SIXTH ANNUAL REPORT 1974

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Interdepartmental Committee on Space

Comité Interministériel sur l'Espace

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INTERDEPARTMENTAL COMMITTEE ON SPACE

SIXTH ANNUAL REPORT

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SCIENCE AND TECHNOLOGY
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J. H. CHAPMAN
CHAIRMAN

I. S. McLEISH
SECRETARY

OTTAWA
FEBRUARY 1975

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1. INTRODUCTION

The purpose of this document is to report on the activities of the Interdepartmental Committee on Space (ICS) for the year 1974. It should be noted however that financial data contained herein necessarily cover the Federal Government's Fiscal Year 1974-75, i.e. 1 March, 1974 to 30 April, 1975.

2. COMMITTEE ACTIVITIES.

During the calendar year 1974 the ICS met for five formal meetings. Early in the year full ICS endorsement was given to the MOSST-sponsored Memorandum on "A Space Policy for Canada" which was subsequently approved by Cabinet.

The logic of the approved space policy can be summarized in several short paragraphs:

To make effective use of space application systems Canada requires:

a) appropriate knowledge of space science and technology;

b) the ability to acquire and operate effective and economic systems; and

c) the ability to have space hardware, e.g. satellites, launched when required.

Canada could meet these prerequisites in many different ways ranging from complete foreign dependence to self sufficiency.

Over the years Canada has built up a joint government-industry capability to design and manufacture space systems as illustrated by the current Communication Technology Satellite (CTS) of DOC, and has depended on the U.S. for satellite launching services. From an examination of optional courses of action involving increasing levels of Canadian capability it is concluded that the best course of action for Canada to follow is to:

a) Maintain, improve and move out into industry the present joint government-industry capability to design and build space systems;

b) Continue dependence on foreign launch vehicles and services but enhance Canadian access to such launching services by participating in the supplying nation's space program in a meaningful way.

Implicit in this option is the requirement that not only should the government's capability to design and build satellites be moved out into industry but that the industrial capability be maintained by an enlightened policy of purchasing Canada's space research, development and production systems from Canadian industry supplemented by technological programs relevant and necessary to develop the capability to meet future operational system requirements.

Also implicit in this option is the need for effective coordination of Canada's space activities. This does not need the creation of a separate space agency, but can be adequately done by an interdepartmental committee supported by a small secretariat. The Interdepartmental Committee on Space with minor revisions in its terms of reference to reflect changes in Cabinet Committee and departmental structures which have taken place since it was created in 1969 could perform this function reporting to the Minister of State for Science and Technology.

The revised terms of reference for the ICS as approved by Cabinet, are attached as Annex I.

Later in the year the ICS decided to revise its sub-committee structure. The previous five sub-committees were reduced to three to deal with the areas of special interest, i.e. the International Aspects, the Industrial Aspects and the Scientific Research Aspects of Space Policy. The latter sub-committee will continue to act in a dual capacity since it also functions as the NRC Associate Committee on Space Research.

Terms of Reference for the new sub-committees had not been approved by the ICS at the time of publication of this report.

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 agencies and departments of the Federal Government as well as Canadian Universities and industry. A copy of the latest report, reference SRFB 090, dated January, 1975, is attached as Annex 4 for general information. Specific highlights of the Federal Government departmental activities are given in the following sections.

3.1 International Space Activities.

During 1974 Canada participated in the 17th Session of the UN Outer Space Committee and its various subordinate bodies. (For further details see Annex 4, page 71.). Canada continued to co-operate with the US in the development of remote sensing technology under the Canada-US ERS Agreement. Because the ERS Agreement is due to expire in May, 1975, Cabinet authority to renew the agreement was sought and obtained, and the American authorities were approached in late 1974.

In 1974 Canada continued to participate as an observer to the European Space Conference, at meetings of the ESC Committee of Alternates and the Working Group on United Nations matters.

Other international activities over the year include signing of the AEROSAT Agreement with the United States and ESRO for an international aeronautical communications experiment utilizing satellites, discussions between the National Research Council of Canada and US scientific agencies for a cooperative project in January, 1975 to study plasma characteristics in the vicinity of the solar cleft in the polar latitudes of the earth's magnetosphere, and informal technical discussions with French space scientists on a variety of subjects including remote sensing and communication satellites during the French Science and Technology Week in early October, 1974.

Canada, as in other years, participated in COSPAR and the ITU and Canadians participated in the International Astronautical and Space Institute Conference and its affiliated agencies.

3.2 Communications Technology Satellite (CTS).

The general objective of this project is to advance the state-of-the-art in spacecraft and related ground-based technologies relevant to future communications and other satellite application systems; in particular, to investigate the operation of a high-power repeater satellite to provide two-way

voice communications, FM broadcast and data transmission, and colour TV broadcasts for communities with low-cost ground terminals. Particular emphasis will be placed on communications to remote areas in Canada. A number of advanced technology developments will be demonstrated including a travelling Wave Tube having greater than 50% efficiency at a power output of 200 Watts at a frequency of 12 GHz. The use of high-power travelling wave tubes in the satellite, will enable the cost and size of ground terminals to be minimized.

The launching of CTS into geosynchronous orbit by means of a Delta 2914 Launch Vehicle is scheduled for late 1975.

In 1974, the Engineering Model spacecraft was integrated and thermal/vacuum testing successfully completed at NASA/Lewis Research Centre. Integration of the protoflight spacecraft began October, 1974 and several sub-systems were integrated before the end of the year. Preparations for mission operations were well advanced, including the design of software.

In accordance with the recommendations made by an independent Evaluation Committee, the Minister of Communications has accepted proposals from over 20 organizations for experiments to be carried out using the CTS. These experiments are concerned, not only with the technology of communications but with its applications in the fields of tele-medicine, tele-education and community interaction. They have been proposed by federal and provincial government departments and agencies, industry, universities and native associations.

Contracts have been awarded to Canadian industry for the procurement of earth stations and other equipments to be used in the communication experiments. The earth stations will include two transportable stations equipped with antennas 3 metres in diameter for the transmission and reception of sound and television programs, two-way and high speed data, network control and telephony and for time division multiple access experiments; eight stations fitted with antennas of 2 metres in diameter for reception of television, for two-way voice and experiments in sound broadcasting;

and a number of stations having antennas of one metre in diameter for experiments in two-way voice or sound broadcasting. Synchronization equipment is being constructed in Canadian industry for the testing of a system of time division multiple access, using satellites with spot-beam antennas.

3.3 UHF Multi-Purpose Satellite Communication System.

Work on the multi-purpose UHF satellite communications systems resulting from a strategic planning study completed in 1973 was carried forward as a potential system for meeting military and civil government requirements for low capacity telephone, data and fascimile services to highly portable and mobile ground stations. Complementary services which could also be included are read-out of data from remote environmental monitoring stations and monitoring of emergency radio beacons. In May 1974, an Interdepartmental Senior Steering Committee was formed to provide policy guidance and it directed that the requirements of government users be investigated. This was carried out through a feasibility study in which major user departments co-operated fully in the definition of their potential needs. The study concluded that there was a substantial government requirement for UHF satellite communications services and that it is technically feasible to meet this requirement. Assuming that the DND participation is large enough, the shared costs may be acceptable to other users and would ensure its financial feasibility.

In December, the Senior Steering Committee recommended that the project be carried forward to the definition phase by an interdepartmental team in order to develop full cost information and a proposal for a Project Definition Phase. This will in turn allow user departments to confirm their intent to use the system as well as the drafting of appropriate submissions to gain authority to proceed with implementation. An offer by Telesat Canada, to provide a parallel proposal, was accepted.

3.4 DOC Communications Experiments.

a) Microwave Propagation along Satellite-Earth Paths.

During 1973 and 1974, radiometers operating at

13 GHz were installed at seven locations across Canada as part of a program to measure the effects of precipitation attenuation on satellite communications. Measurements obtained in 1974 are being analyzed.

Trans-horizon propagation data which have been obtained at 15.7 GHz over a 500 km. path are being analyzed to separate the various propagation mechanisms, such as turbulent and particulate scatter, and to relate these data to the interference between terrestrial and space communication systems using the same frequency bands.

Measurements of fading and coherent bandwidth at low elevation angles in the high arctic were obtained at 4 and 6 GHz using transmissions via an ANIK satellite. The measurements are being analyzed to obtain distributions of path attenuation, fading rate, coherent bandwidth, and correlation between up-link and down-link fading.

b) Small Terminal Satellite Communications.

Through in-house R&D and industrial development contracts, several sub-systems relating to small terminal satellite and mobile communications are being developed for delivery in February and March of 1975. It is expected that these sub-systems will result in competitively priced small terminal satellite stations which could be of use in Aerosat, Telesat, Marisat and the proposed UHF satellite.

3.5 International Aeronautical Satellite (AEROSAT).

During 1974 the Ministry of Transport and Department of Communications in cooperation with other Departments, continued activity toward further definitions of AEROSAT system requirements and resolution of international matters relating to the development of such a satellite. On August 2, 1974, a "Memorandum of Understanding on a Joint Program of Experimentation and Evaluation Using Aeronautical Satellite Capabilities" was signed by representatives of Canada, USA and ESRO. On December 2, 1974 an "Arrangement to Establish an Aeronautical Space Segment Capability" was signed by

Canada, ESRO and Comsat General Corporation. The First Aerosat Council Meeting was held in Washington, December 3 and 4, 1974.

Throughout 1974 the Ministry of Transport and the Communications Research Centre of the Department of Communications have conducted an experimental program using the ATS-6 spacecraft, and a Ministry of Transport Jetstar with a Canadian developed high gain linear phased array antenna. The work will continue in 1975 and will provide information useful in the AEROSAT experimental program.

An important element of the program from the Canadian standpoint is the placing of space segment contracts with Canadian industry to the extent of 6% of the contracts placed by the Space Program Office. To this end, joint Department of Communications/ Department of Industry, Trade and Commerce discussions have taken place with potential space segment prime contractors in the US and with leading Canadian space industries.

