure intensity, angular distributions and energy spectra of electrons and protons. An energy range of 1 KeV to 1 MeV is covered for electrons. There are two energy ranges for protons, auroral energies 2-20 KeV and "solar flare" energies 0.8 - 30 MeV.

Beacon Experiment: The beacon experiment aboard ISIS II is an improved version of the equipment aboard ISIS I. The purpose of the experiment is to detect and measure inhomogeneities in the ionosphere between the spacecraft and a number of ground stations. The inhomogeneities are detected by the modifications in direction of propagation, amplitude and polarization imposed on the radio waves in propagation through the irregularities. These are detected by angle-of-arrival (relative phase), amplitude and polarization measurements made in the ground equipment. When the orbits of the ISIS I and ISIS II satellites are suitable, the beacons on both satellites will be used to obtain data in quick succession on the same volume of ionosphere.

Cylindrical Electrostatic Probe: The objectives of the experiment are:

a) To extend through the waning phase of the 11-year solar cycle the study of the global behaviour of electron temperature and density that was begun with data from the ISIS X* (Alouette II and Explorer XXXI) and ISIS I satellites;

b) by use of the extended resolution of this instrument, to examine in greater detail polar cap and magnetosphere/plasmasphere interactions, and

c) to look at global behaviour of the ionosphere from a circular polar orbit, thus avoiding mixing the effects of altitude and latitude.

*ISIS X - Refers to launching of Alouette II and Explorer XXXI in the same vehicle.

Red Line Photometer: The purpose of this experiment is to map the global distribution in the intensity of the 6300 Å line emission from the D level of atomic oxygen. This upper level lies only 2 eV above the ground state; hence it can be excited by a number of mechanisms and the emission is useful in interpreting the physical processes of the F-region. (The emission is strongly collisionally deactivated by N_2 and does not appear at lower altitudes.) The

mechanisms to be studied are auroral excitation by electrons and protons, mid-latitude red arcs, photodissociation of O_2, dissociative recombination of O_2^+, excitation by photoelectrons generated both locally and at the magnetically conjugate point, and thermal electron excitation. The global behaviour patterns and the simultaneous measurements of other experiments aboard ISIS II should make it possible to delineate these mechanisms.

Aurora Scanner Photometer: The scanning photometer is designed to map the distribution of auroral emissions at 5577 Å and 3914 Å over the portion of the dark earth visible to the spacecraft. A combination of internal electronic scanning and the natural orbital and rotational motions of the spacecraft causes a dual wavelength photometer to scan systematically across the earth. The data is being reproduced directly in the form of separate pictures representing emissions at each wavelength. The pictures will be used to study the ratio of 3914 Å to 5577 Å emissions (thought to depend upon the energies of exciting particles), and to compare auroral activity with phenomena recorded by other instruments on board the spacecraft and on the ground.

ISIS II Operation

All experiments and spacecraft systems are working well and up to seven hours of data is acquired daily.

Satellite Support Services

In addition to spacecraft design, the ISIS program provides support services in the form of two telemetry stations and a data processing centre. One telemetry station is situated at Resolute Bay on Cornwallis Island and the other, as well as the data centre, at Ottawa. The Ottawa station is the control station for Alouette/ISIS satellites.

COMMUNICATIONS TECHNOLOGY SATELLITE

The Department of Communications/NASA Communications Technology Satellite joint project now enters the hardware production phase with plans for launch at the end of 1975. All spacecraft subsystems have been designed, the ground control station at DOC's Communications Research Centre at Shirley Bay is being constructed and equipped and the communications terminals are about to be procured.

As previously reported, the objective of the project is to place an advanced technology communications satellite in synchronous orbit at 116° longitude to carry out communications and technological experiments during a two year mission life. The high power 12-14 GHz band transponder, which is built around a 200W super-efficient TWT supplied by NASA Lewis Research Center, will provide an EIRP of 55 dBw. This will permit the use of relatively inexpensive communications ground terminals, suitable for deployment in small communities or by mobile parties operating in inaccessible regions.

Construction of an engineering model spacecraft is well underway with SPAR, Toronto and RCAL, Montreal, providing the major portion of respectively the mechanical and electrical subsystems. This activity will culminate in 1974 in the integration of the subsystems into a complete spacecraft at CRC's specially constructed assembly and test building. An extensive environmental test program will thereafter be carried out at NASA facilities. Considerable confidence in designs has been generated as a result of completed vibration, acceleration, shock, thermal vacuum and solar simulation testing on a Dynamic Thermal Model spacecraft produced over one year ago.

Weight growth problems during the design phase forced the elimination of the Mercury Bombardment Ion Engine and the Liquid Metal Slip-rings technological experiments from the project baseline. The basic spacecraft however, remains unchanged as a three-axis stabilized platform, equipped with lightweight extendible solar arrays producing better than 1KW of power in synchronous orbit. The single channel SHF transponder operates through two 2.5° 3 dB beamwidth steerable antennas to provide approximately time zone coverage capability in Canada. ESRO, through a Memorandum of Understanding with DOC are developing the flexible blankets for the extendible arrays and providing 20W TWTs and a parametric amplifier for the SHF transponder. Stability of the platform is maintained by an earth and sun sensing system whose error signal outputs are used to either alter the momentum of a variable speed wheel or operate reaction control hydrazine engines. This hydrazine reaction control system is also used to maintain satellite E-W stationkeeping.

On conclusion of engineering model spacecraft testing, a prototype flight model will be built. After full acceptance testing, this spacecraft will be launched by a Delta 2914 launch vehicle provided by NASA, into a elliptical transfer orbit whose apogee is at synchronous altitude. At synchronous altitude the spacecraft's apogee motor will be fired to circularize the orbit. NASA will have the responsibility to place the satellite on station, thereafter it will be DOC's responsibility to bring the satellite under three-axis control with solar arrays extended and in a fully operational configuration. SED Ltd. are under contract to produce the necessary attitude acquisition software for DOC.

To date 41 Canadian Communications Experimenters have submitted proposals to DOC to participate in the CTS mission. These proposals are now being assessed by an Evaluation Committee. NASA has accepted eight proposals from US

Communications Experimenters. Satellite availability for communications experiments will be shared equally between Canadian and US experimenters. The technological experiments are however, being retained as a DOC/NASA activity.

STUDIES OF THE NATURAL RADIO ENVIRONMENT

Studies of the upper ionosphere (through the Alouette-ISIS programme) and of the lower ionosphere (by means of the partial reflection experiment and VLF/LF propagation) have continued during 1973.

The upper ionosphere researches have included studies of the equatorial ionosphere (particularly field aligned ducts), of the distribution of ionization over the north polar cap, and of ionization, electron temperature and radio noise phenomena associated with the magnetospheric cleft region of the ionosphere. Some progress has been made on the physics of hot plasmas. The occurrence of conjugate (ducted) echoes observed by top-side sounders has been studied, and the diurnal, seasonal, longitudinal and lunar variations have been established. Studies have been made of top-side sounder data for passes where three satellites (ISIS I and II and Alouette II) traverse the same region at about the same time, to obtain a picture of the distribution of ionization over the polar cap. Whitteker has found that the ambient electron density and particularly the temperature are systematically enhanced at high altitude in the vicinity of the day side cusp region of the ionosphere; James and Hartz have studied radio noise enhancements associated with this and with other regions (particularly at auroral latitudes) at other times using dispersion relations for a hot plasma, Muldrew has been able to explain in detail (amplitude and phase) interference fringes observed laboratory plasmas between electrostatic and electromagnetic fields.

Routine scaling of Alouette I data is essentially complete, and ten Alosyn Data basics are being published.

Studies of the lower ionosphere and of the neutral atmosphere by the partial reflection of MF and HF radio waves have been productive. An investigation into the height resolution of the differential-absorption, differential-phase partial reflection experiment has been completed, which concludes the present work aimed at establishing the reliability of this experimental technique. Improved instrumentation to measure differential-amplitude and differential-phase is under development, and the addition of three close-spaced antennas and three receivers to the system, to measure mesopheric winds (50-90 km), is nearly completed. An on-line PDP 11 computer will be used to preprocess the data, which are recorded digitally on a 7-track incremental tape recorder. The research studies in this programme have been concerned with diurnal and seasonal changes in electron loss rates, with electron production and electron loss rates during day time energetic particle events, and with development of electron density distributions over dawn.

The use of VLF/LF propagation data to deduce ionospheric electron density height profiles in the D-region has been reviewed, and presented to the COSPAR Konstanz Symposium on Lower Ionosphere Structure, May 23-25, 1973.

The studies of electron density changes in the D- and E- region measured by rocket and ground based techniques over East Quoddy, Nova Scotia during the July 10, 1972 eclipse are not yet completed.

THE SHF PROPAGATION PROGRAM

The objective of this program is to study the effects of the troposphere on radiowave propagation at frequencies above 3 GHz, particularly as these effects relate to the design of space communications systems. Efficient utilization of new bands above 10 GHz will require a sound knowledge of propagation effects such as precipitation attenuation and scattering which become increasingly important with increasing frequency.

Precipitation Attenuation Statistics

This program is primarily concerned with the study of attenuation due to precipitation. Given the drop-size distribution and the distribution of rainfall intensity along the propagation path, a reasonable theoretical estimate of attenuation can be made. However, little is known of the distribution in time and space of these meteorological parameters or of the variation of the statistics of occurrence of attenuation due to rainfall with location and elevation angle as required by the systems designer.

With the completion of previous research to evaluate indirect methods of determining precipitation attenuation using a weather radar or microwave radiometer, attenuation statistics are now being measured at seven locations representative of the various climatic regions of Canada. A 13 GHz radiometer and associated data recording system designed at CRC for this purpose was installed at each location in 1973. Each radiometer is directed at the position of a geostationary satellite at 114°W longitude to obtain attenuation statistics appropriate to a satellite serving Canada. The experiment is expected to run continuously for approximately three years.

The analysis of the 2.9 GHz weather radar data obtained at Ottawa in 1970 has been completed during the past year. In the experiment performed, the radar antenna was scanned in both azimuth and elevation during most of the rain events which occurred. From the measurements, distributions have been obtained for the sizes of precipitation cells producing various attenuations, and for the spacings and relative orientations of adjacent cells. From these results, with two

simplifying assumptions, curves specifying the relative joint probability that an attenuation is simultaneously exceeded at both stations in a site-diversity system have been obtained as functions of attenuation level and station separation.

McGill University, under contract to CRC, has previously used radar data to develop precipitation attenuation statistics for earth-space paths. More recently, methods have been developed which use raingauge and radar-derived storm motion data to obtain attenuation statistics for terrestrial microwave links of various lengths and spacings. These methods are now being applied to develop a precipitation attenuation climatology for Canada.

Transhorizon Propagation

Measurements of tropospheric structure and the characteristics of transhorizon propagation are being obtained with a forward-scatter system operating at 15.7 GHz over a 500 km path between Boston and Ottawa. The scatter system employs narrow-beam transmitting and receiving antennas which are synchronously controlled to permit the scatter volume to be rapidly scanned over a large region of the upper troposphere. In a remote sensing experiment using this system, estimates of average wind speeds obtained from Doppler frequency measurements have been shown to agree favourably with simultaneous radiosonde measurements. In another experiment completed during the past year, statistics of transmission loss over the path at several receiver elevation angles have been obtained as part of an investigation of interference between terrestrial and space communication systems. These data will be separated according to the occurrences of the turbulent scatter, hydrometeor scatter, and ducting mechanisms involved.

Low Angle Tropospheric Fading

It is necessary to operate geostationary satellite communications systems at low elevation angles when coverage of the Canadian north is required. Under these circumstances, sufficiently severe signal fading can occur so as to effect the design of these systems. A series of measurements has been undertaken since 1967 to determine the dependence of this fading on elevation angle, frequency, season and climate. A more fundamental investigation has begun in the past year to relate the fading observed during specific periods of time to the appropriate meteorological data obtained from radiosonde measurements.

ATS-5 Experiments

Beacon signals from the LES-6 and the NASA ATS-5 satellite have been monitored over a period of 13 months at frequencies of 254 MHz and 1550 MHz. The monitor sites were at Churchill, Manitoba (latitude 58°) and Ottawa, Ontario

(latitude 46°). This data has been analyzed to determine ionospheric fading statistics. The maximum peak-to-peak fading amplitude measured at Churchill was 5 dB at 1550 MHz and 22 dB at 254 MHz. The maximum fade levels measured at the Ottawa site were 1.2 dB at 1550 MHz and 16 dB at 254 MHz.

A power spectral analysis of the ionospheric fading signals showed that for the 1550 MHz fading signal no appreciable power is present in frequency components beyond 0.4 Hz. For the 254 MHz case, appreciable power density levels exist for frequency components of up to 3.0 Hz.

The results of a series of measurements of the scattering from ocean surfaces of electromagnetic waves at 1550 MHz are now available. These results show reflection coefficient as a function of differential time delay. The grazing angles included in the study range from nine degrees to 22.5 degrees. Time dispersions ranging from 0.125 to 1.8 micro-seconds were observed.

Weather Radar

A 2.9 GHz weather radar has been calibrated by comparing attenuations calculated from measurements of backscattered power from precipitation along the propagation path with attenuations measured directly at 15.3 GHz using the ATS-5 satellite.

The radar antenna was also scanned in azimuth and elevation. The spatial resolution provided by the radar was used to determine the size distribution of precipitation cells producing various attenuations. With two simplifying assumptions, the relative probability that a given attenuation is jointly exceeded in a site-diveristy system was calculated as a function of attenuation level and path separation. These results are essential for the effective design of a site-diversity system.

Tactical Satellite Communications Project

During 1972, a continuing program of propagation measurements at 250 MHz was carried out using the beacon signal from the LES-6 satellite. Data on the statistical behaviour of ionospheric scintillations has been obtained during the year in order to determine the synoptic variation of this parameter. Analysis of the spectral distribution of the scintillation fading is also being carried out.

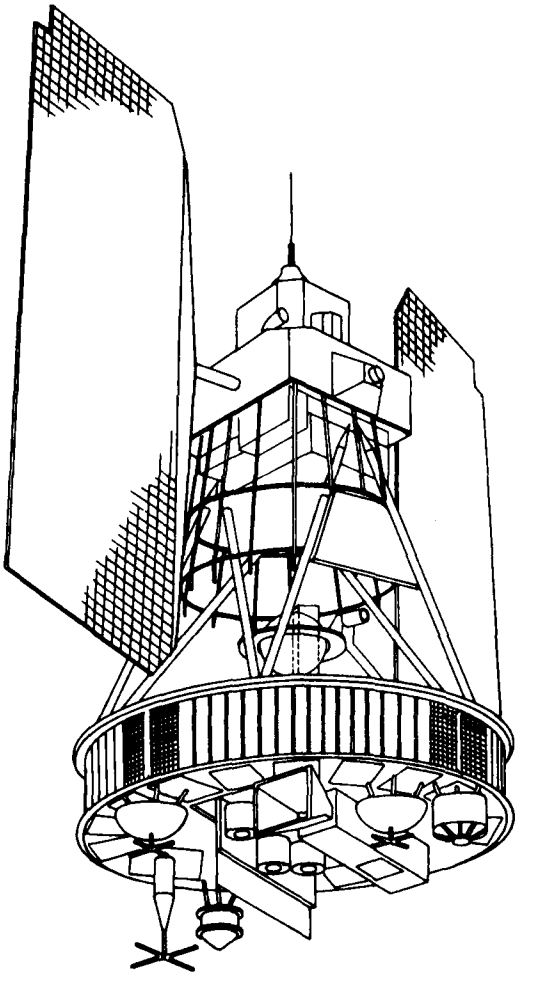
Shipborne multipath measurements have been made during the year. The data obtained is being used to evaluate various antenna concepts for a shipborne UHF satellite communications terminal.

LES - Lincoln Experimental Satellite

ERTS Ground Station at Prince Albert

Operational responsibility for this station was transferred from the Communications Research Centre (CRC) to the Canadian Centre for Remote Sensing (CCRS). Since the launch of ERTS I the station has recorded on broad-band magnetic tape all of the imagery of Canadian terrain that has been acquired by the satellite. The magnetic tapes are shipped to Ottawa where they are used to produce black and white and colour 9" X 9" images in both corrected and uncorrected formats and the tapes are archived at CCRS. The Quick-Look imagery in black and white at full resolution is produced at the ground station and used to check station performance. A commercial contractor reproduces this imagery and distributes it on a cost recoverable basis to the users who require rapid access to the imagery.

THE EARTH RESOURCES TECHNOLOGY SATELLITE (ERTS)



DEPARTMENT OF ENERGY, MINES AND RESOURCES

Geological Survey of Canada

Participation in Apollo Lunar Sample Studies

Chemical Composition (Dr. J.A. Maxwell, Principal Investigator)

Determinations of the major, minor and some trace elements in three samples of lunar rocks, and one sample of the lunar regolith, collected during the Apollo 16 mission were completed and the results have been submitted for publication. Work has been started on the three samples of Apollo 17 material, which will terminate this study which has produced analytical data on samples from all of the manned lunar landings.