3.6 Remote Sensing.

During 1974, several major policy decisions were reached concerning the national remote sensing program of the Canada Centre for Remote Sensing. First, Cabinet approval was obtained to initiate negotiations with NASA for the renewal of the ERTS agreement and negotiations are now underway. A Canadian company, MacDonald Dettwiler and Associates of Vancouver was awarded a contract to build a semi-mobile satellite receiving station to be located in Pouch Cove, Newfoundland. This station will provide coverage of that part of the Maritime provinces situated beyond the range of the Prince Albert station, and will make it possible to provide Canadian users with timely remote sensed data including oceanographic and ice information of value to maritime transportation and exploration activity on the East Coast.

Finally, preliminary discussions were initiated with NASA regarding possible Canadian participation in the US programs relating to the Heat Capacity Mapping

Mission (HCMM) satellite which will be potentially useful for snow, ice and soil moisture studies, as well as SEASAT, an all-weather ocean monitoring satellite which is of potential benefit to Canadian maritime activities.

3.7 International Maritime Satellite (INMARSAT)

During 1974 the Ministry of Transport and the Department of Communications have participated in the work of the Panel of Experts on Maritime Satellites, established under the aegis of the Inter-Government Maritime Consultative Organization (IMCO). The Panel of Experts produced a report on the Establishment of a Maritime Satellite System for consideration at a Conference of Governments planned for April 1975.

3.8 Meteorological Satellites.

The Satellite Data Laboratory of the Atmospheric Environment Service (AES) of DOE continued to acquire and distribute imagery directly from the Automatic Picture Transmission (APT) mode from orbiting US meteorological satellites. Routine daily receptions in 1974 originated from ESSA-8, NOAA-2, NOAA-3 and NOAA-4. The data was archived on magnetic tape. Approximately 30,000 copies of the images were distributed to government and private agencies. APT receiving stations at Halifax and Vancouver continued to acquire satellite data for operational use. Equipment has been purchased to acquire the Very High Resolution Radio-meter (VHRR) data from NOAA spacecraft.

3.9 Shuttle Attached Remote Manipulator System.

As part of an expansion of Canada's space policy, announced in July, 1974, the National Aeronautical Establishment has been conducting negotiations with NASA to explore possible Canadian participation in the United States Space Shuttle program. Discussions have centred upon the Shuttle Attached Remote Manipulator System (RMS), suitable for the handling of shuttle payload. The RMS will be installed in the Shuttle payload bay and will be operated from the Shuttle crew compartment. With the aid of special guideways and payload retention devices installed in the orbiter,

the RMS will be capable of performing several operations, such as (a) removing the payload from the cargo bay and deploying it in a stabilized condition, (b) attaching itself to a stabilized payload in the retrieval zone and moving the payload into its position in the cargo bay, and (c) removing a crewman from the area of the side access door or the airlock door of a disabled orbiter and transferring that crewman to a rescue orbiter.

NASA has recently conducted a technical evaluation of Canada's capabilities of carrying out the necessary research and development for producing the manipulator. Negotiations on a Memorandum of Understanding between the National Research Council of Canada and NASA for a cooperative program are now underway and it is hoped that they will be successfully concluded by March, 1975. It is intended to procure all the necessary RMS research, development and production from a suitable composed team of Canadian industrial companies.

3.10 National Defence.

During 1974, a statement of DND Policy for Space was approved as a basis for departmental planning of future space activities. This policy reaffirms DND's commitment to the principles of the approved Canadian Space Policy. Within DND the Inter-Group Advisory Committee on Space is the body responsible for the coordination of the department's space-related activities and is chaired by the Director General Capabilities Planning (DG Cap P).

The Canadian Forces contribute to the NORAD Space Detection and Tracking System (SPADATS) by operating a Baker-Nunn camera facility in Canada. The Forces also are potential users of earth-oriented space systems for communications, navigation, search and rescue and surveillance and annually invest in programs to define requirements through the Canadian Forces Development Program.

3.11 NRC Space Research.

In support of NRC and NRC-sponsored programs of basic and exploratory research, the Space Research

Facilities Branch (SRFB) provides service to Canadian scientists engaged in upper atmosphere and space research using sounding rockets, balloons and ground-based instruments. The principal permanent facility operated by SRFB is the Churchill Research Range (CRR), located near the town of Churchill, Manitoba on the shore of Hudson Bay. Because of recent scientific interest in the Magnetospheric Dayside Cusp phenomenon, which occurs in the polar regions of Canada, SRFB established a temporary rocket launching site at the Dew Line station at Cape Parry, NWT.

During 1974, 9 Black Brant rockets, sponsored by the National Research Council of Canada, carried 84 experiments to heights ranging from 60 to 70 km to make measurements under quiet and disturbed conditions. With the exception of two vehicles from Cape Parry, Northwest Territories, 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 1974. During this program, 26 balloons were launched from four sites carrying experiments from four US and two Canadian universities, the US Goddard Space Flight Centre and the Canadian Atmospheric Environment Service. Other Canadian agencies and ground stations participated in this program.

During 1974, the Division of Physics continued with auroral particle studies employing experiments flown in two sounding rockets, magnetospheric studies based on data from particle detectors on the ISIS satellites, and cosmic ray studies based on data from the cosmic ray monitor stations at Deep River, Alert, Inuvik, Goose Bay and Ottawa.

During 1974, the Upper Atmosphere Research Section carried out auroral spectra and emission studies, radio aurora studies of the relationship between radio aurora, visual aurora and magnetospheric-ionospheric current flows, meteorite entry studies and cosmic dust studies employing balloon borne micro-meteoroid collecting equipment. In addition, auroral plasma measurements were made with electrostatic

probes carried on four rockets flown from Churchill and two from Cape Parry, and routine observation of meteors was continued at the Springhill Meteor Observatory and at Shiels Meteor Station.

The Radio Astronomy Section carried out daily measurements of the intensity of the 10.7 cm radio flux from the sun and any unusual variations in this intensity at the Algonquin Radio Observatory, Lake Traverse, Ontario and continued to use the 10 inch aperture photoheliograph at the Ottawa River Solar Observatory 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.

In the field of Aerothermodynamics the co-operation with NASA continued on the wind tunnel studies of dynamic stability of aircraft at high angles of attack. This research program is of interest for the re-entry flight of the shuttle orbiter.

3.12 Canadian Industrial Capability.

The Department of Industry, Trade and Commerce continued during 1974 its support of the Canadian space industry. Some highlights follow.

a) Search and Rescue Satellite (SARSAT)

The Department continued to promote a joint project with the US Navy under which Canadian industry would develop and provide electronic packages for an experimental evaluation of the Global Rescue Alarm Net (GRAN) concept. (GRAN would involve the retransmission via a geostationary UHF satellite of the Omega signals received at a crash site.) During the year, Leigh Instruments Ltd. completed a theoretical study under DITC contract on the applicability of the GRAN concept to search and rescue in the Canadian environment. It was concluded that additional satellites in inclined orbits would be required to eliminate the gaps in coverage at high latitudes and in mountainous

terrain which otherwise would prevail. In particular a system of two satellites in a polar, 24-hour elliptical orbit, with the two satellites spaced 12 hours apart, appeared to offer considerable promise.

b) Design, Development and Manufacture of Future Communication Satellites.

An AIAC-sponsored, DITC funded study by a Canadian industrial team on the extent to which Canadian industry could provide the next-generation Canadian communication satellites continued through 1974. It is scheduled to be completed by the end of the first quarter of 1975. The team defined a "typical" next-generation communication satellite, its system, sub-system and component specifications and the specifications for test and support equipment. It then conducted surveys of the industry in terms of these requirements. As part of the study, an evaluation is being made of the benefit/cost for various degrees of upgrading of capability.

c) TDMA developments.

The Department's continued efforts toward the development of a Time Division Multiple Access capability in Canadian industry began in 1973. Three Canadian users are purchasing this type of equipment: Telesat is using American equipment, CRC will be using Canadian Marconi equipment, while COTC is currently evaluating bids. However, because of COTC's international tender, no Canadian company bid a Canadian system because of the competition expected from the USA and Japanese suppliers who had already developed systems using outside funding. Although three of the first four systems will be used in Canada, it does not appear that Canadian industry will be active in the future in this technology.

d) Earth Resource satellite ground stations.

The Department supported the export market activities of Canadian companies through the Program for Export Market Development. With this assistance, Computing Devices of Canada won a contract for the Italian requirements.

e) Aerosat

DITC is providing funding for the development of avionics equipment and is cooperating with DOC and MOT in attempting to maximize the Canadian industrial input to the space and ground segment.

f) Special Purpose Manipulator System (SPMS)

Spar Aerospace has constructed a development model of the Special Purpose Manipulator System for the Space Shuttle. The system has undergone compatibility testing with an Earth Observation Satellite at NASA Goddard. Together with Rockwell International Flight Support System, it is now being installed in the full scale Shuttle mock-up at Rockwell's Downey plant for mission simulation tests. Work is shortly to commence on the design and construction of the end effector to enable various module sizes to be handled. The costs of these projects are being shared equally by DITC and Spar Aerospace.

g) Meteorological rocket development.

Bristol Aerospace is participating in a joint development program with the US Army Missile Command to develop a 250,000 foot altitude meteorological rocket. Successful firings of pre-production models have been made at White Sands Missile Range, New Mexico, and the NASA range at Wallops Island, Virginia.

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 2, and are summarized in the following table:

SUMMARY STATEMENT OF FEDERAL GOVERNMENT EXPENDITURES ON SPACE ACTIVITIES FOR FISCAL YEAR 1974-75 AND 1975-76 (FORECAST) ($1000's)

	1974-75	1975-76
DOC	21,905	16,453
EM&R	3,904	4,617
DOE	575	700
NRC	4,600	9,115
DND/DRB	1,437	1,407
IT&C	2,206	1,487
MOT	336	807
TOTAL	34,963	34,586

From the above table it can be seen that total expenditures for space activities are estimated to decline by approximately $400 thousand in Fiscal Year 1975-76. It should be noted that this approximately stable situation results from a major increase in expenditure by NRC for the Shuttle Manipulator System which largely makes up for a sharp drop in planned expenditures by DOC. The manipulator project is still subject, however, to successful completion of negotiations with NASA on a Memorandum of Understanding as well as to the granting of specific Treasury Board approval.