Mineralogy-Petrology (Dr. R.J. Traill, Principal Investigator, Dr. A.G. Plant, Mr. M.R. Dence and Dr. R.A.F. Grieve, Co-investigator)

This project is concerned with using mineralogical, chemical and petrographic data to determine and interpret the roles of volcanic and impact processes in the genesis of lunar rocks and glasses. The importance of impact melting and annealing as rock-forming and modifying processes is evaluated, and comparisons made with terrestrial sites of hypervelocity impact. Several samples returned from the lunar surface have had an adhering glass coat and studies of two such Apollo 16 samples have been completed and are reported in the Proceedings of the Fourth Lunar Science Conference (in press). Glass coatings on highland basalt and anorthositic gabbro breccia represent splashed-on impact melted material of highland basalt composition. Heat supplied by the splash glass has been sufficient to produce zones of partial melting within the samples. Analytical data indicate a genetic relationship, at least on a small scale, between anorthositic and Fra Mauro basalt compositions through the low pressure partial melting of materials with highland basalt composition. The partial melts have compositions similar to Fra Mauro basalts, while the residual crystalline materials are relatively anorthositic. Variations in the degree of melting and the composition of the parent lithologies have produced only minor compositional differences in areas of partial melt within and between samples.

Studies of remaining Apollo 15 and 16 samples are now being concluded, and examination of samples from the Apollo 17 mission to Taurus-Littrow, which are currently being received and which include a sample of the orange glass-bearing soil from near Shorty Crater, will commence soon.

Electrical Characteristics of Lunar Samples (Mr. L.S. Collett, Principal Investigator and Dr. T.J. Katsube, Co-Investigator)

The proposal to measure electrical properties of lunar rocks returned by Apollo 15, 16 and 17 flights submitted by the authors to cover the period for one year commencing February 1, 1973 to continue in the Lunar Sample Program was accepted by the National Aeronautics and Space Administration.

During the early part of the year, measurements on five lunar samples from Apollo 16 have been carried out over the frequency range from 10^2 to 2×10^8 Hz. A paper summarizing the results of these measurements has been submitted to the Proceedings of the Fourth Lunar Science Conference, Houston, Texas, March 5-8, 1973.

Studies on the characterization of the electrical parameters of lunar rocks have been found to depend on the electrical mechanism of current conduction through the rock matrix, on the effect of moisture and other liquids if they exist in the rocks, and on the inherent problems of electrical measurements associated with high temperatures. The results of these investigations have also been submitted in a paper to the Proceedings of the Fourth Lunar Science Conference.

Present investigations on electrical measurements on lunar and terrestrial rock samples are being directed to study the effect of grain boundaries between the mineral facies and the problem of measurement accuracies. Cross-checks between measurements in our laboratory are being made with the laboratories at the University of Toronto and the University of Utah in order to increase the reliability and accuracy of the data.

In keeping with the Post-Apollo Lunar Science Program whereby the proposed research should attempt to provide more specific insight into lunar processes, origin, history and structure, a proposal was submitted to NASA during the summer, 1973, with the idea of being asked to analyze more lunar samples only where there appears to be gaps in our knowledge of the moon, or to test particular theories by more work on particular samples or classes of samples. Some problems may require the efforts of a consortium of PI's bringing various approaches and techniques to a particular problem. It could happen that we may be asked to do more electrical measurements or we could investigate in depth some types of rock that appears to have anomalous characteristics at our own instigation .

Earth Physics Branch

The Division of Geomagnetism operates 10 permanent magnetic observatories and eight variation magnetic stations. Nine of the magnetic observatories are now recording in digital form on magnetic tape at one minute intervals. These digital systems and recorders are interrogated and checked daily by

a semi-automatic system over standard telephone lines from Ottawa. A new magnetic observatory is being established at Yellowknife and should be operational by mid 1974. Of the six variation magnetometers along a meridian through Churchill, three will be updated by a new battery-powered digital data acquisition system by early 1974. A fourth digital system will be added to the line at Herchmer which is 150 km south of Churchill. The line of magnetometers is expected to operate through to the end of the International Magnetosphere Study in 1978. The ATS-6 and SMS-1 satellites are expected to be along the same magnetic meridian early in 1974. The table gives the geographic coordinates and method of recording for observatories and variation stations.

Microfilm copies of the magnetograms from the observatories and variation stations are sent to the World Data Centre on a monthly basis, as well as edited versions of the digital data from the observatories. Microfilming of old magnetograms and the corresponding mean hourly values and digital data have been nearly completed for all the magnetic observatories, and deposited in the World Data Centre.

Data from these stations is used for studying many diverse fields in earth and space geophysics. The basic configuration and slow changes in the source of the earth's magnetic field and the conductivity of the crust are determined from observatory and repeat station data. Dynamics of the magnetosphere, magnetospheric currents and oscillations are studied from observatory and variometer records. The direction of the sun's magnetic field in the vicinity of the earth is determined from diurnal magnetic variations in the polar cap.

Analysis of magnetic variations during the recent VB-33 rocket flight at Churchill together with photometer and electric field measurements have revealed the location of the auroral electrojet to be on the poleward edge of the arc and not within the arc. Secondly while the magnetic disturbance corresponded to a small substorm, the Joule heating of the neutral atmosphere is an order of magnitude larger than expected and compares to that of a large storm.

Large current vortices are found to exist in the polar cap during the growth phase of the unusually large magnetic storms August 4-5 and August 9, 1972. A correspondence was found between the sense of the polar cap current circulation and the interplanetary magnetic field.

Canadian Centre for Remote Sensing

The Canada Centre for Remote Sensing (CCRS) was established in 1971 to act as the lead agency for co-ordinating remote sensing activity in Canada. The Centre is concerned with remote sensing of earth resources from satellite and aircraft platforms.

The satellite program includes the readout of the Canadian data from the United States National Aeronautics and Space Administration's experimental earth resources satellites. The first of these - ERTS-1 was launched on July 23, 1972. The sensors on board -- a three camera Return Beam Vidicon System and a four spectral channel Multi-Spectral Scanner -- transmit imagery data covering a swath 185 km wide. Complete coverage of Canada is obtained repetitively every 18 days. An 85-foot parabolic antenna system at the Prince Albert Satellite Station has been converted to receive and record ERTS data. A data handling system has been built at the CCRS headquarters in Ottawa for the processing of ERTS and aircraft remotely sensed data. The National Air Photo Library Reproduction Centre, located in the same building as CCRS, is responsible for the photographic reproduction, indexing and distribution of ERTS aircraft and aerial survey imagery. Individual ERTS satellite images encompass an area of 185 km x 185 km with 10 per cent overlap between adjacent pictures. There are usually four orbits and 60-65 scenes per day over Canada.

The Quick Look Facility, originally installed by the Communications Research Centre as a means of monitoring the quality of the data being received, is now being operated on a continuous basis under contract to Donald Fisher & Associates Ltd. Special customers who require the data in quasi-real-time receive black and white prints at 1:1,000,000 scale within two to three days of the satellite pass. This service is proving very useful to arctic navigation in particular. A facsimile system is in operation between Prince Albert and Ice Central in Ottawa, so that selected images can be transmitted within hours of the satellite pass.

ENVIRONMENT CANADA

Atmospheric Environment Services

Experimental and Theoretical Studies

Experimental and theoretical activities are underway in Atmospheric Environment Services (AES) to assist in interpreting the aeronomic and dynamic processes in the stratosphere with particular reference, in the short term, to understanding the possible effects of pollution there by supersonic aircraft.

An experiment to measure stratospheric water vapour by infrared solar absorption was flown on rocket VB-37 in May. Analysis of the measurements should yield a water vapour profile over the range 15 to 50 km.

In a cooperative experimental program with the University of Toronto a series of measurements of NO_2 was carried out during the Fall on board the Concord SST using a newly-designed spectrophotometer.

A series of balloon flights to measure stratospheric constituents is being planned for the summers of 1974 and 1975. These will include instrumentation to measure ozone, NO, NO_2, nitric acid, water vapour and the solar ultraviolet radiation.

Arcasonde data from Churchill and Primrose Lake are being analyzed to obtain stratospheric temperature variability and climatostatistical features. Falling-sphere temperature data (mainly U.S.; a number from Australia; some Canadian from Churchill) have been evaluated, processed and tabulated; spatiotemporal studies on these are to be undertaken in the near future.

Twilight photometer observations of scattered and polarized light from the sky are being made to determine stratospheric aerosol content and variation.

The visual and photographic observational programs for noctilucent clouds are continuing.

The computer-controlled high-resolution spectrometer is under development for ground-based investigations of the atmosphere.

Global analysis of the total ozone values derived from the ultraviolet experiment on Nimbus 4 have been carried out to investigate the depletion in the tropical south Pacific expected to be associated with the nitrogen oxide production in a nuclear explosion. A model is being developed to predict the depletion for comparison with the observations.

Numerical experiments are continuing with the steady-state two-dimensional model of the stratosphere with coupled radiative, photochemical and dynamic processes. The photo-chemical scheme has been modified to include reactions involving HO_x and NO_x. The HO_x and NO_x groups are treated as dependent variables in the transport model instead of specifying their concentrations.

Weather Satellite Activities

The Satellite Data Laboratory of the Meteorological Services Research Branch at AES Headquarters, Downsview, continues to acquire, utilize and distribute data transmitted directly via the Automatic Picture Transmission (APT) mode from orbiting US meteorological satellites. During the past year data have been acquired from ESSA 8, which has completed five years of constant operational use and continues to transmit useable pictures from one of its two Vidicon cameras. Data have also been obtained from NOAA 2 and, of recent date, NOAA 3, utilizing the visual and Infrared time-shared outputs from these spacecraft.

During the last six months, tracking of the spacecraft during its transect of the reception area has been accomplished by utilizing a small computer to calculate the sub-satellite path of the spacecraft from orbital parameters and from

these calculations provide the necessary look angles to control the antenna servos to acquire the satellite data.

An FH 8100 picture reproduction unit built by CAE Industries, Montreal, Quebec, was acquired during the past year. This unit, after some initial difficulties, is now reproducing good copy from the Vidicon transmissions and from the Scanning Radiometer outputs in the Infrared and Visual spectra. This unit can, by choice, expand either the Infrared or Visual data to make it more applicable for meteorological and other environmental applications.

During the past year, two APT-mode receiving stations were installed and put into operation at Halifax and Vancouver. Receptions from these new stations have been of good quality and, at the present time, outputs from these stations are being transmitted to the Canadian Meteorological Centre at Montreal via a broad band circuit and distributed by facsimile lines to 13 different major weather offices across Canada in near real-time.

Data from current weather satellite receptions and from magnetic tape archives continues to be distributed to governmental and private agencies, universities, etc., for applications to weather and other environmental studies. Approximately 30,000 photos are forwarded to users each year.

The Satellite Data Laboratory is carrying out studies and plans related to establishing a Very High Resolution Radiometer (VHRR) readout capability and additionally hopes to have, with this system, access to the Vertical Temperature Profile Recorder data (VTPR) which the latest NOAA 3 spacecraft is now transmitting in the direct mode to user stations modified to receive it.

During the coming year experiments will be carried out on automatic digitization and processing of APT-mode data for use in numerical weather prediction studies. It is hoped that this will permit a fuller utilization of the potential of meteorological satellite imagery in weather prediction.

NATIONAL RESEARCH COUNCIL OF CANADA

Division of Physics

Auroral Particle Studies

Studies of various aspects of auroral particles has continued during the past year using sounding rocket techniques.

Observations of electron pitch angle distributions in the 2 to 60 keV energy range, measured in a post-breakup aurora indicate that the electron precipitation resulted from the loss of newly injected particles from a region of closed geomagnetic field lines, the loss mechanism being associated with pitch angle diffusion. Diffusion coefficients for these particles were determined by fitting the measured angular distributions to calculated loss cone distribution functions. The variation in the value of the coefficient with energy is consistent with diffusion resulting from two sources. Electrostatic wave turbulence is invoked to explain the large coefficients at low energies (E <5 keV) and scattering from whistler mode turbulence to explain the gradual rise at energies greater than 20 keV.

Measurements of the ionospheric ion distribution function and energetic electron and ion precipitation during an auroral substorm near local midnight have been made. Thermal ion measurements were used to determine the ion bulk flow velocity, temperature, and density. The ion flow velocity was highly correlated with energetic electron precipitation. The convective component (perpendicular to the local magnetic field $\underline{B}$) was found to be large (equivalent electric field $E_{\perp}$ ~ 100 - to 200 mv/m) poleward of a series of poleward expanding arcs. Inside the arc the convective flow dropped to a low value ($E_{\perp}$ ~ 10 - to 30 mv/m).

High velocity (~2 km/sec) ion flows parallel to $\underline{B}$ were also observed and found to be correlated with electron precipitation. Poleward of the arc the flow was directed away from the ionosphere whereas inside the arc the flow switched to earthward. Parallel electric fields ~ 0.1 mv/m required to produce these vertical flows are consistent with energetic electron pitch-angle distributions.

Magnetospheric Studies

Particle detectors on the ISIS I and II satellites continue to be used to study magnetospheric problems.

Further studies of energetic trapped particle boundaries have been carried out. At high latitudes and on the outer edges of the trapping regions, there are boundaries where both injection and loss processes are important. The quasi-static boundaries determined at quiet times tend to emphasize loss processes. The dynamic boundaries occurring during disturbed magnetic conditions combine both

injection and loss in a more complex manner. The influence of substorms on the night side configuration of the magnetosphere has been studied and the need to study the development of the plasma sheet during moderate localized substorms and inter-bay magnetic activity is indicated.

Some work has been done on the relation of trapping boundaries and the cusp particles. It has been shown that in some cases particles which are identified as cusp plasma occur on closed rather than open field lines. This implies that some mechanism other than direct entry on open field lines is important for the entry of magnetosheath plasma into the magnetosphere.

By studying flux enhancements of solar protons at auroral latitudes in the April 1969 event it has been concluded that low energy (~1 MeV) proton intensities at these latitudes can exceed the intensity in interplanetary space. The position of the solar proton knee latitude as a function of local time and the observation that pitch angle distributions are isotropic above the knee latitude lead to the further conclusions that the proton enhancements occur on closed field lines and that the life-time of the protons in this region is less than a few minutes.

Cosmic Ray Studies

At the beginning of 1973, the NRC Cosmic Ray Group assumed responsibility for the operation of the cosmic ray monitor stations at Deep River, Alert, Inuvik and Goose Bay, formerly operated by Atomic Energy of Canada Limited.

Cosmic ray neutron monitor data is being used in conjunction with interplanetary data to study Forbush decreases. The observations are consistent with a model which pictures the enhanced solar wind generated by solar flares pulling closed magnetic loops out of the solar corona to form an expanding magnetic bottle in space.

The motion of individual cosmic ray particles in the spiral inter-planetary magnetic field is being studied using a Monte Carlo computer model which includes particle scattering. It is found that particles in the 1-10 GV rigidity range undergo considerable drift in heliolatitude (20-70 degrees) due to the gradient and curvature of the magnetic field. The cosmic ray intensity at earth must therefore be influenced by the scattering properties of the field at mid-heliolatitudes.

A prototype multi-element particle detector array with a total sensitive area of 4 m^2 has been set up to monitor the cosmic ray muon intensity at zenith angles between 80° and 90°. The sensitive elements are proportional counters operated with continuous gas flow. The array will ultimately be expanded by a factor of 12 to measure the sidereal anisotropy of cosmic rays of 500 GV rigidity.

AURORA OVER CHURCHILL RESEARCH RANGE

Astrophysics Branch

Upper Atmosphere Research Section

Auroral Rocket Photometry

Data from the 1972 flights have been analyzed and the results were presented at the IAGA meeting in Kyoto. Two three-channel photometers have been flown thus far in 1973 and the data are being analyzed to determine the vertical emission rate profiles of the auroral N_2^+ING (O, O) and N_2IPG molecular bands and the OI 5577 Å emission. Additional flights are planned.

Auroral Spectra and Photometry

Auroral observations with the eleven-channel photometer and 1/2 metre spectrometer were conducted over a two week period in January and February of 1973. The spectrum from 4500 to 8800 Å was recorded at a slit width of 8 Å. Synthetic band and atomic spectra have been generated and summed in an attempt to explain the observed spectral features. It is intended that observations during the 1973-74 winter should concentrate on the 3100 to 4500 Å region.

An enhancement of the O_2 1.27μ band was observed during auroral displays; a three-channel photometer employing a germanium detector was employed. The enhancement was related to the amount of precipitated energy, and the decay time was about one hour.

A computer-controlled data acquisition system was used for the first time in February 1973 at Gillam, Manitoba. At present, only a meridian scanner is interfaced to the computer. The system is expected to be completed by the end of 1974 and will be used, among other things, to get high time resolution data on the growth phase of the substorm. The 1973 data are beginning to yield interesting results, but lack hydrogen data which have to be incorporated by manual analysis of paper charts.

Radio Aurora

The study of periodically varying radio aurora which sometimes follows SSF'c showed that the delay in onset of the radio aurora after the SSC is inversely related to the SSC amplitude. The data also showed that there is an upper limit to the period of this periodically varying radio aurora and it is inversely proportional to the SSC amplitude.