5. COMMITTEE MEMBERSHIP AND TERMS OF REFERENCE.

The membership of the ICS for the year 1974 is given in the attached ANNEX 3, and the terms of reference in ANNEX I.

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 departments on policy matters, and representing:

   Department of Communications
   Department of Energy, Mines & Resources
   Department of the Environment
   Department of External Affairs
   Department of Industry, Trade & Commerce
   Ministry of Transport
   Ministry of State for Science and Technology
   Department of National Defence
   National Research Council.

2. Observer status shall be accorded to representatives of:

   Treasury Board Secretariat
   Department of National Health and Welfare (Health)

3. A Secretariat for the Committee shall be provided by the Ministry of State for Science and Technology.

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 Minister of State for Science and Technology.

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 on 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 concerning cooperation in the space activities of foreign and international entities in the best interest of Canada.

4. To report annually on February 1st, or more often if desirable, to the Minister of State for Science and Technology.

Approved April 9, 1974.

ANNEX 2
TO THE SIXTH ANNUAL
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FEDERAL GOVERNMENT EXPENDITURES ON SPACE ACTIVITIES FOR FISCAL YEAR 1974-75 AND 1975-76 (FORECAST)

DEPARTMENT		x $1000's 1974-75	1975-76
1.	Department of Communications.		
I	Spacecraft Technology and Satellite Operations.	16,547 (1)	7,304 (3)
II	Satellite Communications System.	5,203 (2)	8,994 (4)
III	Scientific Research Utilizing Satellites and Rockets.	155	155
		21,905 (5)	16,453 (6)

NOTES:

(1) 7 Recoverables from DND not included.

(2) 55 Recoverables from DND and industry not included.

(3) 7 Recoverables from DND not included.

(4) 263 Recoverables from DND not included.

(5) An estimated 15,936 have been contracted to industry.

(6) An estimated 8,637 will be contracted to industry.

2.	Department of Energy, Mines & Resources.		
	Canada Centre for Remote Sensing.		
	Administration of Program	663	909
	Spaceborne Remote Sensing	2,495	2,990
	Integrated Applications	746	718
		3,904 (1)	4,617 (1)

NOTE:

(1) Aircraft Remote Sensing expenditures of $2,347 for 1974-75 and $2,448 for 1975-76 are not included in these totals.

DEPARTMENT	x $1000's 1974-75	1975-76
3. Department of Environment		
Space Expenditure	575	700
4. National Research Council.		
Space Research Facilities Branch.	2,750 (1)	2,800 (1)
Physics - Cosmic Ray and High Energy Particles.	250	275
Radio - Upper Atmospheric Research	150	165
Grants to Canadian Universities	750	825
NAE	50	50
Shuttle Attached Remote Manipulator System.	650	5,000 (2)
	4,600	9,115

NOTES:

(1) Includes 500 recoverable from USA

(2) Subject to specific T.B. approval.

5. Department of National Defence.		
Chief of Research and Development (CRAD) Intramural Program.	573 (1)	591
CRAD Defence Industrial Research	33.8	3.8
Chairman of the Defence Research Board (CDRB) University Grants	168.2	121
Canadian Forces Development Program	360	345
Canadian Forces NORAD/SPADATS	302.2	346
	1,437.2	1,406.8

NOTE:

(1) Transfer of 20 from DOC for battery research is not included

DEPARTMENT		x $1000's 1974-75	1975-76
6.	Department of Industry, Trade & Commerce.		
I.	Earth Stations (DIP)	400	400
II	Satellite Transponders (DIP/DEV)	500	540
III	Satellite Navigation (DIP)	236	147
IV	Aerosat Antenna (DIP)	100	150
V	Satellite Communications (DIP/IMDE)	565	-
VI	Rocket Development (DIP)	50	100
VII	Space Manipulators (DIP)	235 (1)	150
VIII	SARSAT Study	20	-
IX	AIAC Study	100	-
		2,206	1,487

NOTE:

(1) Includes expenditures from September 1, 1972.

7.	Ministry of Transport.		
	Aerosat Program	161	607
	Applications Technology Satellite Studies	175	100
	Maritime Satellite Studies	-	100
		336	807

ANNEX 3
TO THE SIXTH ANNUAL
REPORT OF THE ICS

INTERDEPARTMENTAL COMMITTEE ON SPACE

1974 MEMBERSHIP

Dr. J. H. Chapman (Chairman)	- Department of Communications
Mr. D. Armstrong Alternate - Mr.E.F.Porter	- 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. L. Bourgault Alternate - Dr.D.I.R.Low	- Ministry of State for Science & Technology
Mr. N. Haffey	- External Affairs
Dr. M. C. B. Hotz	- Department of Environment
Mr. I. S. McLeish (Secretary)	- Ministry of State for Science and Technology.

1974 SUB-COMMITTEES

International Aspects of Space Policy.

Mr. N. Haffey (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

ANNEX 4
TO THE SIXTH ANNUAL
REPORT OF THE ICS

SRFB 090

SPACE AND UPPER ATMOSPHERE PROGRAMS IN CANADA

1974

A SUMMARY PREPARED BY

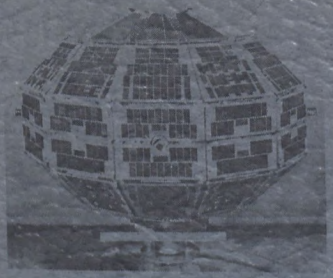
WILLIAM H. WATERS

SPACE RESEARCH FACILITIES BRANCH

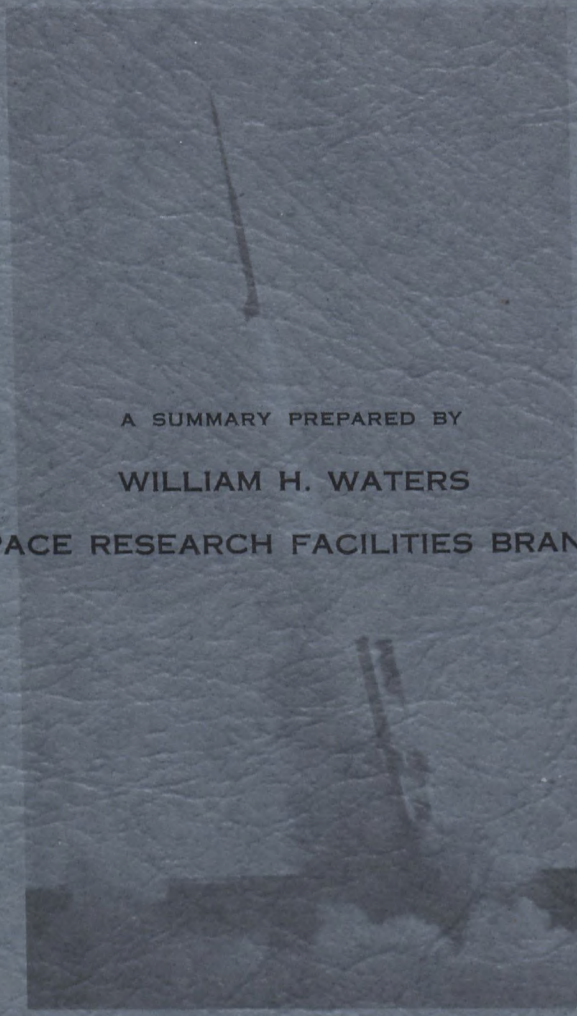
NATIONAL RESEARCH COUNCIL OF CANADA

JANUARY 1975

SRFB 090



Space And Upper Atmosphere Programs In Canada 1974

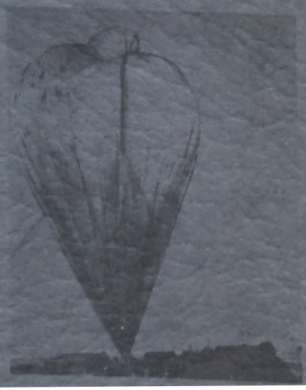


A SUMMARY PREPARED BY

WILLIAM H. WATERS

SPACE RESEARCH FACILITIES BRANCH

JANUARY 1975



National Research Council Canada

Conseil national de recherches Canada

SPACE AND UPPER ATMOSPHERE PROGRAMS IN CANADA

1974

A Summary Prepared By

WILLIAM H. WATERS

SPACE RESEARCH FACILITIES BRANCH

NATIONAL RESEARCH COUNCIL OF CANADA

JANUARY 1975

FOREWORD

This is the seventh annual edition of this report. The information it contains is brought up to date in December of each year.

The report contains material contributed by Canadian organizations and agencies which are involved in space and upper atmosphere programs. 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.

Correspondence about this report should be addressed to the Space Research Facilities Branch, National Research Council of Canada, Ottawa, Ontario, K1A 0R6.

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TABLES

INTRODUCTION

Canada has had an active upper atmosphere research program particularly since the International Geophysical Year (1957) when sounding rockets were first used for scientific experiments. However ground-based studies of the aurora had taken place as early as 1867 and balloons had been used in upper atmosphere research since the start of this century.

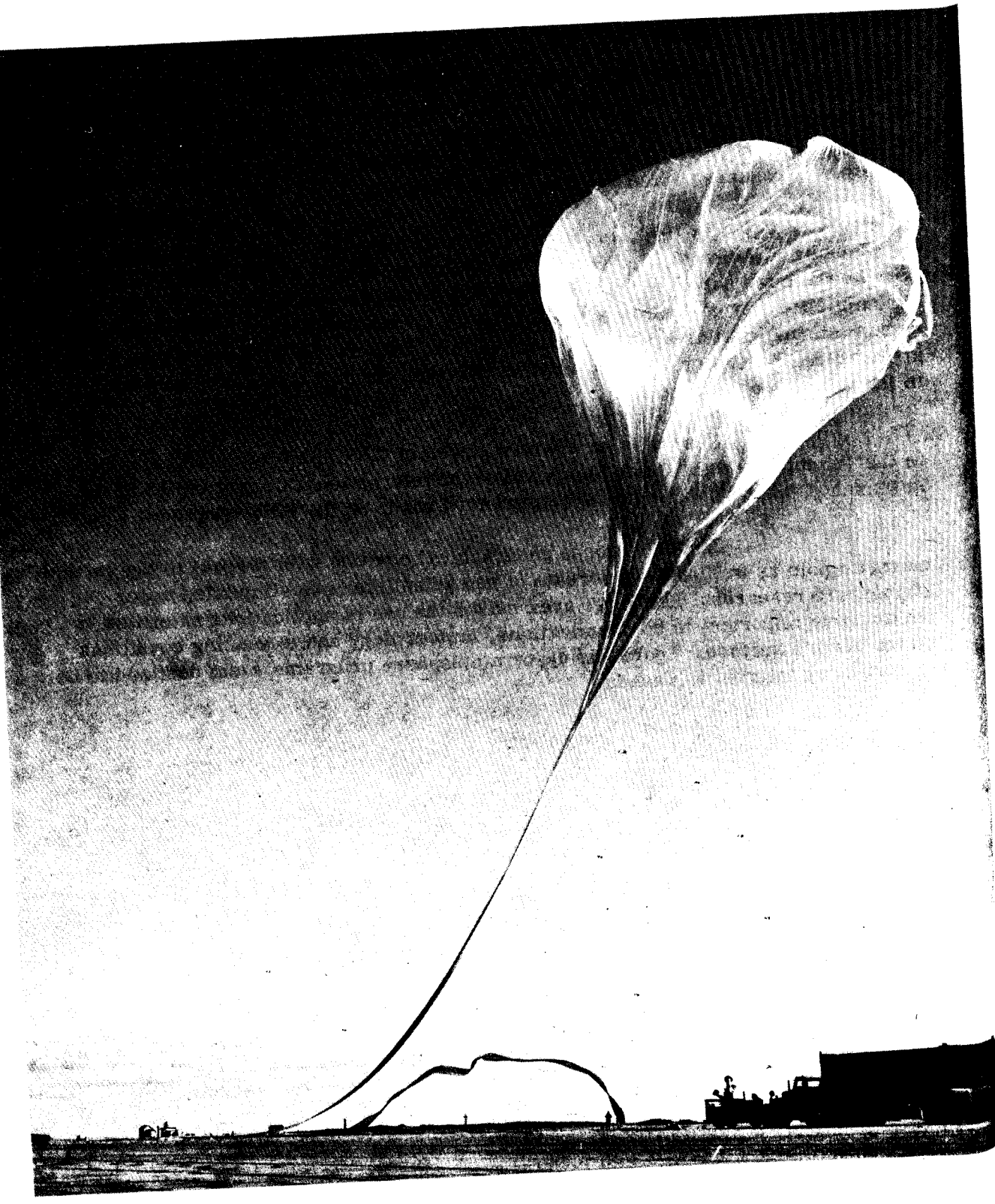
In 1958, research using satellites was initiated in Canada with the planning of Alouette I. When that satellite was placed in orbit in 1962, Canada became the third nation to build and to operate its own space vehicle. This was accomplished in a co-operative program with the United States. The continuation of this international co-operation resulted in additional research and space applications, activities which now affect the daily lives of Canadians, especially in the field of communications.

Canada is an active member of the United Nations Committee on the Peaceful Uses of Outer Space and of the International Committee on Space Research (COSPAR). The COTC represents Canada on the ICSC*(Intelsat).

Canada's unique geographical position with respect to the earth's magnetic pole as well as the interests of her scientists have stimulated upper atmosphere research. Her large area makes the use of applications satellites particularly important in communications, meteorology and in sensing conditions on the earth's surface. Space and upper atmosphere programs seem destined to be of continuing interest to Canada.

* International Communications Satellite Consortium

INFLATING A BALOON 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 aneroid-bimetallic devices for recording pressures and temperatures on small glass plates. 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 were 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, balloon flights have been instituted by the Universities of Calgary and Saskatchewan. Flights have been carried out at Cold Lake, Alberta, Waldheim and Battleford, 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 participated in this program in 1974.

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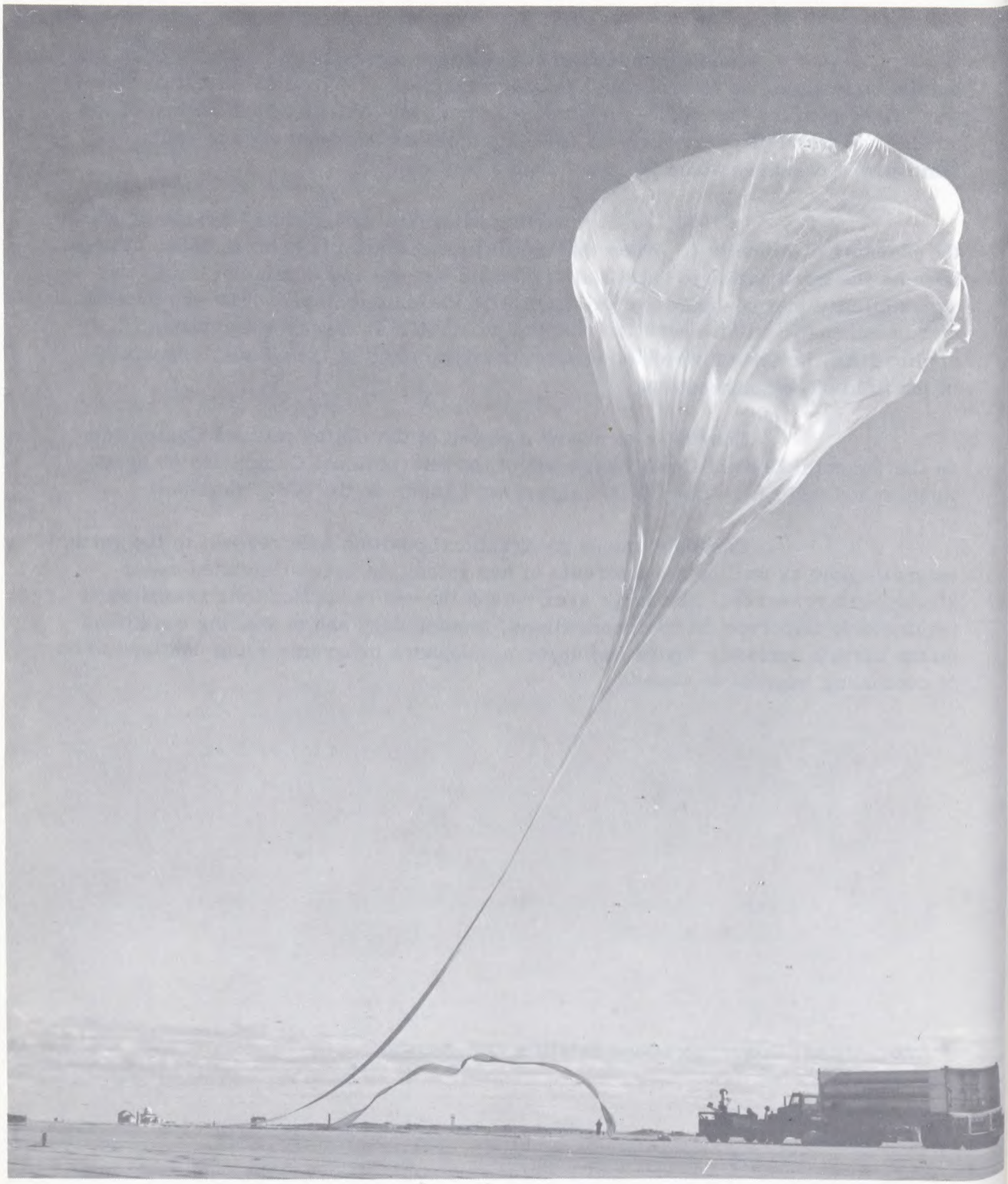

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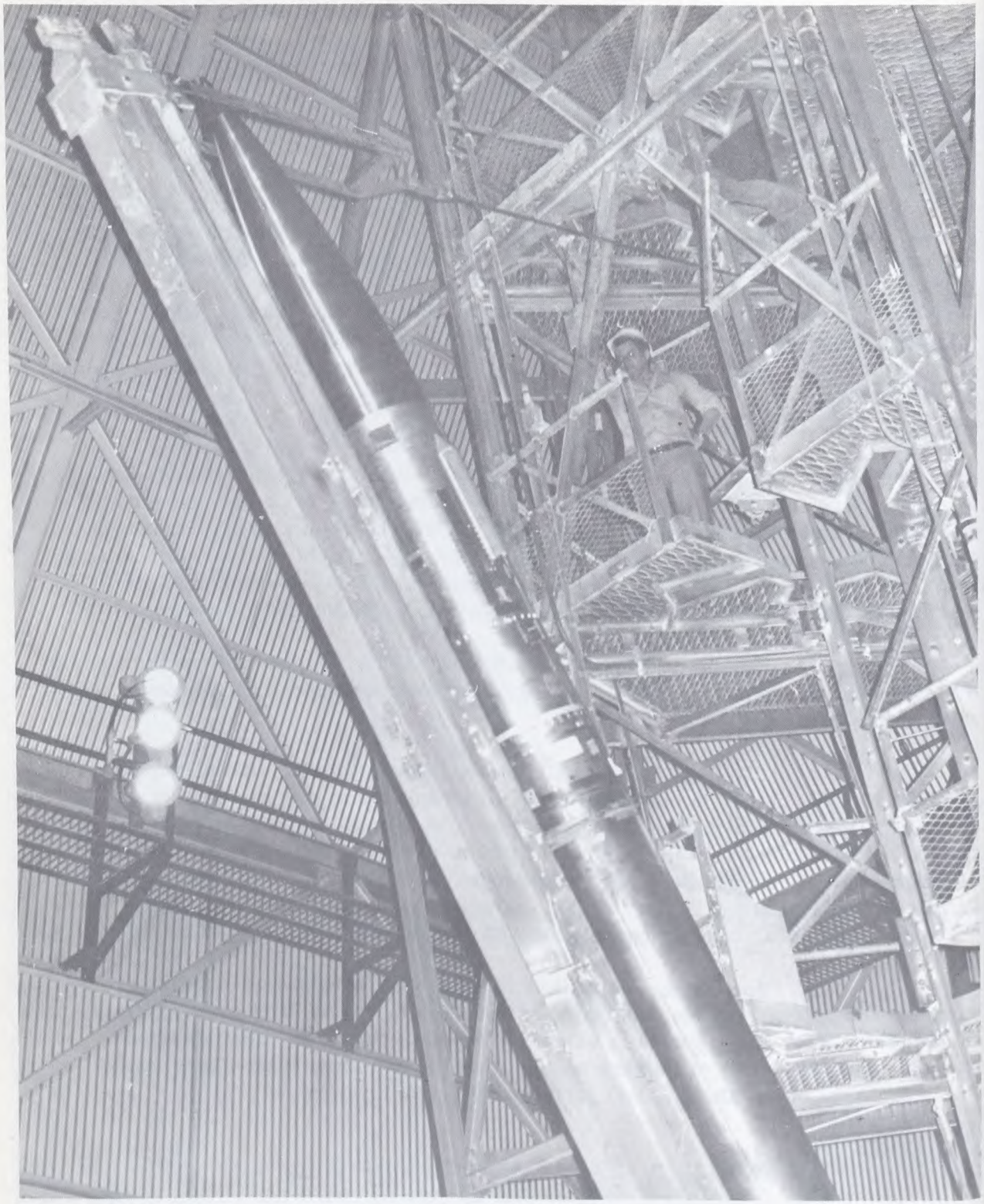
BLACK BRANT VB ROCKET BEING ELEVATED PRIOR TO LAUNCH