Currently data obtained from a magnetometer chain through Churchill, from the ATS-E magnetometer, from the Churchill and Great Whale all-sky cameras, and from the Thompson auroral radar are being analyzed to determine the behaviour of ionospheric currents, radio and visual aurora during substorms.

Improvements have been made in the auroral radar systems now operating at Ottawa, Churchill, Thompson, and Great Whale. Design of a new doppler radar system is continuing.

Rocket Measurements of Radio Aurora

Rockets AAF-IIIB-64 and 65 were specially instrumented and launched in February of 1973 to test a new technique for measurement of the scattering of radar waves by radio aurora. The first rocket launched had an electronic problem and only engineering data were obtained. The deficiency was corrected for AAF-65, but the clamshells failed to separate on this vehicle, thus negating the effort. Efforts to make a successful measurement will be continued.

Rocket Measurements of Auroral Plasmas

Plasma measurements were made successfully with experiments carried on seven rockets during January and February 1973. Most of these were made in concert with the coordinated observations at Gillam and Churchill.

Conjugate Point Auroral Photometry

It has proved to be impossible to transfer the data recorded at Great Whale and Byrd during the two seasons 1970-71, from the original magnetic tapes to a computer-compatible format. The data tapes are 1/4-inch wide and contain information in a four-channel, pulse-duration modulated form, and there appears to be enough "wow" and jitter to introduce an unacceptable number of errors into the BCD (Binary Coded Decimal) output from the interface unit.

Relative intensity records are available for the 5577 Å channel on the paper charts used as a back-up and these exist for the period 1968-71. The data will not be treated in a routine synoptic fashion because of the labour involved, but specific events may be analyzed as the occasion arises.

Infrasound from Aurora and Meteors

In the MORP* project, fireballs can only be detected during periods of darkness and clear skies. It is known that the atmospheric flights of large meteoroids generates sound waves by explosions or shock wave phenomena. Although the higher frequency sound waves are attenuated to the extent that they are seldom heard beyond a 50 mile radius, waves having periods of tens of seconds are detectable at much greater distances. This suggests the possibility of detecting meteorite entry on a 24 hour basis.

* MORP - Meteorite Observation and Recovery Program.

Auroral infrasonic waves (AIW) have been observed for many years, but only recently have measurements been attempted from within the auroral zone, by C. R. Wilson, at the Geophysical Institute, University of Alaska. The results obtained have been useful in that they have prompted suggestions as to the generating mechanism for AIW, and it is considered that further observational work would be worthwhile.

Development of instrumentation for detection of infrasonic waves from either or both of these phenomena is underway. Various designs of microbarographs are being investigated, with the ultimate aim of operating several stations at observing sites in the MORP network, and in the auroral zone.

Micrometeorites and Cosmic Dust

One acoustic, ejectable, multi-sensor, micrometeoroid detecting system was flown and ejected from a Black Brant V rocket. The transmitted data were good; no impacts were recorded.

Two attempts were made at collecting cosmic dust, one from a superpressure balloon which floated for 210 days, and the second by a collector ejected from a rocket. All indications point to a successful operation of the experiments but unfortunately, both payloads were not recovered. It is planned that these experiments can be repeated in the future.

Meteor Observing Program

The program of routine observation of meteors using grating spectrographs and two backscatter radars was continued at Springhill Meteor Observatory and at Shiels Meteor Station. Bright moon and/or adverse weather restricted observations of the major meteor showers to four partially successful nights. Automated instrumentation at Shiels is now reasonably complete and the cameras at the station will be operated on any night of good observing conditions.

Meteor Spectra

Analysis continues of meteor spectra obtained on closed-loop television systems, in particular: an image orthicon equipment in cooperation with Dudley Observatory (Albany, N. Y.) and Smithsonian Astrophysical, and a SEC* vidicon in cooperation with NASA Marshall Space Flight Center. These spectra extend the observed range of spectra down to meteors of the 3rd and 5th visual magnitude, and will provide valuable information concerning the nature of meteor luminosity near the lower limit of objects seen with the unaided eye.

*SEC - Secondary Electron Conductor

Meteorite Recovery

The 12 stations of the Meteorite Observation and Recovery Program (MORP) on the western prairies recorded several bright fireballs over the year, but none that dropped meteorites. The computer programs for trajectory analysis and prediction of fall area have been completed. Lens distortion corrections have been determined for some of the cameras.

Analysis of Visual Meteors

A study carried out in conjunction with the Astronomical Institute of the Slovak Academy of Sciences developed criteria for assessing and correcting the visual magnitude estimates of any given observer. It was concluded that the observations with large systematic errors could be corrected and were then useful in statistical reductions of data. Observers with a poor magnitude distribution could be detected and their observations discarded.

Analysis of the durations of the persistent trains accompanying meteors showed that the frequency of occurrence is about 15 per cent for meteors at a velocity of 70 km/s but drops to less than 5 per cent below 30 km/s. The relation between log duration and magnitude is linear and relatively independent of velocity.

Radio Astronomy Section

Daily Observations of Solar Radio Flux

Daily measurements of the intensity of the 10.7 cm radio flux from the sun and any unusual variations in this intensity are measured at the Algonquin Radio Observatory, Lake Traverse, Ontario. This radio emission has been found to accompany the X-rays, ultra-violet light and energetic particles from the sun, which are the major factors in the space environment of planet Earth. In view of this close relationship, solar radio observations have proven useful in describing the solar condition for the operation of spacecraft and for determining that portion of the ionization of the earth's upper atmosphere under the solar influence as part of the international exchange of data. The radio information from the observatory is contributed daily to the Space Disturbance Center in Boulder, Colorado, and the measurement of the radio flux at 17:00 U.T. appears in their daily forecast of solar weather conditions as the Ottawa 10.7 cm flux. The continuous nature of the watch of solar conditions, as well as the complexity of the solar phenomena, requires cooperation among various observatories on earth. The lack of 10.7 cm solar noise observations between stations on the eastern coast of North America and in Japan was met by the installation of equipment by the National Research Council at the Dominion Radio Astrophysical Observatory near Penticton, B.C. The observational

material is collected in monthly reports and published in divisional reports at six-month intervals. These are entitled "Observations of Solar Flux at the Algonquin Radio Observatory on 2800 MHz and at the Dominion Radio Astrophysical Observatory on 2700 MHz". The issue for July-December 1967 (Divisional Report ERB 780) contains details of the method of observing and selected bibliography.

The Astrophysics Branch has constructed and is operating at Algonquin Radio Observatory an EW array of three meter reflectors which produces high resolution fan beam scans of the solar surface. At this time of declining solar activity, the emission from individual sunspot regions can be studied during various stages of their evolution.

Optical Solar Patrol Telescope

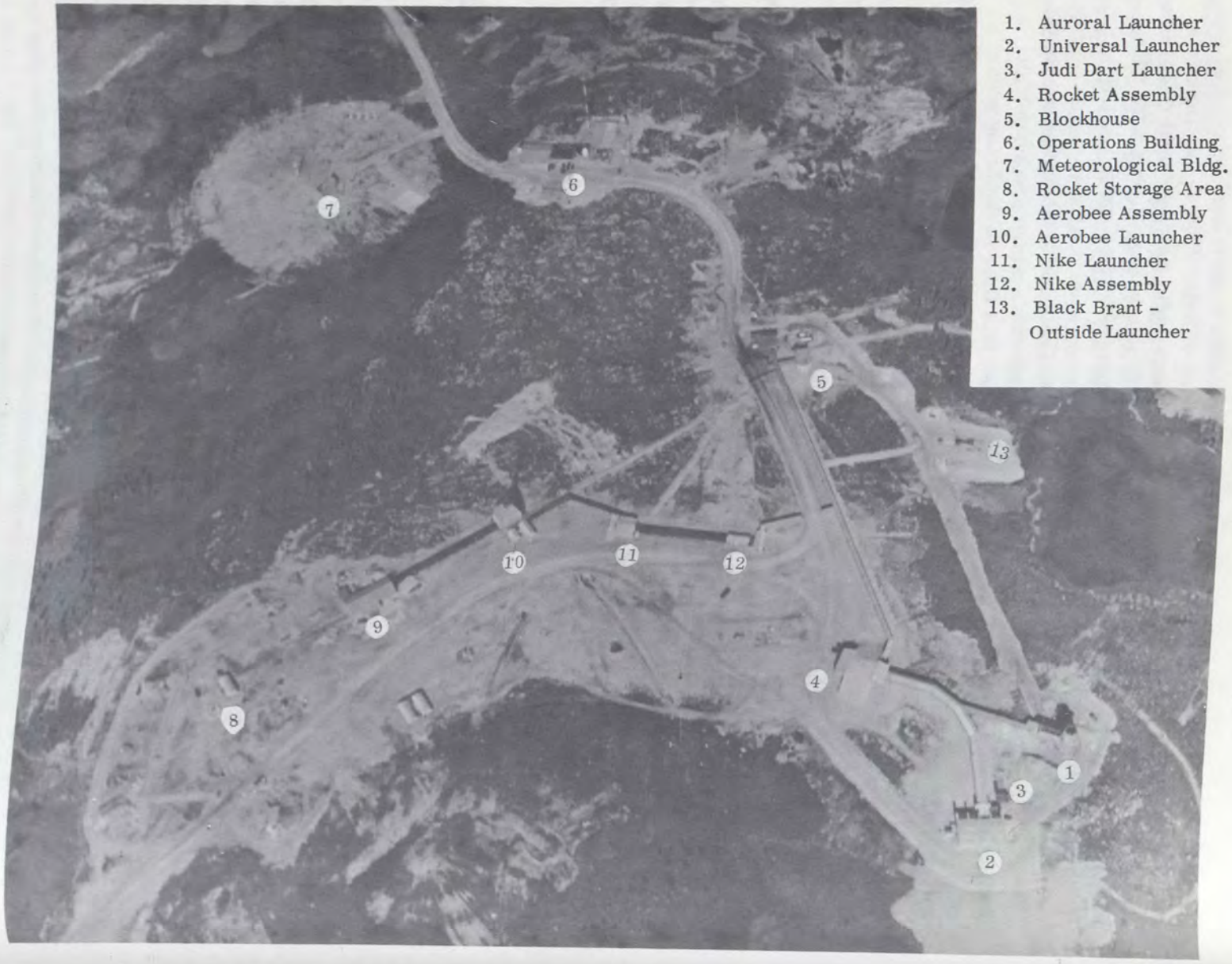
The 10 inch aperture photoheliograph at the Ottawa River Solar Observatory has continued in use for patrol cinematography of single sunspot regions in monochromatic light sampled with a narrow band optical filter at several wavelength positions in the H-alpha absorption line. Dynamic changes in chromospheric structures accompanying flares are under study for events associated with unusual radio bursts. Instrumental additions being made to the photoheliograph will permit simultaneous observations of the same active region in the chromosphere (in a narrow wavelength band at H-alpha) and the photosphere (in several broad wavelength bands).

National Aeronautical Establishment (NAE)

In the field of Aerothermodynamics an assessment was made, under a NASA contract, of the needs for dynamic stability experiments for various types of aerospace vehicles including the space shuttle, with special emphasis on effects of the very complex flow fields that occur during flight at high angles of attack. This work included also a survey of the wind tunnel capabilities that are available for this type of experiments in the USA and Canada. A new wind-tunnel apparatus was developed and built, under another NASA contract, for the determination of dynamic moment cross-derivatives due to pitching and yawing of aircraft-like models at transonic and supersonic speeds. It is expected that such derivatives will be required for analysis of the re-entry flight of the shuttle orbiter.

In the field of Structural Analysis, the emphasis has been on the application of advanced finite element techniques to conventional aircraft or civil structures. Some of these studies such as the prediction of the transient, non-linear, response of plate structures and the stress analysis of multi-cellular boxes may also be relevant to problems of structural analysis of spacecraft.

CHURCHILL RESEARCH RANGE LAUNCH SITE



Space Research Facilities Branch

General

The Space Research Facilities Branch (SRFB) is a support organization which provides services to the Canadian scientists who are doing upper atmosphere and space research by means of sounding rockets, balloons and ground-based instruments. The main services provided include the procurement of rocket motors, the procurement and engineering monitoring of instrumented rocket payloads, the planning, designing and operation of temporary and permanent launching facilities, the acquisition and recording of scientific data, and the conversion of such data into formats which are readily usable by the scientists who are being supported. In addition SRFB prepares and publishes engineering reports on all launches as well as general annual reports covering all Canadian activities in space and upper atmosphere research. The Branch carries out its procurement and operational activities by means of production and services contracts with Canadian industry.

The principal permanent facility operated by SRFB is the Churchill Research Range (CRR), near the town of Churchill, Manitoba on the shore of Hudson Bay, which provides an excellent rocket impact area in a location where important geophysical events occur. The CRR is a fully-equipped, sub-arctic research range which has been operated by NRC since 1965. Regular scientific rocket launching activities take place at the CRR and in addition various ground-based instruments are operated on a continuing basis, and a meteorological sounding rocket station of the North American synoptic network is located there. The CRR assists in scientific balloon launching programs involving balloons up to one million cubic meters in size which carry payloads of up to one thousand (1,000) kilograms. The Branch also operates the Great Whale Geophysical Station at Poste-de-la-Baleine, Quebec which is manned by technicians to record auroral phenomena. There is also a small rocket launching facility at Resolute, NWT, which is manned as required.

SRFB has the capability of conducting expeditions for the launching of 25.4 cm diameter sounding rockets from any location where there is reasonable access and a measure of logistic support. To enhance our transportable launch capability, a launcher to handle 43.2 cm diameter rockets is being obtained so that the whole family of Canadian Black Brant rockets can be launched from any suitable location.

The Canadian scientific program which SRFB supports is based on projects which have been approved by the Canadian Sounding Rocket Planning Group which relies on the recommendations of its Scientific Evaluation Panel. The approved program is implemented by SRFB within the limits imposed by financial and technical considerations. SRFB provides services to government agencies outside of NRC-supported scientific programs, on a cost recoverable basis. The same basis applies when SRFB supports non-Canadian user scientists.

Range Section

The Range Section is responsible for the administration and supervision of NRC operated sounding rocket ranges. This includes liaison with foreign government agencies regarding their use of range facilities. At present, there are two ranges in use; the Churchill Research Range (CRR) in Manitoba and the expeditionary range facility at Resolute, Northwest Territories. Temporary launch sites at East Quoddy, Nova Scotia and at Gillam, Manitoba were used for launchings in 1972 and 1973 to investigate solar eclipse effects and auroral substorms. Both these launch sites have now been closed.

The Churchill Research Range has the capability of launching more rockets than are involved in the Canadian program. The surplus range capability is available at agreed costs to foreign government agencies on a non-interference basis. Other agencies most interested in making use of CRR facilities are the USA National Aeronautics and Space Administration and Air Force Cambridge Research Laboratories. To facilitate launch scheduling and financial arrangements, an NRC/NASA CRR Working Group was established in January 1971 under the provisions of the 1970 Canada/US agreement governing the support of US activities at CRR. Canada also has an agreement with the Federal Republic of Germany which provides for the launching of rockets and the operation of a satellite tracking station at the Churchill Research Range. An agreement exists with Belgium and experiments have been launched for that country in Canadian rocket payloads.

Churchill Research Range

This range is manned by 50 to 60 contractor personnel depending on workload, and by a resident staff of four NRC personnel. The facility can be used to launch numerous types of sounding rockets, can track the rockets by radar, and can recover and record data at a telemetry ground station.

The Range has the capability of launching 30 to 35 major sounding rockets per year and of supporting a continuing meteorological sounding rocket program for the Atmospheric Environment Services Branch of the Department of the Environment and for the World Meteorological Rocket Network. Details of Range facilities and services are contained in the Handbook for Range Users, Churchill Research Range.

Resolute, Northwest Territories

During 1966, a requirement to launch scientific payloads in a region not influenced by the Van Allen Belt led to the establishment of an expeditionary launching facility at Resolute, NWT. Several Canadian and US launchings have taken place there.

Gillam, Manitoba

In December 1970 a proposal was received for the launching of a series of three scientific sounding rockets to study the break-up phase of an auroral substorm. These rockets were launched in January 1972 to make measurements over as wide a latitude spread as possible. Two were launched from Churchill Research Range while the third was launched from Gillam. In January 1973, the auroral substorm rocket program was repeated after which all equipment at Gillam, except the operations trailer, was removed. This trailer will be used in January 1974 to accommodate a telemetry receiving station which will be operated in support of a rocket launching program at CRR.

Great Whale Geophysical Station

The Great Whale Geophysical Station at Poste-de-la-Baleine, Quebec, is operated on a continuing basis to make various geophysical measurements for Canadian and American scientists. Additionally, NRC operates a magnetic observatory there on behalf of the Department of Energy, Mines and Resources.

Rocket Systems Section

The Rocket Systems Section is responsible for the procurement of rocket payloads and rockets to meet the requirements of Canadian experimenters and with the conversion and distribution of telemetered data and other pertinent information.

At present 19 rocket payloads are in various stages of planning and manufacture. Sixteen of these are intended for launching from CRR during the 1973-74 winter auroral season. Two of the others were launched from CRR in May of 1973. One was an engineering launch which successfully tested the deployment of the new 43 cm vertical hinge clamshell and evaluated the vibration and accelerations involved in the launch of a Black Brant VB from the modified Aerobee launch facility. The other was a small rocket designed to capture cosmic dust and return it to earth for examination. While this launch also was successful, the payload has not yet been recovered.

The other rocket (a new departure) was the launch in June from Kauai in the Hawaiian Islands, of a payload to measure cosmic x-rays. This flight was undertaken in cooperation with the United States Atomic Energy Commission. Among innovations to be considered for the future is the provision of accurate pointing systems for certain experiments.

A total of eight rockets, four at CRR and four at East Quoddy were launched during the total solar eclipse of 10 July 1972 to investigate the effects on the upper atmosphere of the sudden cutting off of the sun's radiation. This was the largest number of Canadian scientific rockets ever launched in a single day.

Other payloads have been used to investigate infra-red cosmic background radiation, galactic and cosmic x-rays, while a series of rockets including one launched from Gillam explored various phases of auroral substorms. The makeup of a radar aurora (or radio aurora which gives rise to radio reflections in the VHF and UHF frequencies) was examined using rockets equipped with both electromagnetic and electrostatic probes, and the payload from a previously recovered rocket was reflown to measure radiation in the vacuum ultra violet region.

Development of an improved design for the deployment of vertical hinge clamshell nosecone fairings has been carried out at Bristol Aerospace Limited. Both the 25.4 and 43.2 cm diameter versions have been successfully flown.

The analog-to-digital translation system capable of handling both telemetry and radar data, designed and built by the Data Systems Section of Radio and Electrical Engineering Division (REED) has been completely overhauled by REED. This provides the experimenters with digital records of their data in forms suitable for computer processing. This equipment is now operated at SED Systems Ltd. of Saskatoon. The digitized radar data is smoothed and tabulated on the NRC IBM-360 computer in Ottawa.

As soon as possible after the flights, SRFB publishes brief reports of all rocket launchings.

To data SRFB has issued 79 publications reporting rocket launchings sponsored by the National Research Council of Canada, together with annual editions of Space and Upper Atmosphere Programs in Canada and a Bibliography of resulting scientific papers. The scientific results are published in the appropriate journals by the scientists concerned.

DEPARTMENT OF EXTERNAL AFFAIRS

Scientific Relations and Environmental Problems Division
Legal Operations Division

United Nations Committee on the Peaceful Uses of Outer Space

During 1973 Canada participated in the sixteenth session of the Committee on the Peaceful Uses of Outer Space (25 June to 6 July), the tenth session of the Scientific and Technical Sub-Committee (May 7 to May 18) and the twelfth session of the Legal Sub-Committee (26 March to 20 April).

At the Legal Sub-Committee session the Canadian and French delegations presented a revised version of their joint draft Convention on the Registration of Objects Launched into Outer Space which took account of suggestions made at the 1972 session and in subsequent consultations with a number of interested countries. It was possible to reach general agreement on the details of the draft convention except on two questions: (1) whether the convention should contain a clause providing for some sort of "review" of the convention after it has been in force for a number of years; and (2) whether the convention should provide for the compulsory "marking" of space objects by launching states. Agreement was eventually reached on an appropriate review clause at the 1973 session of the parent Outer Space Committee, but the question of marking remains to be resolved either at the 1973 session of the General Assembly or, more likely, at the 1974 session of the Legal Sub-Committee.

The 1973 session of the Legal Sub-Committee gave further consideration to both USSR and USA texts of the draft treaty relating to the moon, pursuant to the original initiative of the USSR at UNGA XXVI. Unfortunately little progress was made at the 1973 Legal Sub-Committee session toward completion of a final text of a draft agreement primarily because of fundamental continuing differences of opinion on a number of issues, referred to in last year's report, including whether the moon treaty should also apply to "other celestial bodies", the nature of proprietary rights that states may claim with regard to the moon's natural resources, and the question of prior notification of launchings. These points of contention may be resolved at the 1973 Session of the United Nations General Assembly.

The work of the Scientific and Technical Sub-Committee is, at present, centered in its Working Group on Remote Sensing of the Earth by Satellite. This body held its first substantive meeting in January 1973 during which a draft background document on remote sensing, as prepared by the U.N. Secretariat with the assistance of a task force established by the Working Group, was considered. Upon revision, this document was referred to the Scientific and Technical Sub-Committee at its tenth session in May 1973. At this session, following the recommendations of its Working Group, the Sub-Committee formulated a questionnaire with supporting documentation (including the Secretary-General's background paper) which has been circulated in an

attempt to survey U.N. member states' views on remote sensing, and also established a task force to identify and report on alternatives for the dissemination and utilization of environmental and resource data. This task force held an organizational meeting concurrent with the sixteenth session of the U.N. Committee on the Peaceful Uses of Outer Space in June 1973 and subsequently issued a request for relevant information on remote sensing activities from members of the Outer Space Committee. The responses to this request will be considered at a second meeting of the task force in February 1974. With regard to its space applications program designed to benefit developing countries, the Sub-Committee recommended that the Secretary-General prepare a comprehensive report on the various types of assistance extended by the U.N. family in this field. The Sub-Committee, in considering its future work, decided that remote sensing and the space applications program would continue to be priority items.

The Outer Space Committee's Working Group on Direct Broadcast Satellites (DBS) met in New York in June and considered a joint Canada/Sweden working paper containing draft principles governing direct television broadcasting by satellite. These draft principles attempt to establish a realistic and responsible balance between the protection of sovereign rights, on the one hand, and the facilitation of an important new technology, on the other hand. The USSR draft international convention on principles governing the use by states of satellites for direct television broadcasting, which had been tabled at the 1972 General Assembly, was also discussed. Many countries felt that this draft convention placed too much emphasis on the protection of sovereign rights. It is anticipated that at the current session the General Assembly will decide that the elaboration of principles should be continued at a fifth session of the Working Group to be held in Geneva in March 1974, and also at the next session of the Legal Sub-Committee to be held in Geneva in May 1974.

THE INTERDEPARTMENTAL COMMITTEE ON SPACE (ICS)

The formation of an Interdepartmental Committee on Space was announced in January 1970. The committee was established to meet a need for improved co-ordination of the planning, the optimum use of resources and the balance of development of all federal government space activities.

Membership of the committee is made up of senior officials representing:

Department of Communications
Department of Energy, Mines and Resources
Department of External Affairs
Department of Industry, Trade and Commerce
Ministry of Transport
Defence Research Board
National Research Council of Canada

Observer status is accorded to representatives of:

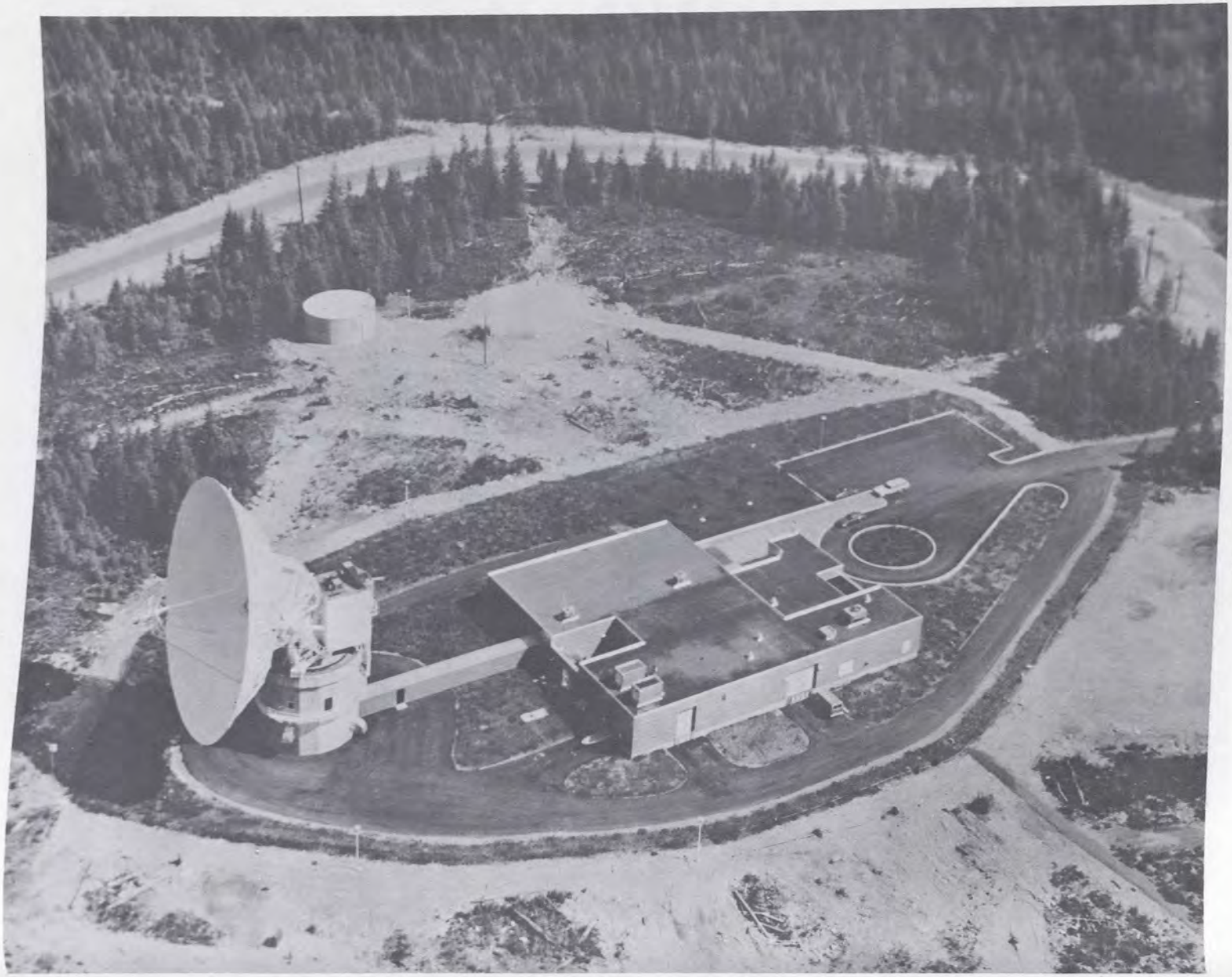
Ministry of State for Science and Technology
Treasury Board Secretariat.

THE ASSOCIATE COMMITTEE ON SPACE RESEARCH (ACSR)

The Associate Committee on Space Research has recommended to the ICS that an official invitation be presented to COSPAR at its next Plenary meeting in Brazil in June 1974, to hold its 1976 Plenary meeting in Canada.

This committee has been requested by the ICS to comment on a draft Space Policy for Canada, and to review and comment on a proposal for a Canadian experiment for the 1978 Pioneer Venus Orbiter Spacecraft.

LAKE COWICHAN EARTH STATION



CANADIAN OVERSEAS TELECOMMUNICATION CORPORATION

ACTIVITIES IN SPACE RADIO COMMUNICATIONS

The Canadian Overseas Telecommunication Corporation has now fully commercial satellite communication earth stations operating on both the east and west coast of Canada. The new station located near Lake Cowichan on Vancouver Island, is now operating via Intelsat IV satellite over the Pacific Ocean and is presently in direct communication with Australia, Japan, Hong King, Philipines and China with plans in the near future to include two more destinations (New Zealand and Singapore).

The East Coast earth station complex located near Mill Village, Queen's County, Nova Scotia, consists of two antennas with the associated communication equipment which are designated as Mill Village No. 1 and Mill Village No. 2 earth station. These stations are operational via two Intelsat IV Satellites in the Atlantic Region.

West Coast

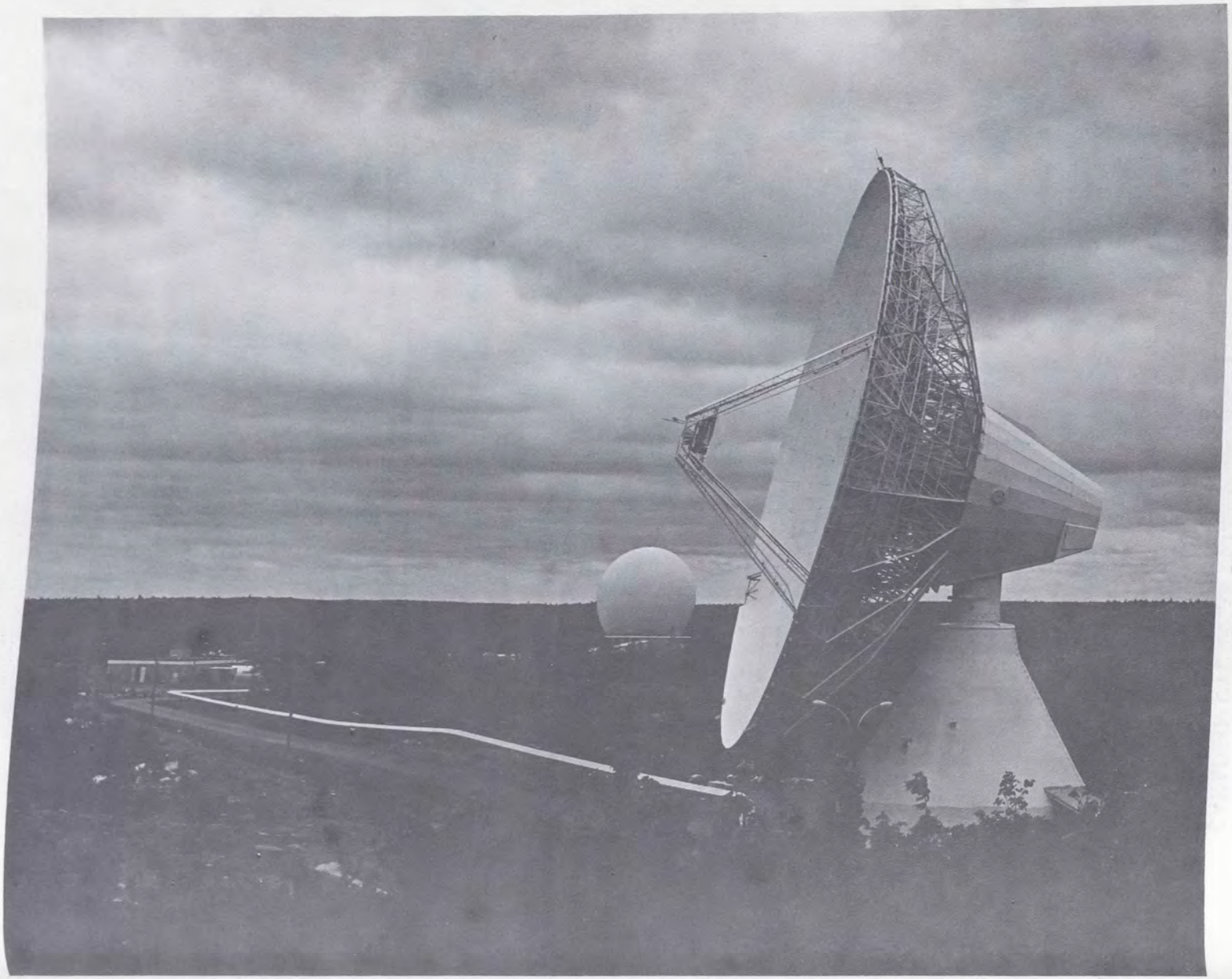
Construction of the Lake Cowichan earth station consisting initially of one antenna, was completed on August 31, 1972, with the official opening September 26, 1972, at which time commercial service was established. The earth station is located in the southern interior of Vancouver Island approximately 20 miles from the east coast of the Island. The site location is shared jointly by Telesat Canada and COTC with each having separate antennas and central facilities.

The COTC control building is located approximately equidistant from a potential three antenna sites at an average distance of 150 feet from the control building.

A cassigranian type 30 meter antenna mounted on a wheel and track arrangement is used with a transmit gain of 60 dB at 4 GHz and a G/T performance of 40.7 dB at 4 GHz.

The 500 MHz integrated multi-mode feed horn with provisions made for spectrum reuse in the future, provides full utilization of the 3.7 to 4.2 GHz band as well as the 5.925 to 6.425 GHz frequency spectrum portion which is used presently by the Intelsat (International Telecommunications Satellite) Consortium of which COTC is a member.

The station is equipped with three transmit chains (two operational and one standby) using three 3 kilowatt Klystron High Power amplifiers.



The receiver front end consists of two 500 MHz bandwidth low Noise Receiver Amplifiers operating at a noise temperature of 16° Kelvin in the 4 GHz band on a one for one basis. Ten receive chains are now in service (8 operational/1 Video/ 1 Standby) with future plans of adding four more chains in the next two years to accommodate the growing traffic on the West Coast.

East Coast

Mill Village No. 1 Earth Station

Mill Village No. 1 earth station was built as an experimental station by D. O. T. in 1965. The station is used for direct communication with United Kingdom. Due to rapidly growing international traffic in the Atlantic Region, COTC has undertaken a modification program to upgrade that station to meet standard earth station mandatory requirements as specified by Intelsat and to expand its operational capability to meet the traffic demand. The modification program will be concluded in the first half of 1974.