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.

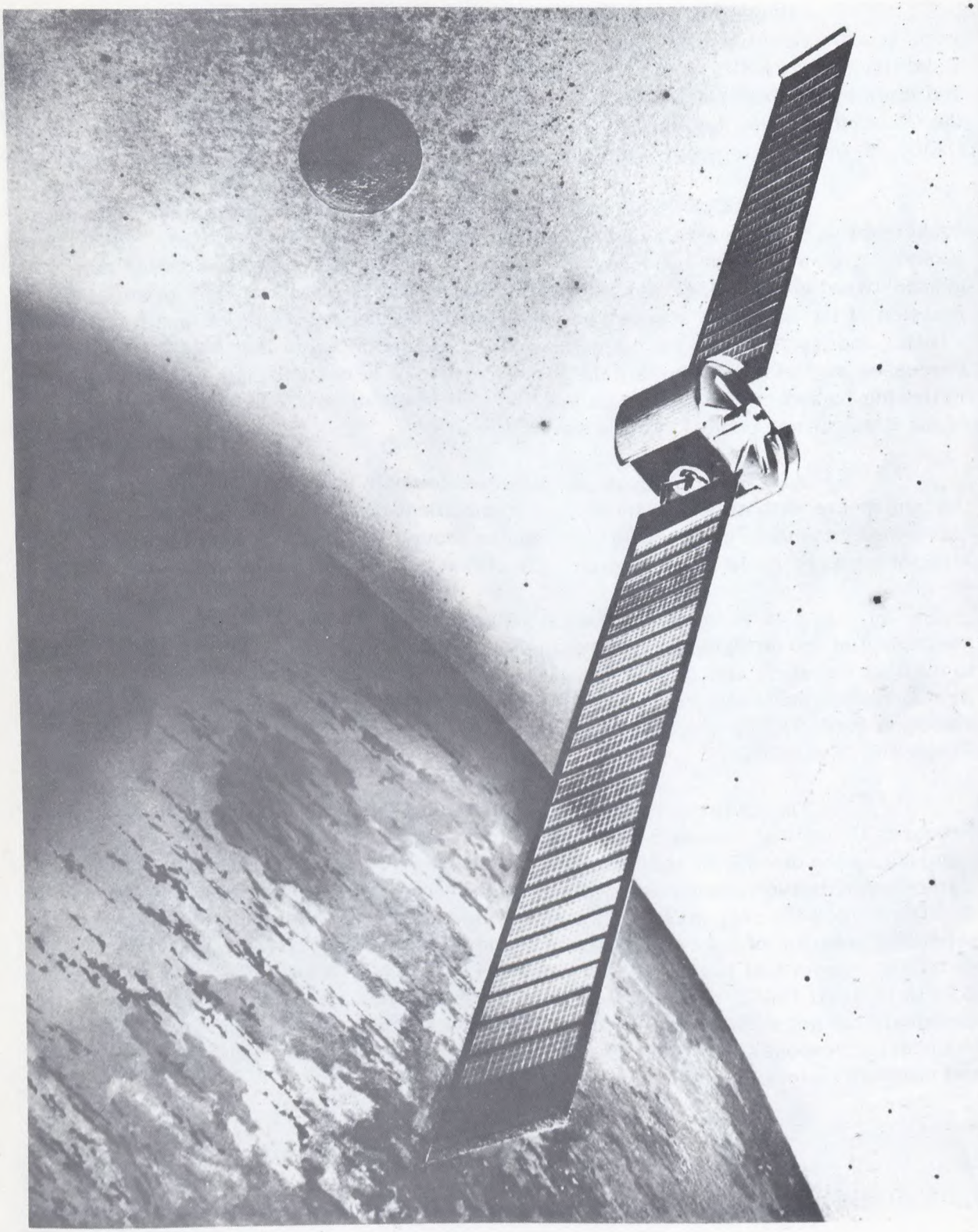
At DREV, direct high-altitude measurements began in 1957-1958 with rocket-borne measurements of the sodium airglow and hydroxyl profiles. More recent rocket flights were used to release nitric oxide into the atmosphere in order that ground-based observations of the resulting luminescence could be used 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, the 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.

ARTIST'S CONCEPT OF THE COMMUNICATION TECHNOLOGY 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 1973 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. ANIK III is scheduled for launch early in 1975.

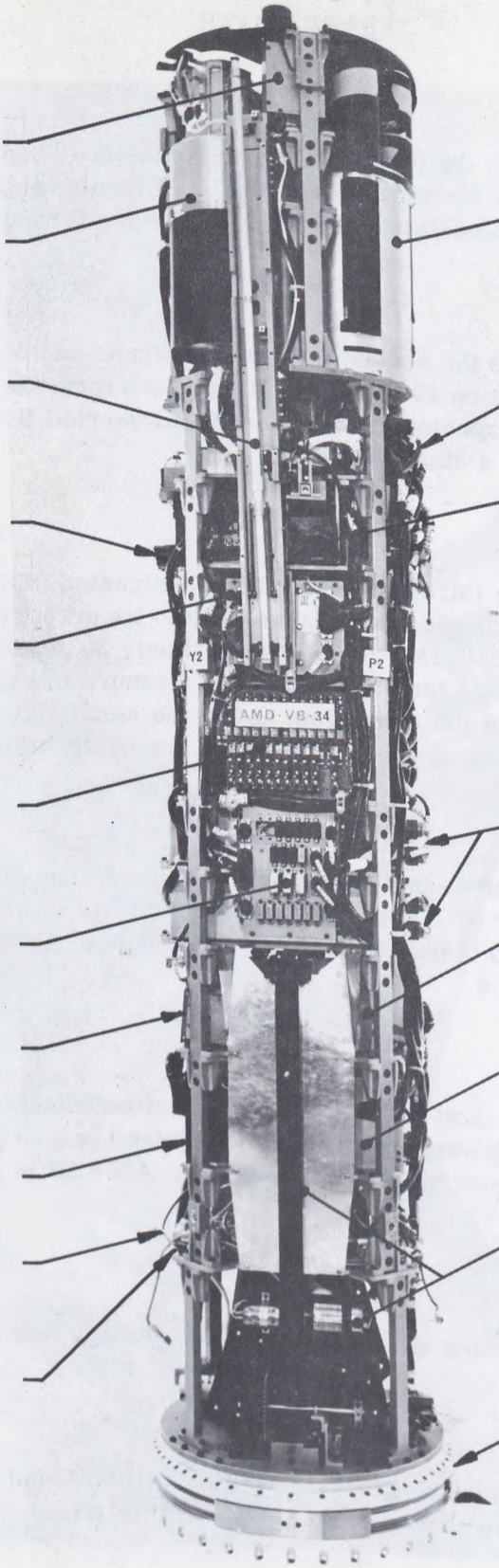
CTS

The launching of this Canadian Technology Satellite is scheduled for late in 1975.

Further Details

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

AMD-VB-34 PAYLOAD



EXPERIMENT #13
PHOTOMETER

EXPERIMENT #6
SPECTROMETER

EXPERIMENT #11
RECEIVER

EXPERIMENT #5
PHOTOMETER

DC/DC CONVERTERS

REGULATOR CARDS

RELAY BOX

EXPERIMENT #9
SPECTROMETER

ENCODER-PCM

RAM SENSORS

BEACON AND
TELEMETRY ANTENNA

EXPERIMENTS #1 & 2
PHOTOMETERS

PATCH BOX

EXPERIMENT #12
PHOTOMETER

BATTERY PACKS

COMMUTATOR

BUFFER COMPLEX

EXPERIMENTS #3 & 4
BOOMS

SED DESPIN UNIT

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 have been 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. Additional flights of the recently developed Black Brant VI were carried out successfully. This rocket can lift payloads with gross weights between 5 and 12 kgs to altitudes ranging from 84 to 61 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 coordinating 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.

Many ground based experiments have been conducted in association with those carried in rockets, either at the launch site, or located some distance away. Examples include launches from Churchill Research Range with measurements from Saskatoon, Saskatchewan and Gillam, Manitoba and from East Quoddy during recent eclipses of the sun with measurements at Ottawa and the launch site.

Ground based experiments have been carried out by the universities of Alberta and Saskatchewan, the Department of Communications,

Energy Mines and Resources and the National Research Council of Canada.