Upon completion of the modification program the station will operate via Intelsat IV F2 satellite located at 330. 5°E longitude.

Mill Village No. 1 employs an 85 ft. cassigranian type antenna with king post type construction covered by a radome. The transmit gain is 60. 6 dB at 6 GHz and the receive gain is 58. 2 db at 4 GHz with a G/T of 40. 7 dB/°K at elevation angles greater than 15°.

A multi-mode feed horn provides for the transmission and reception of carriers at 6 GHz and 4 GHz respectively with a bandwidth of 500 MHz in both the transmit and receive bands.

A provision is made in the feed for future frequency reuse by means of dual orthogonal polarization.

The station will be equipped with three transmit chains operating on a (1+1) basis (i. e. one operational and one standby) using three 3 KW and two 8 KW Klystron type amplifiers on a (2+1) and (1+1) basis.

Two low noise amplifiers with a 16°K noise temperature and a bandwidth of 500 MHz at 4 GHz operating on a one for one basis form the front end of the receive chains. Initially there will be 14 separate receive chains operating on a (12+2) basis.

Mill Village No. 2 Earth Station

This station was built in 1968 and became operational in February 1969. It is presently in direct communication with 14 countries namely Barbados, Belgium, France, Germany, Greece, Israel, Italy, Jamaica, Netherlands, Scandinavia, Spain, Trinidad, United Kingdom. Early in 1974 communication will also be established with Portugal, Switzerland and Yugoslavia. In addition, the station is equipped for transmission and reception of PCM Demand Assignment multidestinational SPADE system for voice and data communication with Germany, Greece, Argentina and Italy.

Mill Village No. 2 is currently operating with the Intelsat IV F3 satellite located at 335.5°E longitude.

A 97 ft. cassigranian antenna with king post type construction is used with a transmit gain of 62 db at 6.2 GHz and 60 db at 4.0 GHz and a G/T of 40.7 db/°K.

Like Mill Village No. 1 this antenna has an integrated multimode feed horn with a 500 MHz bandwidth in both the transmit and receive bands.

This station has a total of three transmit chains, two telephony, one TV video, one TV sound, one SPADE and three standby.

These chains operate in conjunction with 3-8KW TWT high power amplifiers on a (2+1) basis.

The receive system consists of two low noise amplifiers operating on a one for one basis with a total of 21 separate receive chains.

Experimental Video Transmission

Because of the continuous growing traffic demand and limited frequency spectrum in the satellite, it was decided by Intelsat to introduce two video carriers in one satellite transponder with appropriate modification of transmit and receive parameters.

COTC (Mill Village) in collaboration with the French Administration have successfully carried the first teleconference between two groups of people located respectively in Lyon, France and in Montreal, Canada. This was the first time that a single transponder was used for two live simultaneous television transmissions. The Intelsat IV satellite carry a total of 12 transponders. By using only one for two-way transmission instead of the usual two, the experiment needed only one-twelfth of the satellite capacity.

The experiment took place between the Heart Institute in Montreal and the Heart Institute of Lyon for a period of two hours. The telecast was in black and white and testing on the previous days demonstrated that this new method could also be used for transmitting colour programs.

The utilization of two video carriers through one transponder of an Intelsat IV satellite was possible by the use of 17.5 MHz I. F. filters on both the transmit and receive sides. The associated sound channels were multiplexed on the main telephony carriers existing between Canada and France. This method was developed for two reasons, one to reduce satellite traffic congestion over the Atlantic and second to reduce the cost of Video transmission.

*Lake Cowichan and Mill Village Earth Station photographs courtesy of COTC.

LUNAR MATERIAL STUDIES

Several Canadian scientists are involved in research into the properties of lunar glass, moon rocks and dust which have been brought to earth by the Apollo missions. Groups continuing in this research include McMaster University, and the Department of Energy, Mines and Resources (the Geological Survey of Canada). Further details of these studies will be found elsewhere in this publication under the title of the group concerned.

The National Research Council of Canada in Ottawa acts as the coordinating authority for Canadian agencies studying moon material.

TELESAT CANADA NORTHERN TELECOMMUNICATIONS STATION, RESOLUTE

TELESAT CANADA

On January 11, 1974 the Telesat Canada domestic communications satellite system commenced commercial operations with the inauguration of telecommunication transmission services by satellite. The successful launch of the second satellite ANIK II on April 20, 1973, and an equally successful transfer orbit mission positioned this satellite on-station at 109° west longitude, adjacent to ANIK I at 114° west longitude. This effectively established the planned space segment for the initial Telesat system.

The planned earth station complex consisting of 37 stations has been completed and made operational consistent with customer schedules. Furthermore, the initial months of operational service have exposed the vast array of communications ground equipments to a "break in" period to weed out equipment infant failures and to achieve a very high level of reliability and operational availability. The system is currently exceeding customer reliability goals and figures of 99.99% availability are currently being met for most services. Furthermore, the quality of communications system performance is exceptional.

The Satellite Control group based at Ottawa, having successfully completed the transfer orbit missions for ANIK I and ANIK II, has refined its capability to maintain the satellites in an operational role. By utilizing unique ranging techniques and software systems, the ability to determine the satellite orbits and attitudes has been refined such that an orbital position of ±0.05° in latitude and longitude, and an attitude control deadband of ±0.1° can readily be achieved with a minimum of computer data processing and satellite fuel expenditure.

The current satellite communications services being provided by the Telesat system utilizing the ANIK I satellite can be summarized as follows:

a) TV Distribution (3 R. F. Channels) - High quality television transmission and reception from any of two Heavy Route or six Network Quality Television stations and reception only by an additional 26 Remote Television stations for the Canadian Broadcasting Corporation (CBC).

b) Heavy Route Trunk Message (2 R. F. Channels) - High quality 960 two way telephone circuit service capacity between Vancouver and Toronto for the Trans-Canada Telephone System and CN/CP Telecommunications.

c) Northern Service (1 R. F. Channel) - Medium density message service linking Frobisher Bay and Resolute Bay with the Canadian southern terrestrial links for Bell Canada.

d) Thin Route (1 R. F. Channel) - Thin route low density message service providing from one to six voice circuits and radio program capability to small northern communities for Bell Canada. The initial service linking the two communities of Igloolik and Pangnirtung with the Canadian southern terrestrial links is being expanded to an additional 15 far north communities.

e) COTC Message Service (1 R. F. Channel) - Two carrier F. M. system providing a 240 two-way circuit link between the CANTAT II trans-Atlantic cable terminal at Beaver Harbour, just north of Halifax, with the COTC switching centre in Toronto for the Canadian Overseas Telecommunications Corporation (COTC). A contract has been let for procurement of equipment to expand this service to a 400 two-way circuit link using TDMA* techniques.

f) Standby Spares (2 R. F. Channels) - Two of the 12 transponder channels in ANIK I are retained as standby spares.

g) Added Service (2 R. F. Channels) - The remaining two out of 12 transponder channels are available for lease to Canadian customers.

* TDMA - Time Divisional Multiple Access

The initial planned deployment of 37 earth stations is being expanded and may be summarized as follows:

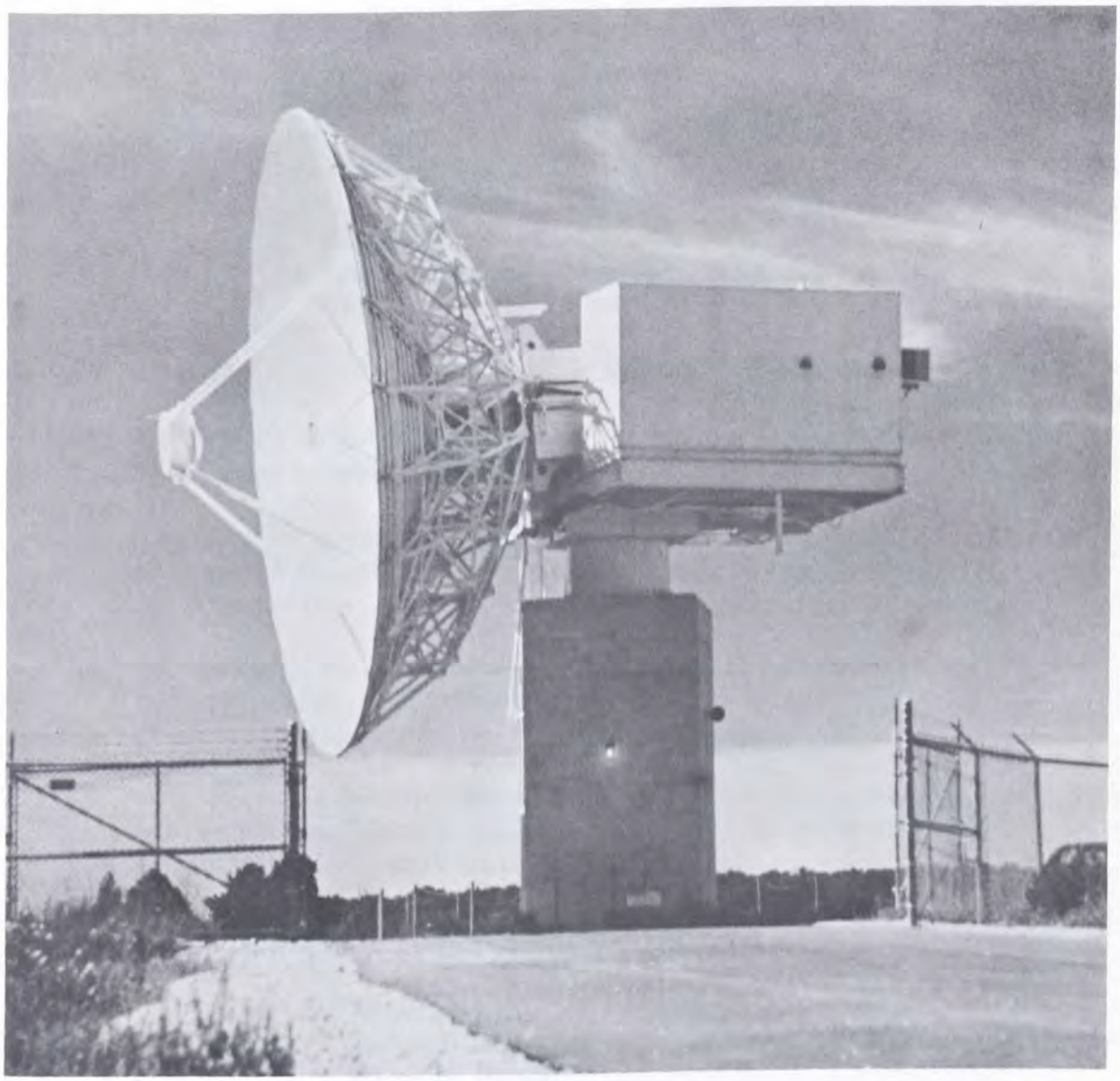
TYPE	PLANNED	OPERATIONAL
Heavy Route	2	2
Tracking Telemetry and Command	1	1
Telemetry and Command	1	1
Network Television	6	6
Northern Telecommunications	2	2
Remote Television	24	24
Thin Route	17	2
Transportable Television	1	0
Transportable Thin Route	1	0
Total	55	38

Of the above, the Telemetry and Command station is the only dish dedicated to ANIK II. The expansion of the thin route system calls for completion of seven stations by January 1974 and the remaining eight stations by January 1975. The two transportable stations are scheduled to be completed in June 1974.

The second satellite, ANIK II, is fulfilling its role as an in orbit spare to ANIK I, guaranteeing continuous service to Telesat's customers, and providing additional capacity for future system growth. Currently, some of its R. F. channels have been committed to provide interim service to RCA Globcom and American Satellite Corporation enabling them to provide U. S. domestic satellite communication services in advance of the commencement of operations of U. S. domestic satellites.

The third spacecraft of the ANIK series is approaching completion at Hughes Aircraft. It is being modified to withstand the higher vibration levels predicted for the larger 2914 series of Thor Delta launch vehicles. It is expected to be accepted and placed in storage early in 1974. A contract has been placed with the U. S. National Aeronautics and Space Administration (NASA) for a 2914 type launch vehicle and launch services for a planned February 1975 launch of ANIK III to be positioned at 104° west longitude.

TELESAT CANADA TELEMETRY TRACKING AND COMMAND STATION, ALLAN PARK, ONTARIO



ACTIVITIES IN INDUSTRY

AIR INDUSTRIES ASSOCIATION OF CANADA LIMITED

SPACE SUBCOMMITTEE REPORT, 1973

Approximately one year ago, several member companies of the Association who have been engaged in various space projects for a number of years felt that new direction and thrust should be given to Canada's expenditures on space-related matters. In short, a Government policy on space was felt to be required. A Subcommittee under the auspices of the Air Industries Association of Canada (AIAC) was formed and named the "Space Subcommittee".

The companies involved in the Subcommittee's activities were:

Bristol Aerospace Limited
Canadair Limited
Dilworth, Secord, Meagher & Associates Limited
Fleet Industries Limited
Northern Electric Limited
RCA Limited
Spar Aerospace Products Limited
United Aircraft of Canada Limited

The Committee's terms of reference were established as follows:

1. To provide an Industry focal point for the discussion and subsequent formulations of Space Policy for Canada.

2. To assist the government in the direction and formulation of a coordinated Space Program as it can best relate to the Canadian Space Industry.

3. To encourage the development of a "World Class" Industry through funding provided from Government to Industry, both directly and via various Government user agencies.

4. To ensure that Canadian Industry participates to the fullest in future Canadian Space Programs. Such involvement to maximize the potential for export to the world at large.

and definitions of space were established as follows:

- Satellites
- Boosters and Propulsion Systems
- Sounding Rockets
- Earth Terminals

The Subcommittee met with many Government departments and agencies during the year resulting in useful exchanges of views. Key events included:

February 1973	A briefing from the Interdepartmental Committee on Space.
May 1973	Initiation of a proposal to the Department of Industry, Trade and Commerce relating to investigating the viability of designing and building communications satellites in Canada.
June 1973	Preparation of a space systems market model identifying future business opportunities for Canadian industry.
October 1973	Presentation of a brief entitled, "Towards A Space Policy for Canada", at the AIAC's Annual General Meeting.
November 1973	Presentation of the brief, "Towards A Space Policy for Canada", to members of the Inter-departmental Committee on Space.

The brief concluded that:

1. Canada will be a significant purchaser of space systems to satisfy communications and earth observation requirements.

2. With procurement policies favouring domestic R & D and manufacturing, an attractive market was available to Canadian industry.

3. Better coordination, at the project planning stage, between Government and industry was required in order to make the market place viable.

4. A clearly enunciated Government policy and a strategic plan for its implementation was required with respect to space systems.

The Subcommittee plans to continue its activities for the foreseeable future.

The present Chairman of this Subcommittee is the Vice-President, Marketing and Planning, SPAR Aerospace Products Limited.

BRISTOL AEROSPACE LIMITED

Bristol Aerospace manufactures the Black Brant family of sounding rockets. These nine (9) vehicles, developed specifically for high altitude scientific research, have demonstrated reliability and performance. They are widely accepted by North American and European space research groups.

In addition to the production of rocket vehicles, Bristol produces a complete line of airborne telemetry equipment, ancillary sub-systems such as parachute recovery, payload separation, and despin as well as conical and ogival split nose fairings. Payload integration, checkout and environmental testing is carried out in the facilities of the Rocket and Space Division. Experienced range crews are available to provide field services for payload and vehicle systems.

1973 represents a year of considerable activity and achievement in that:

- The total number of Bristol rockets launched reached 398
- Black Brant launchings during the year were 33, representing the largest annual number of firings to date
- The first Black Brant VI rocket for scientific research was flown on an NRC program
- The highly successful NASA Skylab Support - Black Brant VC Calibration Rocket Program was virtually completed with one launch deferred.
- The latest Black Brant rocket, the BB IVB - Mod 1 achieved a completely successful flight and is now operational
- Detailed design and analysis of the Nike boosted BB VC is well on its way
- A new 17 inch diameter para recovery system was developed.