By December 1974 the National Research Council of Canada had participated in 142 rocket launchings which carried aloft 990 different experiments. Twenty-four of these rockets carried experiments from the United States, Sweden, the Federal Republic of Germany, Czechoslovakia, the United Kingdom, Belgium, and Japan in addition to the Canadian experiments. By the end of 1974, Canada had launched more than 210 scientific sounding rockets.

UPPER ATMOSPHERIC ROCKET AND BALLOON RESEARCH IN 1974

Up to January 1974 the Space Research Facilities Branch had arranged for 114 scientific rocket launchings. These vehicles carried a total of 676 experiments from the National Research Council of Canada, the Communications Research Centre of the Department of Communications, Atmospheric Environment Services and the Universities of British Columbia, Calgary, Saskatchewan, Western Ontario, Toronto, York, Montreal and Simon Fraser. In addition, 28 experiments from 7 other countries were included in 22 of these vehicles.

During 1974, 9 Black Brant rockets sponsored by the National Research Council of Canada, carried 84 experiments to heights ranging from 60 to 700 km to make measurements under quiet and disturbed conditions. With the exception of two vehicles from Cape Parry, Northwest Territories, 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 1974. During this program, 26 balloons were launched from four sites carrying experiments from four U.S. and two Canadian universities, the U.S. Goddard Space Flight Center and the Canadian Atmospheric Environment Service. Other 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, dust collectors, 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.

Communicationa 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 and spectrophotometer 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 oxygen atom probes and resonance absorption 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, micrometeoroid detectors, OH dayglow instruments, barium cloud, ozone measuring instruments (above 55 km), solar X-ray, Lyman alpha, spectrometer, photometer and electron temperature probe experiments were carried in 24 of the above rockets for the United States, Sweden, Federal Republic of Germany, Czechoslovakia, the United Kingdom, Belgium and Japan. Some of these experiments were ejected from rockets during flights, while others remained with the parent vehicles.

ACTIVITIES IN UNIVERSITIES

THE UNIVERSITY OF ALBERTA

Institute of Earth and Planetary Physics

During the past year the space physics group has continued its studies of solar-terrestrial interactions. An extensive field season was undertaken under the supervision of D. D. Wallis and in conjunction with the geomagnetism field program directed by D. I. Gough. An array of five magnetic observatories was set up during the summer and early fall in a cross configuration centered on Fort Smith where an allsky camera was also operated. The data from this field season will be used to carry out detailed studies of the westward travelling surge and the behaviour of the westward electrojet in the morning sector, as well as in the study of the degree of longitudinal asymmetry of the region of pc 5 micropulsation activity. After October 1974, the group will continue to operate observatories at Fort Smith and Inuvik, while the primary activity will center around analysis of data from the meridian line and cross configurations.

G. Rostoker is now concentrating a large portion of his research effort in collaborative efforts with researchers from other groups involved in similar research projects. The major result of his research centers around the character of field-aligned current flow in the region of the auroral oval. In collaboration with J. C. Armstrong (APL, Johns Hopkins Univ.) and S.-I Akasofu (Univ. of Alaska) he has shown that it is extremely important to know the position of high altitude satellites with respect to the disturbed region of the upper atmosphere in order to correctly interpret the in situ data. In particular, a satellite within 100 km of a westward surge regime will observe an entirely different signature during a substorm than one on a field line which maps into the surge or into the westward electrojet to the east of the surge. Dr. Rostoker has further recently shown, in collaboration with J. C. Armstrong and A. J. Zmuda (APL, Johns Hopkins Univ) that a high altitude polar orbiting satellite crossing the substorm westward electrojet in the evening sector before crossing the gross eastward convection electrojet will detect first a morning sector magnetic signature followed by the typical evening sector signature. Their results strongly suggest that the electric field which drives the substorm westward electrojet in the evening sector does not arise as a consequence of the substorm, and that the substorm electrojet exists primarily as a consequence of the enhanced ionospheric conductivity.

In a recently completed study with R. D. Sharp and E. G. Shelley (Lockheed Palo Alto Research Laboratory), Dr. Rostoker has found that it is possible to synthesize the variations in current intensity in the region of the substorm electrojet equatorward of the poleward border using information on the trapped particle fluxes at synchronous orbit and assuming the convection electric

field in the heart of the electrojet region to stay relatively constant. This result suggests that, over a large portion of the westward electrojet, current intensity variations are associated primarily with variations in ionospheric conductivity during substorm disturbances.

Together with R. Boström (The Royal Institute of Technology, Stockholm), Dr. Rostoker has developed a theoretical model for the generation of Birkeland current flow observed across the auroral oval by high altitude polar orbiting satellites. They find that the closure of the sheet currents may be effected in the magnetotail through the slowing of plasma sheet particles as they convect towards the flanks of the magnetotail. Thus, inertial forces may play an important role in the energy transfer process within the magnetotail.

D. D. Wallis and G. Rostoker, in collaboration with C. D. Anger (Univ. of Calgary), have completed a study of the relationship of the diffuse auroral oval as defined by the ISIS II satellite green line photometer to the auroral electrojets. They find that the electrojets, as defined by the modelled current intensities obtained from the ground based magnetic data, are always contained within the region of diffuse auroral glow.

J. V. Olson and G. Rostoker have continued their studies of pi 2 micropulsation activity using data from the meridian line of stations. They have found that, within the latitudinal regime of the substorm electrojet, the entire pi 2 spectral band contains significant power. Contained within this spectral band are one or more dominant narrow band signals which dominate the spectrum equatorward of the auroral electrojet. The frequency of these dominant signals do not appear to change over the lifetime of the substorm. The polarization of pi 2 pulsations across the electrojet is quite ill defined due to the contamination of the frequency spectrum by irregular variations in electrojet strength. It is considered that reliable estimates of signal polarization in the electrojet regime are unobtainable given existing analytical techniques.

Studies of the eastward and westward auroral electrojets are continuing, with the aim of studying the character of thermal plasma density variations in the topside ionosphere across the electrojet regime using topside sounder data from the ISIS II satellite. This work, commenced by M. Hron and G. Rostoker and now being carried out by R. P. Sharma and Dr. Rostoker, is part of the ongoing effort to calibrate ground based magnetic observations against in situ measurements made by various satellite detectors.

Three doctoral research programs are presently underway within the space physics group.

R. G. Wiens is continuing his studies of the stepwise development of the substorm westward electrojet. He is presently relating the behaviour of the westward travelling surge to the observed character of the

electrojet motion, and is also investigating the behaviour of the substorm electrojet development to the east of the expansion phase sector. He is developing modelling routines which will eventually permit one to synthesize evening sector magnetograms characteristic of substorm disturbed conditions.

T. J. Huges has commenced studies of the westward electrojet in the morning sector. He will investigate the variations of this electrojet during substorm and non-substorm disturbed conditions, and will use energetic particle data from the ATS 5 synchronous satellite in conjunction with the ground based magnetic data to investigate the physics behind the generation and characteristic behaviour of the westward jet.

H. Lam is continuing his study of the possible mechanisms for the generation of pc 4 and pc 5 micropulsation activity on the day side. He is using ISIS I and ISIS II topside sounder data to search for thermal plasma density discontinuities in the magnetosphere where it is thought that energy may be coupled into asymmetric toroidal micropulsation modes.

THE UNIVERSITY OF CALGARY

Department of Physics

ISIS II

Principal efforts remain dedicated to the analysis of data from the scanning 5577Å/3914Å photometer on ISIS 2. With increasing experience the department is becoming more proficient at operating the instrument in ways designed to answer specific scientific questions. Good coverage of two Churchill rocket firings was obtained last winter along with an excellent set of passes coincident with ground-based observations at Gillam and Churchill. One of the more immediate results has been that what appears from the ground as post-breakup auroral glows are seen from the satellite to be widespread brightenings of the diffuse auroral belt.

International Magnetospheric Study Plans

The ISIS experimenters team is looking ahead to the IMS with considerable enthusiasm. It is proposed that the operation of ISIS 2 continue through the IMS and many opportunities exist for key scientific work to be carried out using its unique complement of instruments. One possibility which is being considered is the provision of real-time information on the position of the auroral oval.

Technical Progress

The second stage of development in the data processing is essentially complete. The department now (1) plot latitude profiles of auroral emissions as well as intensity profiles projected along the field lines passing through the spacecraft; (2) produce full scale coordinate transformations of the data onto geographic or corrected geomagnetic coordinate grids; (3) use star, city, and limb sightings to refine the spacecraft spin axis orientation and rotation rate so as to locate positions in our pictures to within 20 km; (4) produce dot-matrix pictures that reliably reproduce the full dynamic range of intensities covered by the instrument.

Plans for this winter

Special emphasis is being given to northern polar cap coverage during December and January, with the orbit plane and spin axis optimized for this study. Other than this the main concern is to finish several outstanding analysis projects concerned with optical aurora-electrojet relationships, particle-optical relationships, auroral x-ray-optical relationships, the dayside auroral cleft, polar cap airglow, and mid latitude airglow structure.

Rocket Results

Data from two previous rocket flights are presently being analyzed. Firstly, the data from vehicle AKF-VB-39 launched within one-half hour of a coincident ISIS 2 satellite pass is in the initial stages of analysis. Reduction of the detailed vehicle attitude, necessary for subsequent analysis has essentially been completed.

Secondly, analysis of the auroral scanner data for vehicle AKD-VB-27 is nearing completion and will constitute in part an M.Sc. thesis to be completed hopefully by the new year. Work will be centered around the relative distributions of the λ 3914Å and λ5577Å emissions and the λ5577Å/λ3914Å ratio. Comparisons of optical data with that from other on-board experiments, including electric field probes and an energetic particle detector, will also be made.

New Ground-based Instrument Development

David Naylor, a new graduate student and Commonwealth Scholar, is starting a Ph.D. program involving the application of some of the department's satellite techniques to the development of an all-electronic all-sky scanning and imaging photometer. The instrument is intended for single-station use in airglow and auroral studies and for use as a real time height-finding system in a dual configuration. Communications capability is an important element in the design, including telephone command and monitoring capability.