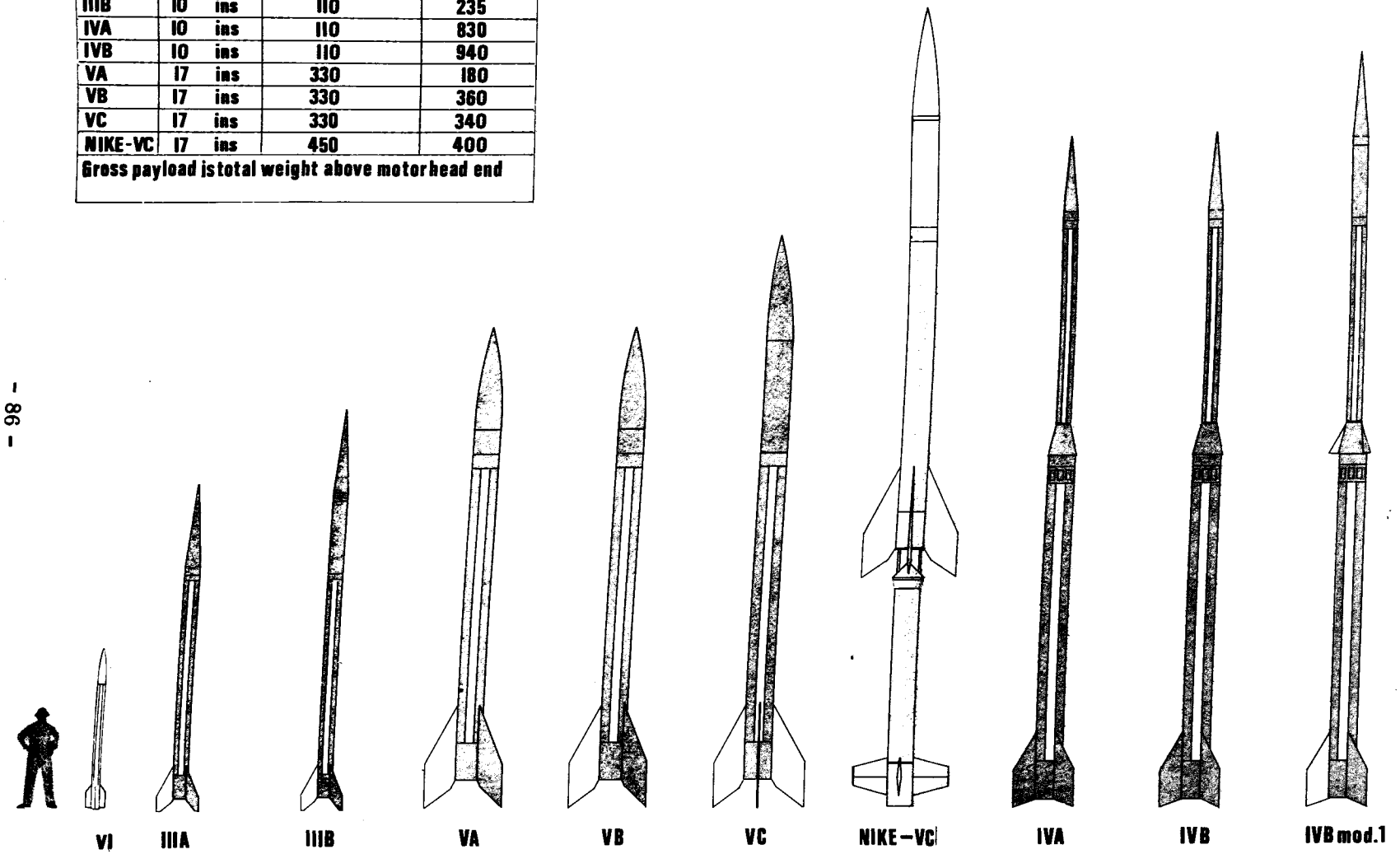
The National Research Council of Canada fired a total of 11 Black Brants in 1973. Four vehicles, a BB IIIB, two BB IVBs, and a BB VB were flown from Gillam and Churchill in a single auroral study. Another NRC operation involved the first launch of a BB IVB from Kauai in the Hawaiian Island chain. In another NRC supporting role, the BB VB has had its first firing from the Aerobee tower at CRR; use of this facility extends the number of CRR launchers which can accept the BB V, and results in a greatly reduced impact dispersion, to the benefit of more expeditious payload recovery. The BB VI firing involved launch of a micrometeorite dust collection device to an apogee of 77 km, at which point the 9 lbs. net payload was ejected to descend under its parachute.

The application of BB VC to the Skylab program represented conclusion of some two years of intensive vehicle and payload systems development. The five "calibration rockets" carried NRL and Harvard College payloads for real time

BLACK BRANT ROCKET SYSTEMS

VEHICLE	PAYLOAD DIAMETER	NOMINAL GROSS PAYLOAD (lbs)	ALTITUDE KILOMETERS
VI	4.85 ins	8.0	80
IIIA	10 ins	110	165
IIIB	10 ins	110	235
IVA	10 ins	110	830
IVB	10 ins	110	940
VA	17 ins	330	180
VB	17 ins	330	360
VC	17 ins	330	340
NIKE-VC	17 ins	450	400

Gross payload is total weight above motor head end



bristol aerospace limited

calibration of the Skylab solar spectrograph experiments. Experiment and range requirements called for accurate trajectory prediction, minimal impact dispersion, despin, payload/motor separation, nose ejection and payload recovery. These payload support functions were provided by Bristol systems. A highly successful series of flights were achieved.

Eighteen BB VC vehicles were fired during 1973; 10 for NASA, two for AFCRL and six for DFVLR, West Germany. The latter launchings, supporting the Aeros satellite program, took place from Natal, Brazil and Andoya, Norway.

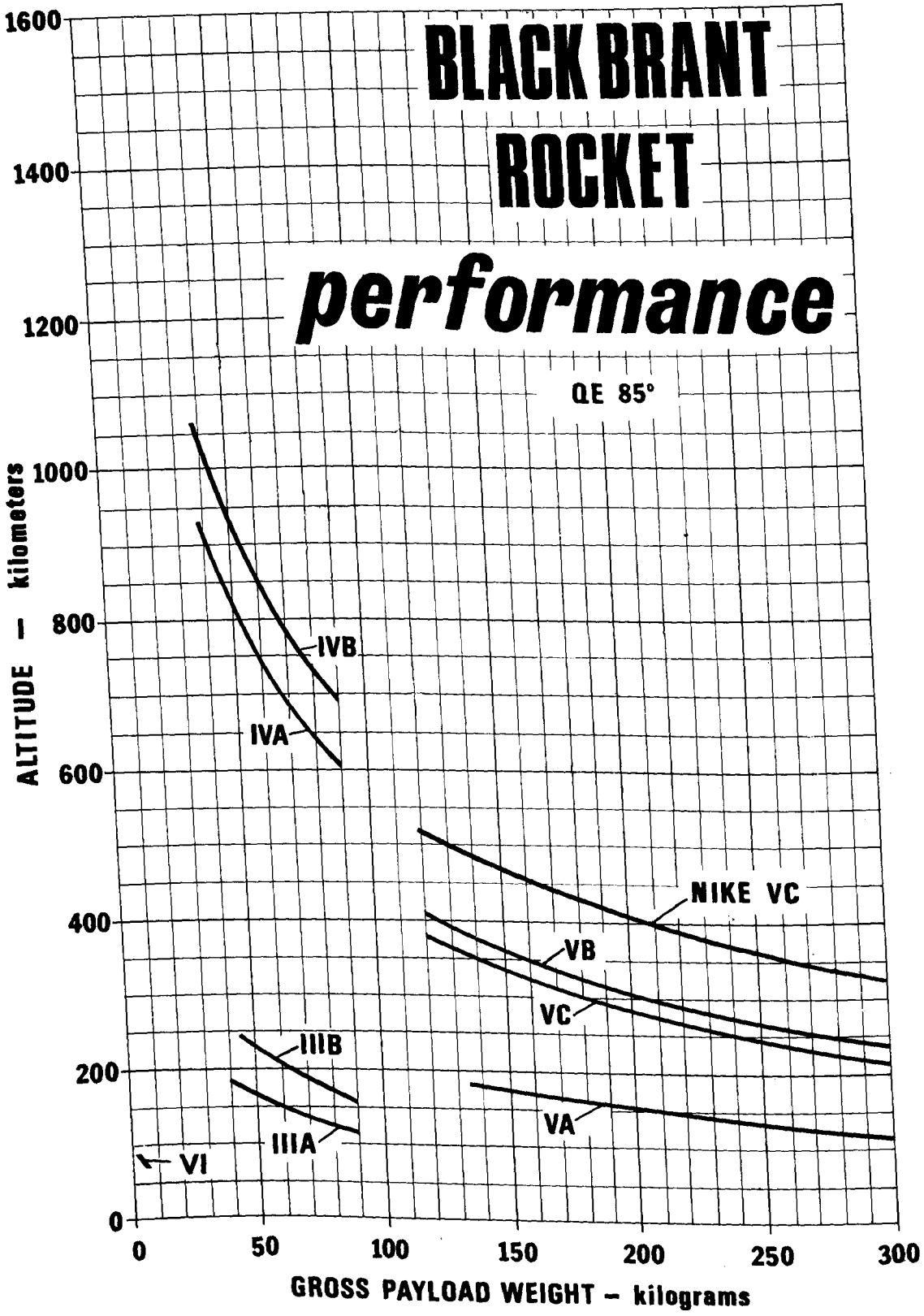
Under contract from DNA, Bristol have designed a 46 foot para recovery system (using a off-the-shelf Paronetics parachute), which will provide a 23 fps impact velocity for a 700 lb. GPL (or 30% slower than with the current system). Four completely successful air drops of the system have qualified the new system, which will be first flown in February 1974.

With successful flight of the BB IVB Mod 1, it is now possible to employ the BB IV to carry very long (and otherwise destabilizing) gross payloads. First scientific use of the vehicle will be by NRC, on BB IVB-31, to be launched in February 1974.

The Nike BB VC represents a totally new operational range of application for Black Brant, since it will be possible to carry payloads of 1,000 lbs. or more. Combination of BB VC with the Nike booster will be achieved with minimal design changes to the BB VC and payload environment in the boosted application will not be meaningfully different to that in the single stage application. When launched from sea level, Nike VC will carry a 700 lbs. GPL* to an apogee of some 260 km. The program is anticipated to enter the vehicle flight test phase by mid 1974.

In summary, 1973 saw the launching of some three BB IIIB, four BB IVA, four BB IVB, one BB VA, two BB VB, 18 BB VC, one BB VI and 38 RDT&E rockets, for a total of 71 firings.

* GPL - Gross Payload


BLACK BRANT
ROCKET
performance
QE 85°
ALTITUDE – kilometers
1600
1400
1200
1000
800
600
400
200
0
IVB
IVA
NIKE VC
VB
VC
VA
IIIB
IIIA
VI
0
50
100
150
200
250
300
GROSS PAYLOAD WEIGHT – kilograms

NORTHERN ELECTRIC COMPANY LIMITED

General

The year 1973 is very significant in the Aerospace activities of Northern Electric. The impact of the successful Canadian Domestic Satellite System on commercial communication system designs was striking. Pressure in the USA for domestic satellite systems increased following the launch for Canada of ANIK I in late 1972 and ANIK II in early 1973. The Federal Communication Commission approved a number of US Satellite Communication Systems and the INTELSAT Organization approved the purchase of new larger satellites for use in the international satellite system.

Western Union Satellite System (WESTAR)

Three satellites procured from Hughes Aircraft, by Western Union were of the HS-333 type as provided to Telesat Canada (ANIK). The entire satellite electronics for these was produced during 1973 at the Northern Electric Lucerne Plant. This electronics system is made-up of microwave transmitters, receivers, telemetry and command transmitters and receivers, digital electronics, power electronics and batteries.

American Satellite System

Satellites of the HS-333 type were ordered in 1973 from Hughes Aircraft by American Satellite Corporation. As with those of the Western Union System, Northern Electric Lucerne Plant is manufacturing the satellite electronics.

Intelsat IV-A

The digital electronics for the telemetry and command system of two type Intelsat IV-A Satellites are in manufacture at Northern Electric. These new satellites are large 24-channel spacecraft, using dual redundant sets of digital encoders and decoders.

Comsat General/Att. Satellites

Work commenced in 1973 at Northern Electric on the digital electronics for four of these large 24-channel spacecraft of a type similar to the Intelsat IV-A Satellite. These satellites are for use in the USA for Domestic Communications, mainly by American Telephone and Telegraph Company.

Satellite Earth Station Parametric Amplifiers

The Telesat Thin Route Earth Stations for use in the Canadian north require 4 GHz low noise amplifiers to provide the necessary receiver sensitivity over the 500 MHz of bandwidth. During 1973, parametric amplifiers were designed and manufactured at Northern Electric Lucerne, to meet the requirements of these remote unattended earth stations.

BELL-NORTHERN RESEARCH

As the research corporation of the Bell Canada - Northern Electric group of companies, Bell-Northern Research is engaged primarily in the creation and development of communications systems. The company's headquarters and central laboratories are in Ottawa and a regional laboratory is located in Bramalea. Space and satellite activities in Bell-Northern Research are focused on the planning, evaluation and design of communication systems used in satellite and space projects, both earth and space segments.

The Systems Engineering Group continued to give technical support to Bell Canada in the implementation and integration of the Canadian ANIK domestic satellite network for east-west major route and northern remote communications. In its role as long-range planner for Bell Canada, the group carried out several studies pertaining to the potential of satellites. These studies included scenarios of satellites in the total communication environment in the long-range future.

During the year a contract study was conducted for the Communications Research Centre, Department of Communications, Canada, on the feasibility of a satellite system for the distribution and broadcast of television and radio programs of the Canadian Broadcasting Corporation. The study examined the available frequency bands, the choice of orbital positions, the modulation techniques, the weight and power of the satellite and suitable launch vehicles. The report was submitted in July 1973.

The group continued its technical support to Northern Electric Company in furtherance of the latter's business as an established manufacturer of satellite transponder subsystems.

SPACE RESEARCH AT RCA LIMITED, STE. ANNE-DE-BELLEVUE, QUEBEC

RCA Limited has experience in space electronics extending from 1959 with over 60 programs completed to a value in excess of $100-million for 22 agencies in 14 countries.

The work has primarily been in the fields of earth stations and satellites. Additionally, Research Laboratories of the company have discharged a significant number of space research programs - studies, experiments, investigations - for the Canadian and United States governments.

Earth Stations

RCA Limited is one of the world's major contractors for the supply of satellite earth stations - 20 complete stations and major subsystems for 47 other stations in the span of the last 10 years, representing a dollar output of products and services in excess of $60-million. The company represents the RCA Corporation in the design, manufacturing, installation and marketing of earth stations for the world market, and engages a technical force for this work of over 100 engineers and technicians.

The year 1972 was a particularly active one for the company in earth station work. For the Canadian Domestic Satellite System, the company completed two 30-meter Heavy-Route Stations at Lake Cowichan, British Columbia, and Allan Park, Ontario, six 10-meter Network Television Stations, two 10-meter Northern Telecommunications Stations, and supplied the feed and communications subsystems to the 10-meter TT&C Station at Allan Park, Ontario

RCA Limited's work for the Intelsat global satellite network in 1972 comprised the completion of three stations - 30-meter stations in Karachi, West Pakistan and at Lake Cowichan, B.C., for COTC for Canada's Trans-Pacific satellite traffic, and a 10-meter station in Shanghai; and the start of work on three new 30-meter stations - two for the People's Republic of China at Peking and Shanghai and a second station for the Government of India near New Delhi.

RCA has carried out continuous development activity in satellite earth station technology under a cost-share program with the Department of Industry, Trade and Commerce of the Canadian Government. For the most part this development has been for the tracking, feed and ground communications subsystems of earth stations.

For the tracking subsystem, the company perfected during 1972 an on-off, signal maximizing type of tracking system using an adaptive controller as a cost-effective alternative to the conventional 3-channel monopulse tracking system. The new system, termed "step-track", operates from the maximum beacon or communications' signal as detected at the output of a conventional receiver chain, and dispenses with the difference mode circuitry of the feed system, the tracking down-

converter and the 3-channel tracking receiver of the conventional monopulse tracking system. The step-track, operates from the maximum beacon or communications' signal as detected at the output of a conventional receiver chain, and dispenses with the difference mode circuitry of the feed system, the tracking downconverter and the 3-channel tracking receiver of the conventional monopulse tracking system. The step-track system has been installed on four 30-meter stations.

In the field of the feed subsystem, RCA produced 14 new sum mode feed systems during 1972 which had the capability for spectrum re-use such as to effectively double the present communications capacity of an antenna system to two 500 MHz bands, orthogonally polarized with respect to the other, for both transmission and reception. Isolation between orthogonally polarized signals of 35 to 37 db was attained for the linearly polarized case and about 28 db for the circularly polarized case.

During 1973 development work was carried out on satellite antenna designs for the 4/6 GHz frequency bands. Designs suitable for U. S. Domestic applications were developed which have the high polarization isolation required by a frequency re-use system. Another development necessary for a frequency re-use system was a polarization tracking system for the ground antenna. In this way, polarization rotation caused by the faraday effect can be tracked so as to maintain the high isolation between orthogonally polarized signals.

A new 5-flare conical feed horn was developed in 1972 for application to 30-meter 4/6 GHz Intelsat stations to improve G/T figure of merit performance across the receive band. RCA completed in 1972 a special oversized waveguide system to carry 4 and 6 GHz signals from the apex of a 30-meter antenna to the low-noise receiver and high-power amplifier mounted at the antenna base. This system was installed in an RCA built earth station in 1973.

In ground communications equipment RCA developed a system of carrying three sound channels and the TV video signal on a 6.8 MHz subcarrier to achieve reduction of transmit and receive equipment in a domestic satellite terminal. Equipment with microintegrated circuitry is under development to achieve an 8-fold reduction equipment volume of the ground communications equipment subsystem.

Satellites

RCA's Canadian industry leadership in the field of satellite technology has continued during the period of 1971-1973.

In 1971 RCA participated with Communications Research Centre of the Department of Communications in Systems planning and program definition of the new Communication Technology Satellite - a joint Canada/US, NASA project with satellite launch scheduled for 1975. RCA has responsibility for most of the electronics design in the spacecraft including SHF antennas and transponder, transmitters and receivers,

power conditioning, and attitude control. The Engineering model has been fabricated and is undergoing extensive engineering tests in preparation for the fabrication of flight quality hardware during 1974.

In 1971, RCA Limited was designated the skill centre with the RCA Corporation for all satellite transponder activity including research and development. In this capacity RCA Limited has carried out significant research and development in the application of Graphite Fibre and Epoxy Composites (GFEC) to the production of light weight temperature stable filters and multiplexers, and in the corresponding development of a light weight 24 channel transponder for US Domestic Satellite applications. The application of light weight materials to satellite transponders makes possible the launching of a 24 channel satellite with a Thor-Delta launch vehicle.

In 1973 the development effort in Satellite transponders resulted in the award of an eight million dollar subcontract for the communications package (transponder and antenna subsystems) for a US Domestic satellite system.

In 1972 RCA received contracts for Communication Satellite Studies from the Canadian Department of Communications which extended a previous study, and from the Canadian Department of National Defence.

Research

RCA's Research activities on aeronomy and space physics continued during 1973. The following is a brief summary of the major projects carried out during the year.

The Research Laboratories have provided a number of consultants to CRC to work on the Communications Technology Satellite (CTS) program.

A trade-off study comparing transistor amplifiers and the driver TWT for use in the transponder of the US Domestic Communication Satellite was carried out. Changes in the transponder configuration were recommended to optimize the system with the transistor amplifier.

A system study was carried out to outline the various possible ways of interconnecting the transponder subsystem and the antenna subsystem on the US Domestic Satellite.

A number of system studies have been carried out on UHF satellite systems for thin route northern communications. These studies involved the transponder, the satellite support subsystems as well as the ground segment. These systems utilized the frequency division multiple access (FDMA) mode of operation with many small ground stations having single voice channel capability.

A mode of projects have investigated multiple access techniques, modulation and demodulation techniques and data switching techniques that would be suitable for thin route satellite communications systems.

The reflectivity of a trihedral corner reflector was investigated for the Ministry of Transport both experimentally and theoretically, when covered with ice, snow and rain. This reflector was being investigated for possible use as an artificial ground, for instrument landing systems, wherever irregular gound contours appear off the end of airport runways.

Sealed off CO_2 lasers with glass or ceramic tubes have been developed for satellite communications applications. Several tubes were supplied to NASA Goddard for evaluation and these performed better than lasers supplied by other sources.

A microwave correlation spectrometer was investigated for application to air pollution monitoring.

A high intensity light source (150 kW) has been developed for airborne illumination of ground terrain. The light source could have application in arctic surveillance as well as in military arenas.

Research work carried out in the past have included basis research in a number of areas.

Studies on the electromagnetic wave interaction with plasmas with emphasis on strong field effects and transfer of information through anisotropic plasmas. Research on Radar backscatter involved theoretical and experimental work on direct and cross-polarized backscatter from turbulent plasmas. Work on antennas in plasmas included detailed theoretical and experimental investigations. Theoretical studies were performed on the accuracy of the Langmuir probe measurements and skin potential on satellites and non-linear sheath admittance, current and charges associated with high voltage drive on a VLF/ELF dipole antenna moving in the ionosphere. Work on a laser side looking radar included laser reflectivity measurements on various rocks, liquids and plants for possible application of satellite or airborne remote sensing of resources. A study was carried out on the possible use of millimeter wave radiometry at 180 GHz on either satellite or aircraft to determine the vertical distribution of water vapour in the upper atmosphere.

SED SYSTEMS LIMITED

This company is engaged in space activities through contracts with the Canadian government and other agencies.

For the Canadian space program SED is involved in systems engineering, hardware production and operations work.

Systems engineering is carried out at Saskatoon and Ottawa for the CTS Satellite. Initially, spacecraft systems are computer modelled to determine design parameters and operational procedures. Subsequently the model is used in the development of airborne and ground based hardware and operational software.

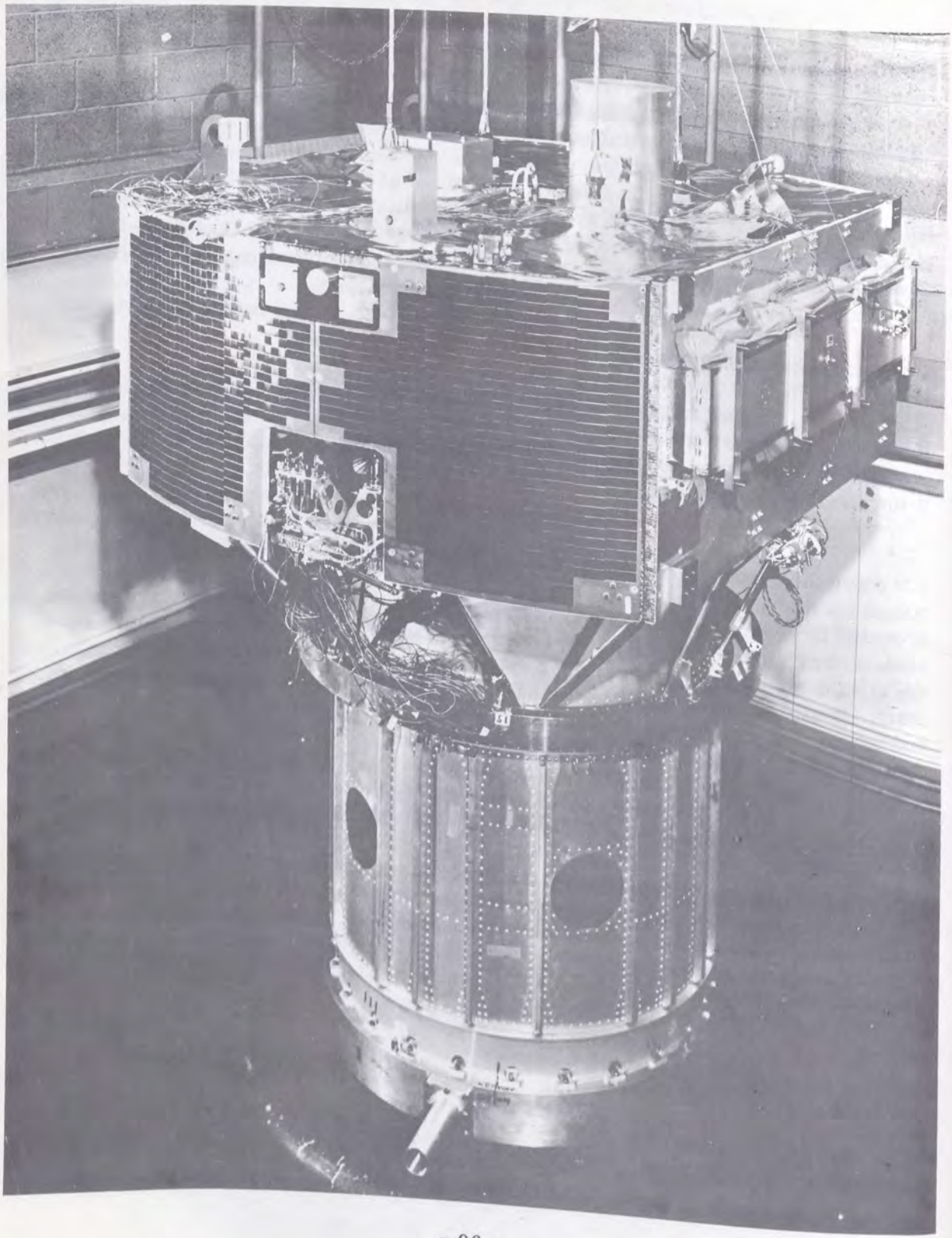
During 1973 for various programs, both ground based and airborne hardware have been produced.

Under contract to Telesat Canada, SED designed, manufactured and installed a telemetry and command station for the "ANIK" satellite program. This station is a permanent installation at Allan Park, Ontario, but it's design is such that it may be air transported and installed in remote locations.

For the SRFB sounding rocket program SED has produced three heavy, 17" diameter, recovery payloads. One of these had been previously flown on two occasions whereas the other two are of new design. They all carry experiments provided by government and university scientists and utilize PCM telemetry, power systems and protection devices developed by this company. A further activity was the installation and operation of the NRC tape digitizing facility at the Saskatoon plant. This equipment converts analog data obtained from payload, FM/FM telemetry and ground radar to digital, computer compatible form. It can also process digital data obtained from payload, PCM telemetry systems.

Operations work is carried out under contract to CCRS at the Prince Albert Satellite Station for the Earth Resources Satellite Program (ERTS). SED maintains a team of ten people at this station to receive and process data transmitted from the satellite.

VIBRATION TEST CTS DYNAMIC MODEL



SPAR AEROSPACE PRODUCTS LIMITED

Spar Aerospace Products Limited has been in the forefront of space research since 1959 beginning with the Alouette I satellite program. Spar has been a major contributor in all of the Canadian satellite programs to date and have exported satellite subsystems and equipment to the United States, England, France, Germany and Japan. More than 500 space mechanisms have been launched aboard satellites from most of these countries.

Approximately half of Spar's business in 1973 can be attributed to space programs. A good portion of the work was associated with Canada's Communications Technology Satellite (CTS) which is summarized below. Other noteworthy programs include Domestic Communications Satellites, American experimental satellites and sounding rockets, Russia's Mars probes, and Space Shuttle systems.

Communications Technology Satellite

Spar's responsibilities include the design and hardware fabrication of major CTS subsystems: the spacecraft structure and thermal subsystem; the extendable and body-mounted solar arrays; the transfer and synchronous orbit attitude control system; mechanical ground support equipment.

Research and Development

A number of research and development projects were carried out this year associated with the CTS program.

Studies were carried out to assess various forms of coatings and finishes for passive thermal control of spacecraft structures and components.

Spar engineers performed dynamics analyses on flexible bodies to predict the behaviour of a flexible spacecraft structure with flexible appendages such as deployable solar arrays, booms and antennas. These studies enabled the CTS attitude control system and structural support design to be optimized.

Structure/Thermal Subsystem

The dynamic/thermal model underwent thorough vibration and thermal-vacuum testing during 1973.

The structure was successfully qualified following sine, random and shock vibration tests at NASA-Lewis Research Center and acceleration tests at NASA-Goddard Space Flight Center (GSFC). Following its return, the CTS structure was refurbished to produce the engineering/qualification model. The procurement of prototype/flight long-lead hardware items has commenced.

The dynamic/thermal model was thermal-vacuum tested in the NASA-GSFC chamber simulating conditions of the transfer orbit and synchronous drift phases. The model is currently being updated to encompass the final components and system adjustments. Further testing will take place on the engineering/qualification model in mid-1974.

Solar Array Subsystem

The development test program for the solar array subsystem progressed well with testing consisting of functional deployment tests, vibration tests, thermal-vacuum testing at CRC, accoustic testing at NRC Laboratories and electron-magnetic compatability tests at DRTE. The subsystem was returned to Spar for refurbishment to produce the engineering model. The solar cell blanket (engineering model) has been received from AEG-Telefunken in Hamburg, Germany, integrated into the system and functional deployment tests have commenced.

Attitude Control Subsystem (ACS)

The engineering model system has been designed and critical hardware such as the momentum wheel assembly, earth sensors and nutation damper have been procured and acceptance tested. Integration of this hardware into the system is in work with testing scheduled for early next year. The ACS electronics have been functionally tested using NRC's hybrid computer. The test equipment to be used for the engineering model tests has been designed and constructed.

Domestic Communications Satellites

Resulting from Spar's performance in the ANIK satellite program, Spar has been contracted by Hughes Aircraft Company to build six further structures for the US Domestic Communications Systems operated by both Western Union and American Satellite Corporation.

Russian Mars Probes

Russia's Mars six and seven probes launched on August 6 and 9, 1973, respectively, had as one of their experiments, Stereo 5, provided by the Paris Observatory which formed part of their experiment. The antenna system for each probe consisted of a full-wave dipole operating at 30 MHz and a half-wave monopole operating at 60 MHz both mounted on one of the solar arrays.

During the coast phase of the mission between Earth and Mars, the French experiment studied solar radio emissions from the sun. The theory of these radio bursts implies that their intensity is a function of the observed direction. The Stereo experiment makes simultaneous observations from the Mars probes as well as from a receiving station on Earth to detect and measure this directivity.

All six fly-off-spool STEM antennas were successfully deployed and the experimenter reports that the raw data received to date is very good.

Remote Manipulator Systems (RMS)

Work is continuing on conceptual studies initiated with NASA-GSFC in 1972 on the Special Purpose Manipulator System (SPMS) for the EOS*series of spacecraft. SPMS will be used for in-orbit servicing and resupply of EOS.

In conjunction with this work, Spar is investigating the Shuttle Attached Manipulator System (SAMS) for the shuttle orbiter vehicle. The combination of SPMS and SAMS in a development program is projected to have technology outputs in advanced RMS which can be applied to future Canadian requirements in underwater, mining and nuclear fields.

Meteoroid Technology Satellite (MTS)

Built by NASA-Langley Research Center in Virginia, MTS was successfully launched aboard a Scout rocket and used deployable pressurized panels to record meteoroid strikes on the spacecraft. Spar designed and built the STEM actuation system which extended and supported the flexible panels following orbit acquisition.

Sounding Rockets

Spar supplied a large quantity of orthogonal STEM antenna arrays to NASA-GSFC for their sounding rocket programs. The antennas were flown aboard both Javelin and Nike-Tomahawk rockets.

*EOS - Earth Orbiting Satellite

TABLE I

DETAILS OF ROCKET LAUNCHINGS AND EXPERIMENTS - 1973

VEHICLE	NOSE CONE Kgs	PLACE TIME DATE	Effective Launch Elevation	Apogee Kms	Apogee Time In Sec.	Roll Rate rps	ROCKET PERFORMANCE	REQUIRED LAUNCH CONDITIONS	EXPERIMENTS	EXPERIMENTERS	EXPERIMENT RESULTS
AAF-IVB-27	84.08	CRR 2302 CST 28/1/73	85°	714	421.5	2.55/ 0.347	Normal	Quiet pre break-up early evening Aurora	Energetic particle Detector Auroral Scanner Electric Field Probes Plasma Probes	B.A. Whalen C.D. Anger and L.L. Cogger A. Kavadas and J.A. Koehler A.G. McNamara	Good data obtained SRFB 074
AAF-IIIB-67	68.5	Gillam 0015 CST 2/2/73	85.4°	199.8	214.8	8.2/ 0.25	Normal	Aurora substorm	Energetic Particle Detector Plasma Probes Photometer	B.A. Whalen A.G. McNamara F.R. Harris	Good data obtained SRFB 074
AAF-VB-36	176	CRR 0020 CST 2/2/73	85°	335.1	292.5	3.2/ 0.3	Normal	Aurora substorm	Energetic Particle Detector Plasma Probes Photometer Twin Photometer	B.A. Whalen A.G. McNamara F.R. Harris A. Monfils	Good data obtained SRFB 074
AAF-IVB-28	84.08	CRR 2053 CST 8/2/73	86°	729	434.5	2.4/ 0.317	Normal	Aurora Substorm	Energetic Particle Detector Auroral Scanner Electric Field Probes Plasma Probes	B.A. Whalen C.D. Anger and L.L. Cogger A. Kavadas and J.A. Koehler A.G. McNamara	Good data obtained SRFB 074
ADD-IIIB-64	63.5	CRR 2149 CST 21/2/73	85°	198	215	6.33/ 0.8	Normal	Clear Sky	Radio Aurora Measurements	A.G. McNamara	Good data obtained SRFB 075
ADD-IIIB-65	63.5	CRR 1920 CST 23/2/73	85°	190	208	7.7/ 1.1	Normal	Clear Sky	Radio Aurora Measurements	A.G. McNamara	No data obtained SRFB 075

TABLE I
DETAILS OF ROCKET LAUNCHINGS AND EXPERIMENTS - 1973 (Cont'd)