Aeronomy Projects at the Arecibo Observatory

Inchoherent scatter observations of electron density profiles are being combined with photometric observations of airglow to study F region recombination processes and neutral composition variations. Some attempt has been made to measure neutral winds from Doppler-shifted atomic oxygen emission lines using a six-inch Fabry-Perot interferometer, but airglow intensities have been unusually low during preliminary tests.

Visible and Near Infrared Atmospheric Emissions

During the past year most effort has been expended on the Fraunhofer filling-in (Ring effect) project. Extended observations are planned in an attempt to obtain some clarifications of the underlying cause. Instrumental modifications are underway to allow electronic scanning of the spectrum instead of conventional mechanical scanning. Once this is accomplished the spectrometer will be taken to the Sulphur Mountain Cosmic Ray Lab for observational work.

Some more work has been done on thermal emissions from the lower atmosphere. The region 4 - 7 μ has been explored with a PbSe detector and this winter should see the use of a HgCdTe detector taking the study out to 14 μ. The acquisition of a spectrum analyser will enable spectral averaging of acquired data to proceed more efficiently.

McMASTER UNIVERSITY

The lunar research programme is being continued. Measurements are being made of sulphur concentrations and $^{34}S/^{32}S$ ratios in grain size fractions of selected dust samples. The variations observed for particle sizes in the range 5μ to 1000μ are related to the processes of fragmentation, comminution and mixing associated with the maturation of lunar soil. Similar measurements are planned on soil types believed to have had widely differing histories.

THE UNIVERSITY OF SASKATCHEWAN

Institute of Space and Atmospheric Studies

Auroral Studies

Progress on electron and optical data obtained from rocket flights has been good. Jim Yee, M.Sc. student, has completed a study of electron energy deposition in aurora, using data from two rocket flights (VB-10 and VB-18), and synthesized optical emission profiles in good agreement with observations. Dr. G.G. Sivjee, Univ. of Alaska, spent two months at the Institute collaborating on a detailed study of characteristics of primary auroral electrons and their interaction with the atmosphere.

An auroral rocket (BBII-128) was flown in February 1974 yielding extremely interesting electron data (18 keV-20 eV) and auroral spectra (1875-1175Å) as well as considerable photometric data on spatial characteristics of 1215Å, 2972Å and 5577Å emissions. The payload was recovered intact. Mrs. E. Armstrong, summer student, assisted in preliminary data processing and analysis and work is progressing on its full interpretation. The rocket descended from apogee at 131 km through an aurora of 100 kR intensity. The N_2 LBH spectrum was well developed and the complete spectra obtained each 1.6 seconds show much of this radiation (above 1700Å) penetrating well down into the atmosphere.

One other flight (VB-34) through an auroral event yielded good electron data which will be analyzed in conjunction with other experimenters' optical data.

A research associate, Dr. P. Venkatarangan, recently joined the author with a background in magnetospheric physics and will allow an extension of studies of auroral electrons to include their origins as well as their fate.

An electron spectrometer and a hydrogen L α photometer were prepared for rocket flight VB-41 at Cape Parry in December 1974 to investigate electron and proton influx in the dayside cusp region. Ground based 5577Å measurements continue at Thompson, Manitoba in conjunction with the ATS particle measurements on that field line. Lack of resources has prevented completion of the meridional scanning multiwavelength photometer planned for that station or any major effort in interpreting the optical data in relation to the satellite electron data.

Auroral Backscatter Studies - Polarization, Fading, Doppler Spectrum

A 42.1 MHz polarimeter is being used to record the complete polarization state (elliptically polarized and unpolarized components) of the auroral scatter. The transmitted signal is from a horizontal dipole. Depolarization of the signal occurs, causing the polarization fraction to drop as low as 0.9, even though the recording interval is only 0.5 ms. A magnetoionic theory of spatial dispersion, similar to the theory of Faraday dispersion in radio astronomy, has been developed to explain the depolarization.

Studies of the fading rates of the backscatter show that, at times, there are definite peaks in the spectral power in the 3-10 Hz range, which may be the radio auroral counterpart of the "flicker" seen often in the television studies of Hallinan and Davis at Alaska, and of the electron flux modulation seen by D.S. Evans with rocket-borne spectrometers.

A Doppler system is nearing completion, in which scatter signal at the receiving site will be mixed with a direct reference signal from the transmitting site some 40 km to the east, in order to obtain the Doppler spectrum by FFT* analysis of the recordings made on a computer-interfaced synchronous tapedeck being completed by Dr. K. Paulson here at ISAS.

ULF Micropulsation Studies

Simultaneous, three-component measurements of ULF micropulsations were made from three stations near Saskatoon during the summer of 1974. The stations are located over fairly uniform sedimentary structure at the apices of a triangle with sides of 118 km. All data were recorded digitally on industry-compatible magnetic tape. These data are now being analysed using spectral vector-array processing techniques in order to provide a better description of the phenomenon and to determine if organized disturbances are being propagated across the array.

Data from one of the above stations have been studied to see if the vertical component of the field may be expressed as a linear function of the two orthogonal horizontal components. The conclusion from this study is that such a description has no validity, at least in the Saskatoon area.

In co-operation with Professor Hajnal, two expeditions were made in the autumn of 1974 to acquire magnetotelluric data in the Bengough area of southern Saskatchewan. Processing of these data, again recorded digitally on magnetic tape, is just beginning. This area is of interest because of the small earthquake that occurred there in 1972 and because of the potential for production of oil.

* Fast Fourier Transform

Digitized auroral photometer data (λ3914 and 5577Å) have been obtained from Dr. K. Henriksen and a new method to evaluate the time-dependent amplitude and phase relations between the two auroral processes is being tested.

Coupling Between Atmospheric Gravity Waves and the Mean Flow

Radiowave partial reflection drift (wind) measurements from 60-110 km, for the years 1973-1974, at Saskatoon, Canada (50°N, 107°W), have been analyzed. Intensive soundings (12 hr^{-1}) have provided hourly, weekly and monthly profiles for the prevailing winds and also for the amplitudes of internal gravity (I.G.) Waves ($\tau \sim$ 60 min).

A relationship between the heights of reversals of the mean flow and of maxima in the wave amplitude profiles has been demonstrated for 1973 and 1974. It is suggested that this is the result of energy and momentum exchange between waves and the mean flow. Hourly changes in the flow are also shown to be consistent with the effects of longer period ($\tau \sim$ 120 min) I.G. waves and/or momentum deposition by I.G. waves ($\tau \leq$ 60 min).

Infrared Aeronomy

Further observations of the evening twilight at 1.27μ oxygen emission have been analyzed using a model profile similar to that determined from the rocket observations (Llewellyn et al 1973). This analysis has indicated that the daytime low altitude profile exhibits almost no seasonal variation while the upper layer exhibits a seasonal change in both peak concentration and half-width. The effects of an auroral contribution to the twilight emission, similar to that proposed by Vallance Jones and Gattinger, have also been studied and it has been shown that for such an auroral contribution the twilight observations cannot be inverted to give a reliable emission profile.

A re-analysis of the solar eclipse observations has been undertaken and has indicated that for the adopted chemical model the twilight and eclipse observations of the same day are not in agreement. However, the twilight observations for the days preceding the total eclipse are in good agreement with the model.

The analysis of the role of the $OH^* + O$ reaction in the atmosphere has been completed and indicated that the upper limit to the reaction rate for $v > 1$ is 5×10^{-13} cm^3 sec^{-1}. It has been concluded that the $OH^* + O_2$ reaction is most probably a vibrational relaxation with a rate constant equal to that of Potter et al. The effect of these mechanisms on the daytime concentration profiles of OH and OH* has also been studied and rocket observations of the OH ($A \rightarrow X$) emission are being re-investigated to determine the H atom concentration in the upper stratosphere and lower mesosphere. It is intended to compare these concentrations with those from previous estimates

derived from Meinel emissions. A further set of rocket observations of the 1.27μ nighttime emissions were made during 1974 on both ADD-II-128 and USAF/NASA Aladdin program. The instrumentation performed well on both occasions and should provide further information on the probable nightglow mechanism. These observations will be supplemented with observations to be made at the end of the Arctic winter during 1975.

During the summer an IR spectrometer was included in the AES payload flown from Fort Churchill and provided excellent data throughout the entire duration of both flights. A preliminary analysis has indicated that the auroral spectrum in the region beyond 1.6μ was detected on the second flight. However, to provide improved data a Michelson interferometer which may be used in both the rapid scan and external modulation modes is being developed. It is intended to have this instrument available for balloon observations during 1975 although it will also be used for ground based studies.

Atmospheric Gravity Waves

Measurements of winds (60-110 km) for Saskatoon, Canada (52^{o}N, 107^{o}W) have been obtained from a partial reflection radiowave system. 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 has been identified mainly as the prevailing wind, and the irregular components from each profile as internal atmospheric gravity waves ($30 < \tau < 60$ minutes, $12 < \lambda z < 30$ km). The amplitudes and shears of the irregular winds have their largest values in winter. A diurnal variation has been found, showing a minimum in amplitude and shear values near noon for all seasons; this variation is especially noticeable above 90 km.

Comparisons of seasonal variations in the prevailing zonal and meridional winds, with the amplitudes of the irregular winds, suggest that interactions occur involving critical layers and momentum transfer.

Mean Winds at 52^{o}N, 1969-73

The results of radiowave partial reflection winds (drift) observations, 62-116 km, for the years 1969-1973, at 52^{o}N, 107^{o}W (Saskatoon) have been analyzed, and are compared with current models. Agreement is satisfactory to 85 km; but at higher altitudes, differences exist; notably an annual variation of zonal flow above 100 km, whose direction is eastward in summer and westward in winter. The semi-annual variation of winds has been shown to be limited to 85-100 km, and is considered to be due to two out-of-phase annual variations identifiable at higher and lower altitudes. A region of positive temperature gradient (high latitude warming) has been identified in the range 80 to > 110 km in winter, and another region of negative temperature gradient is identified in summer.