VEHICLE	NOSE CONE Kgs	PLACE TIME DATE	Effective Launch Elevation	Apogee Kms	Apogee Time In Sec.	Roll Rate rps	ROCKET PERFORMANCE	REQUIRED LAUNCH CONDITIONS	EXPERIMENTS	EXPERIMENTERS	EXPERIMENT RESULTS
ADD-II-127	228.5	CRR 2123 CST 25/2/73	85°	131.1	174	0.54	Normal	Visual aurora intensity 2 or more	VUV Spectrometer Electron Spectrometer VUV Photometer Up & Down Photometer Auroral Scanner Forward and side looking photometers Plasma Probes (3) Photometers	D.J. McEwen C.D. Anger E.J. Llewellyn A.G. McNamara G.G. Shepherd	Good data obtained from most experiments. SRFB 076
AAF-VB-37	215.8	CRR 0419 CDT 16/5/73	87°	301	275		Normal	Solar depression angle 5°	Engineering measurements Electromagnetic Probe Lyman Alpha Detector Micrometeoroid Detector Retractable Probe Water Vapour Measurements Photometer	H. Roberts A.G. McNamara D.J. McEwen R. Wlochowicz J.H. DeLeeuw W. Evans E.J. Llewellyn	Good data obtained. SRFB 077
AAF-VI-01	9.2	CRR 0606 CDT 16/5/73	87°	78.2	130		Normal	Daytime Weather suitable for recovery	Ejectable High Altitude Dust Collector	R. Wlochowicz	Payload not yet recovered. SRFB 078
APF-IVB-30	89.9	Kauai Hawaii 0030 HST 21/6/73	85°	686	428	3.05/ .19	Normal	Quiet Conditions	Soft X-ray probes X-ray Detector	B.G. Wilson D. Vankatesan	Good data from two of three experiments. SRFB 079
AMF-VA-40	191.9	CRR 2047 CST 25/11/73	87°	102.6	155	3.5	Normal until T+18 Sec.	Distinct and sustained aurora	Auroral Photometry (2) Vacuum Ultraviolet Measurements (3) Ionization Density Measurements	R.W. Nicholls D.J. McEwen A.G. McNamara	No data obtained due to early payload failure. SRFB 082

TABLE I

DETAILS OF ROCKET LAUNCHINGS AND EXPERIMENTS - 1973 (Con't)

VEHICLE	NOSE CONE Kgs	PLACE TIME DATE	Effective Launch Elevation	Apogee Kms	Apogee Time In Sec.	Roll Rate rps	ROCKET PERFORMANCE	REQUIRED LAUNCH CONDITIONS	EXPERIMENTS	EXPERIMENTERS	EXPERIMENT RESULTS
AMM-S2-10	5.85	CRR 0745 CST 4/12/73	Details not yet available				Normal	Five to be launched in 24 hour period	Atomic Oxygen Probes	H.I. Schiff	No data due to failure of payload at T+30 Sec. SRFB 083
AMM-S2-11	5.85	CRR 1200 CST 4/12/73	Details not yet available				Normal	Five to be launched in 24 hour period	Atomic Oxygen Probes	H.I. Schiff	Good data obtained SRFB 083
AMM-S2-12	5.85	CRR 1634 CST 4/12/73	Details not yet available				Normal	Five to be launched in 24 hour period	Atomic Oxygen Probes	H.I. Schiff	Good data obtained SRFB 083
AMM-S2-13	5.85	CRR 0052Z 5/12/73	Details not yet available				Normal	Five to be launched in 24 hour period	Atomic Oxygen Probes	H.I. Schiff	No data due to failure of payload at T+28 sec. SRFB 083
AMM-S2-14	5.85	CRR 0805 5/12/73	Details not yet available				Normal	Five to be launched in 24 hour period	Atomic Oxygen Probes	H.I. Schiff	Good data obtained SRFB 083
AAF-VI-02	Scheduled for late December 1973							Daylight Weather suitable for recovery	Ejected High Altitude Dust Collection	R. Wlochowicz	Not launched in 1973 and rescheduled for 1974
AAF-VI-04	Scheduled for late December 1973							Daylight Weather suitable for recovery	Ejected High Altitude Dust Collection	R. Wlochowicz	Not launched in 1973 and rescheduled for 1974

TABLE 2

ROCKETS AND EXPERIMENTS PLANNED FOR 1974

Vehicle No.	Pr. Scientist	Engineering	Launch Period	Conditions	Experimenters	Experiments	Remarks
AMD-VB-34	Shepherd	SED	January 74 CRR	Electron aurora of IBC-II or more, no moon. Good visibility.	Shepherd Young Zipf Harris Kavadas McNamara McEwen Mentall	Photometer Stimulated Fluorescence Mass Spectrometer Photometer Spin Probes Plasma Probe VUV Spectrometer Ultraviolet Photon Detector	Recovery.
ADD-II-128	McEwen	SED	February 74 CRR	Visual aurora intensity Intensity II or greater	McEwen Anger Llewellyn McNamara Shepherd	VUV Spectrometer, Electron Spectrometer Up and Down Looking Photometer and a Forward Looking VUV Photometer Optical measurements of various wavelengths Forward and side looking photometers to measure emissions at various wavelengths. Swing-out side and ejected plasma probes. To measure intensities of H4861, OI 5577 Å emissions looking upward.	Recovery Reflight ADD-II-127
AKF-VB-39	Anger	BAL	February 74 CRR	Diffuse aurora	Anger Whalen McNamara Clark Kavadas Bernstein	Auroral Scanner Electron & Ion Distribution Plasma Probes Infrared Photometer Spin Probes Neutral Hydrogen Spectrometer	Recovery
AAF-IVB-31	Whalen	BAL	February 74 CRR	Quiet Auroral Form	Whalen Anger McNamara Kavadas	Electron & Ion Distribution Auroral Scanner Plasma Probes Spin Probes	
AKF-VI-03	Venkatesan	BAL	February 74 CRR	Active Conditions	Venkatesan	Auroral X-rays	Payload on parachute for measurements during descent.

TABLE 2

ROCKETS AND EXPERIMENTS PLANNED FOR 1974 (Cont'd)

Vehicle No.	Pr. Scientist	Engineering	Launch Period	Conditions	Experimenters	Experiments	Remarks
AMD-VA-35	Young	SED	TBD 74 CRR	Quiet	Young Shepherd Zipf McNamara McEwen	Stimulated Fluorescence Photometer Mass Spectrometer Plasma Probes VUV Spectrometer	Recovery
VB-41	Shepherd		December 74 Cape Parry	Dayside Cusp	Shepherd Whalen McEwen McEwen Monfils Koehler et al Rostoker McNamara Evans	Multi barrel photometer as on VB-34 Particle detectors Soft electron spectrometer Vacuum ultraviolet photometer Photometers, 5200 Å & 3914 Å Spin probes Magnetometers Plasma Probes Nitric oxide and water vapour detectors	
IVB-32	Whalen		December 74 Cape Parry	Dayside Cusp	Whalen Shepherd McNamara Koehler et al	Particle detectors Secondary Photometer Plasma Probes Spin Probes	
VB-42	Wilson		Early 1975 CRR	Full moon, quiet conditions	Wilson Nicholls	Cosmic X-rays Lunar reflectance	Attitude Control System and Recovery
VB-43	DeLeeuw		Early 1975 CRR	Quiet and Solunar Darkness	DeLeeuw Visentin DeLeeuw Harris	Electron Beam Fluorescence Probe Aerodynamic Spectrometer Ion Probe Photometer	Recovery

ABBREVIATIONS

AECL	Atomic Energy of Canada Ltd.
AFCRL	Air Force Cambridge Research Laboratories (U.S.)
ANIK	Eskimo name for brother
ARCOM	Arctic Communications Station
AU	Atronomical Unit
APT	Automatic Picture Transmission
ARCAS	Atlantic Research Corporation Altitude Sounding Rocket
ATS	Applications Technology Satellite
BAC	British Aircraft Corporation
BAL	Bristol Aerospace Limited
BASS	Ball Azimuth Stabilization System
CAE	Canadian Aviation Electronics
CANTAT	Canadian Atlantic Telephone Cable
CARDE	Canadian Armament Research and Development Establishment
CF	Canadian Forces
CHU	A radio station
COMSAT	Communications Satellite
COSPAR	Committee on Space Research
COTC	Canadian Overseas Telecommunications Corporation
CRAM	Centre for Research on Atoms and Molecules
CRC	Communications Research Centre of the Department of Communications
CRESS	Centre for Research in Experimental Space Science
CRR	Churchill Research Range
DCBRE	Defence Chemical & Biological Research Establishment
DND	Department of National Defence
DOC	Department of Communications
DOT	Department of Transport (Now MOT - Ministry of Transport)
DRB	Defence Research Board
DREV	Defence Research Establishment Valcartier (ex CARDE)
DRIR	Direct Reading Infrared Readout
DRTE	Defence Research Telecommunications Establishment (Now CRC)

Abbreviations (Continued)

EMR	Department of Energy, Mines and Resources
ESRO	European Space Research Organization
ESSA	Environmental Science Services Administration (Now NOAA)
EW	East West
GMT	Greenwich Mean Time
GSC	Geological Survey of Canada
GSFC	Goddard Space Flight Center
IGY	International Geophysical Year
IMP	Interplanetory Monitoring Platform
INTELSAT	International Communications Satellite Consortium
IQSY	International Years of the Quiet Sun
IR	Infra Red
ISAS	Institute of Space and Atmospheric Studies
ISIS	International Satellites for Ionospheric Studies
ITU	International Telecommunications Union
IUPAP	International Union Pure and Applied Physics
IUWDS	International URSIGRAM and World Days Service
Laser	Light amplification by stimulated emission of radiation
Maser	Microwave amplification by stimulated emission of radiation
Met	Meteorological
NAE	National Aeronautical Establishment
NASA	National Aeronautics and Space Administration
NIMBUS	Cloud Formation (Latin)
NLC	Noctilucent cloud
NOAA	National Oceanographic and Atmospheric Administration (Previously ESSA)
NORAD	North American Air Defence
NRC	National Research Council of Canada
NRL	Naval Research Laboratory (U.S.)
N.W.T.	Northwest Territories
OGO	Orbiting Geophysical Observatory

Abbreviations (Continued)

OSO	Orbiting Solar Observatory
PCA	Polar Cap Absorption
PCM	Pulse Code Modulated
PSK	Phase Shift Keying
RADINT	Radio Doppler Interferometer
RCA	Radio Corporation of America
REED	Radio and Electrical Engineering Division
SED	Space Engineering Division
SN	Super Nova
SPADE	Single PCM Multiple Access Demand Equipment
SRFB	Space Research Facilities Branch
SSC's	Storm Sudden Commencements
SSCC	Spin-Scan Cloud Camera
S^3 (SSS)	Small Scientific Satellites
SST	Super Sonic Transport
STADAN	Space Tracking and Data Acquisition Network
STEM	Storable Tubular Extendable Member
TACSATCOM	Tactical Satellite Communication
TELESAT	Telecommunications Satellite
TIROS	Television Infrared Observational Satellite
TOS	TIROS Operations System
TT&C	Telemetry Tracking and Command
TWT	Travelling Wave Tube
URSI	International Union of Radio Science
UT	Universal Time
VELA	Nuclear Detection Satellite
WEFAX	Weather Facsimile
WMO	World Meteorological Organization

SYMBOLS

α	alpha
Å	Angstrom
AGC	Automatic gain control
BeV	Billion electronvolt
cm	centimeter
db	decibel
e/cc	electrons per cubic centimeter
ELF	Extremely low frequency
eV	electronvolt
FM	frequency modulated/modulation
ft	foot/feet
GeV	giga electronvolts
GHz	gigahertz
G/T	gain of antenna over noise
GV	giga volt
$H\beta$	hydrogen beta
Hz	hertz
i/cc	ions per cubic centimeter
°K	degrees Kelvin
KeV	kiloelectronvolt
kHz	kilohertz
km	kilometer
L ≈4	invarient shell parameter
lb	pound
MeV	megaelectronvolt
MHz	megahertz
mm	millimeter
N_2^+	ionized nitrogen molecule
OH	Hydrozyl
$O_2(^1\Delta)$	term used in spectroscopy

Symbols (Continued)

$O_2 {}^1\Delta g$	term used in spectroscopy
$(OI)_{32}$	state of oxygen atom
PCM	pulse code modulated
PSK	phase shift keying
R_E	Earth Radii
RF	radio frequency
SCO	subcarrier oscillator
str	steradian
UHF	Ultra high frequency
VLF	very low frequency
w	units of power
μ	micro-micron
λ	wavelength
Δv	the change in vibration quantum number
Λ	Lambda
10^3	thousands
10^6	millions
$\perp$	perpendicular

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ANNEX 3
TO THE FIFTH ANNUAL
REPORT OF THE ICS.

FEDERAL GOVERNMENT EXPENDITURES ON SPACE ACTIVITIES FOR FISCAL YEARS 1973-74 AND 1974-75 (FORECAST)

x $1000s

	DEPARTMENT	1973-74	1974-75
1.	Department of Communications.		
I	Spacecraft Technology and Satellite Operations.	$16,908(1)	$17,589(3)
II	Satellite Communications Systems	4,406(2)	5,020(4)
III	Scientific Research Utilizing Satellite and Rockets.	203	158
		$21,517(5)	$22,767(6)

Notes:
(1) Includes $ 10.3 recoverable from DND
(2) Includes $236.3 recoverable from DND and 10 from industry.
(3) Includes $ 10.3 recoverable from DND
(4) Includes $168.7 recoverable from DND and 12 from industry.
(5) An estimated $14,835 will have been contracted to industry.
(6) An estimated $17,315 will be contracted to industry.

2.	Department of Energy, Mines and Resources.		
	Canadian Centre for Remote Sensing and ERTS Program	$ 6,199	$ 6,238
3.	National Research Council.		
	Intra-mural Space Oriented Programs	$ 3,500	$ 3,500
	Extra-mural Space Oriented Programs	900	900
		$ 4,400	$ 4,400

		x $1000s 1973-74	1974-75
4.	Department of National Defence/ Defence Research Board.		
	DRB Intramural Program	$ 704	$ 611
	DRB Extramural Program		
	A) Defence Industrial Research	76	30
	B) University Grants	208	200
		988	841
	less transfer from DOC for battery research	49	38
	Net D.R.B.	939	803
	Canadian Forces Development Program	245	245
	Total DND Space-related R&D in DND	1,184	1,048
5.	Department of Industry, Trade and Commerce.		
	Project / Program		
	Earth Stations DIP	250	250
	Satellite Transponders DIP	-	500
	Satellite Navigation DIP	100	300
	Aerosat Antenna DIP	120	38
	Satellite Communications. DIP/IMDE	500	100
	Rocket Development DIP	232	316
	Space Manipulators DIP	150	150
	Total	$ 1,352	$ 1,654
6.	Ministry of Transport.		
	Aeronautical Maritime Satellite Studies.	$ 211	$ 205

ANNEX 4
TO THE FIFTH ANNUAL
REPORT OF THE ICS.

INTERDEPARTMENTAL COMMITTEE ON SPACE

MEMBERSHIP

Dr. J. H. Chapman (Chairman)	-	Department of Communications.
Mr. D. Armstrong	-	Ministry of Transport
Dr. L. W. Morley	-	Energy, Mines & Resources
Dr. H. Sheffer	-	Defence Research Board.
Mr. F. R. Thurston	-	National Research Council
Dr. S. Wagner	-	Industry, Trade & Commerce.
Dr. P. Bourgault	-	Ministry of State for Science & Technology.
Mr. G. F. Bruce	-	External Affairs
Dr. J. R. Whitehead	-	Ministry of State for Science & Technology.
Mr. I. S. McLeish (Secretary)	-	Ministry of State for Science & Technology.

SUB-COMMITTEES

International Aspects of Space Policy.

Mr. G. F. Bruce (Chairman) - External Affairs

Space Vehicles and Propulsion.

Mr. F. R. Thurston (Chairman)- National Research Council

Satellite Applications and Technology.

Mr. B. A. Walker (Chairman) - Department of Communications.

Scientific Research.

Dr. R. E. Barrington (Chairman) - Department of Communications.

TERMS OF REFERENCE
INTERDEPARTMENTAL COMMITTEE ON SPACE.

DEFINITIONS:

For the purposes of the Interdepartmental Committee on Space space is defined as the upper atmosphere and space above a lower limit of 50 Kilometres altitude. Space activity includes research or other operations conducted by means of rockets, satellites, high altitude balloons, or other devices, and including associated ground-based activity.

ORGANIZATION:

1. The Committee shall be composed of senior officials, able to speak for their department on policy matters, and representing:

   Department of Communications,
   Department of Energy, Mines and Resources,
   Department of Industry, Trade and Commerce,
   Department of Transport,
   Department of National Health and Welfare (Health),
   Defence Research Board,
   National Research Council.

2. Observer status shall be accorded representatives of:

   Science Secretariat,
   Treasury Board Secretariat,
   Department of External Affairs.

3. The Chairman shall be named by the Committee.

4. The Committee shall have the power to establish sub-committees in areas of special interest, and the sub-committees should include representatives of other departments and agencies, industry, and universities as desirable and necessary.

5. The Committee shall report to the Chairman, Cabinet Committee on Science Policy and Technology, through the Secretary, CCSPT.

DUTIES:

1. To review Canadian space activity including that of Federal Government departments and agencies, the universities, and industry and to make recommendations concerning the optimum use of resources, the coordination of space activity and the dissemination of information of such space activity.

2. To consider Federal policy for space activity in relation to national interests, needs and opportunities and to formulate and recommend appropriate plans and proposals.

3. To make recommendations for the promotion of co-operation in the space activities of national and international organizations.

4. To report annually, on February 1st, or more often if desirable, to the Chairman of the Cabinet Committee on Science Policy and Technology.