Response of Mesospheric and Thermospheric Winds to Major Stratospheric Warmings

The behaviour of winds at 52°N, 107°W (Saskatoon, Canada) at altitudes to ≈ 110 km during major stratospheric warmings of 1969/70, 1970/71 and 1972/73 winters, and also a minor warming in December, 1972, has been studied. The zonal component of flow above the stratosphere is found to be affected to varying altitudes; in January, 1970; the normal eastward flow was reversed to westward at all altitudes from surface to ≈110 km. The pattern of winds is sometimes consistent with current suggestions that at middle and high latitudes, the mesosphere cools as the stratosphere warms, but not always consistent with the suggestion that the mesosphere warms subsequent to its cooling. Examples of mesospheric wind perturbations either as pre-cursors of stratospheric warmings or independent of warmings, have been found.

SIMON FRASER UNIVERSITY

Space Research Activities

A program of low-energy x-ray astronomy using sounding rockets has been in progress since 1970. To date, launches have been conducted from Fort Churchill and Kauai. Data from these flights are currently being analyzed and are expected to yield unique and valuable information on the low-energy particle background, a recurring problem in this type of measurement, as well as limited astronomical results.

Emphasis has been placed on the development of high-sensitivity observational techniques suited to the study of faint extragalactic x-ray sources. Thus far, a new proportional counter gas regulation system incorporating a programmable efficiency feature has been devised. Techniques for the fabrication and testing of thin film proportional counter windows are also under development.

Currently under construction is a prototype x-ray focusing collector employing one-dimensional grazing incidence optics. This instrument is designed to provide angular resolution of the order of a few arc minutes at x-ray energies below 2 keV as well as substantially reduced particle background effects.

An experiment incorporating this new instrumentation will be flown in late 1975 on board an attitude controlled rocket from the Woomera range. The experiment will investigate the emission and/or absorption characteristics of several selected extragalactic objects.

THE UNIVERSITY OF TORONTO

Institute for Aerospace Studies

Studies of the atmospheric temperature and composition in the region from 65 to 200 Km have been continuing using two instrumental techniques developed at UTIAS. Two comprehensive reports are ready for publication, providing descriptions of both methods and presenting the combined results from all flights up to 1974.

A new payload is being prepared for launch early in 1975 and will carry both types of apparatus, thus providing an opportunity for correlation between the two techniques described below.

(1) Electron Beam Fluorescence Probes

In this experiment, an electron gun emitting 5-10 mA of 2.5 Kv electrons is used to excite an undisturbed sample of gas, remote from the rocket, to luminescence. Spectral analysis of this light then yields information on the density, composition and temperature of the gas sample. Time resolution of the system is fast (less than .05 sec for 1% accuracy in the N_2 density at 150 Km).

The latest versions of this experiment employ one instrument with a D. C. beam and a second with a modulated beam, the latter enabling synchronous detection techniques to be applied to the optical signals. In total 9 channels of information will be collected, allowing the determination of partial densities of molecular and atomic oxygen, molecular nitrogen and rotational as well as vibrational temperature.

(2) Aerodynamic Spectrometer

This instrument is capable of determining the molecular scale temperature and the density of molecular nitrogen and atomic oxygen above 100 Km. A continuous local sample of the gas through which the instrument passes is taken by means of a slit at the foremost part of the apparatus. The spatial distribution of the neutral molecular flux behind this slit is a function of the velocity and attitude of the instrument.

Attitude Dynamics and Control of Flexible Spacecraft

A program of basic research is underway to clarify the implications of structural flexibility on spacecraft stability and control characteristics. This effort is supported by the National Research Council (NRC) and the Communications Research Centre (CRC).

In addition to results of a general unifying nature, a specific structural dynamics model has been developed for the Communications Technology Satellite. This was done in collaboration with Spar Aerospace Products Ltd., who used the model as an aid in the design of the CTS attitude control system.

This model will be tested in flight experiments planned during the period 1976-1977. These experiments are made possible by an NRC Special Project Grant, and will be performed in concert with the DOC-CTS Technology Experiments Committee.

David Dunlap Observatory

At the David Dunlap Observatory, University of Toronto, we are continuing our plans to participate in the IUE* satellite to be launched in December 1976. The satellite will provide data for the study of the ultra-violet spectra of the same stars as are programmed for observation in the optical region with ground based telescopes in Canada and in Chile. In another project, ultra-violet spectra of quasars and quasar-like objects will be used in the study of cosmological models.

Experiments have been successfully conducted with the vacuum metal coating equipment of the Dunlap Observatory to provide an effective thermal shield, with proper characteristics in other respects, for exposed components of satellite vehicles being manufactured in Canada.

The radio astronomy project is a collaboration of Observatory and the Electrical Engineering groups and will carry out one of the scientific experiments in the Communications Technology Satellite. This is an experiment for a new technique in radio interferometry which uses the satellite as a data link. It is a joint experiment involving five institutions in Canada and the United States. The technique may open up the possibility of a continental or even global Very Long Baseline Array for the investigation of compact radio sources.

* IUE - International Ultra Violet Explorer

THE UNIVERSITY OF VICTORIA

Department of Physics

Twilight Airglow Studies

Regular monitoring of twilight lithium emission has continued during the past year using the Victoria birefringent photometer. As in 1973 no marked enhancements have been observed, even though 1 kg of lithium vapour was released into the upper atmosphere by a rocket launched from Eglin Air Force Base in Florida near the end of June, 1974. Thus the meridional winds could not have been such as to carry the vapour north to the Victoria region. Results of vapour trail studies have in fact indicated that the wind transport vector at Eglin is predominantly south.

A two-channel sodium dayglow photometer incorporating a sodium emission cell is under construction, and a two-channel twilight potassium photometer is planned for the coming year.

Plasma Wave Studies

Studies are continuing on plasma-wave phenomena such as proton cyclotron echoes, lower hybrid resonance noise, whistlers, etc. OGO 6 satellite VLF data kindly supplied by Dr. T. Laaspere of Dartmouth College, Hanover, New Hampshire have been very recently supplemented by ISIS-2 satellite VLF data supplied by Drs. R. E. Barrington and F. H. Palmer of the Communications Research Centre in Ottawa.

Most of the equipment for a micropulsation station has been acquired and will be set up in the near future.

THE UNIVERSITY OF WESTERN ONTARIO

Centre for Radio Science, Department of Physics

The number of principal investigators engaged in radio probing of the upper atmosphere under the auspices of the Centre for Radio Science is eight. The presently active projects are summarized as follows:

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 (Forsyth). 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 (Moorcroft).

Wind Motions

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

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 (Forsyth). The differential measurements should greatly increase the sensitivity and allow deductions on the irregularities of the electron distribution during quiet conditions. A portable version of the two frequency Minitrack system has been constructed and will be operated at a number of high latitude sites. Both fixed and portable versions have been modified to operate also with the ATS-6 satellite.

Angle of arrival and Faraday rotation data from a rocket launched into a pulsating aurora have been analyzed (Forsyth, Palmer). The results indicate that the technique is very useful for studies of the time-relationships which exist in the auroral ionization during rapidly changing particle fluxes.

Travelling Ionospheric Disturbances

The continuing observations of periodic content fluctuations utilising the geostationary satellite transmissions have been complemented by simultaneous observations of angle of arrival fluctuations (Lyon, Webster). 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 (Moorcroft). 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 Corp. to further the project and hopefully eventually operate the facility. The earliest operating date for the facility, depending on funding, is early 1979.

Probe Studies

A variety of theoretical models have been studied some of which result in current fluctuations with spectral densities in the form of a power law 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. However if $1/f$ noise occurs in the contaminant layer, this might produce serious fluctuations if the mean current to the probe is sufficiently large (e.g. in the electron acceleration regime) (Tunaley).

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 (Abdu, Vogan, Forsyth). 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 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 sporadic meteors have been made and we have found that these are even shorter than those of photographic meteors. A tentative model has been proposed which is in good agreement with these observations (Jones, Hawkes, Morton).

YORK UNIVERSITY

Centre for Research in Experimental Space Science and Department of Physics

Laboratory Astrophysics

Intensity Measurements on Molecular Spectra

Absolute intensity measurements have been interpreted as band strengths for seven band systems of C_2, CN Red and Violet, and the 0_2 Atmospheric System.

Wavelength Measurements and Structure Constants

New measurements have been made for over 7000 lines of the 0_2 Schumann-Runge system and new constants have been established.

Identification Atlases of Molecular Spectra

Identification atlases for NO_2 and SO_2 are in preparation.

Equipment Construction

A 3" automatic shock tube has been completed as had a precision photoelectric scanner for the 21ft Eagle spectrograph (air). Construction of the 21ft Eagle (vacuum) spectrograph continues. Image intensified rocket spectrographs have been constructed.

Theory

Calculations of Franck-Condon factors and r-centroids for important molecular band systems continue. These are published in CRESS Spectroscopic Reports. 10^5 bands have so far been studied. The mathematical bases of the r-centroid concept is under study, and the theoretical bases for the Hδ n1-London factors of diatomic lines has been completed. A versatile computer programme SPECT3 has been extensively used in the synthetic reconstruction of a number of atmospheric and laboratory spectra.

Magnetospheric Cleft Project

The magnetospheric cleft has recently become a focal point of considerable activity here. The ISIS-II red line photometer has revealed the 6300 Å dayside emission as a pronounced, or even a dominant feature, of the red auroral oval. ISIS studies involving most of the experimenters are underway. This work led to a search for a Canadian ground station suitable for cleft observations, in which Cape Parry was identified. Bob Peterson made ground based 6300 Å observations there last winter and the results have been published. His optical cleft observations have given us confidence to launch rocket VB-41 from there, along with Dr. Whalen's IV-32, during Dec. 2-12. The Los Alamos Scientific Laboratory plans to launch two shaped barium charges from Cape Parry in January, and have installed ionosondes at Sach's Harbour and Cape Parry, as cleft identifiers, which will also operate in December. We have also sent a scanning photometer to Sach's Harbour (kindly operated by the University of Alaska, who are running that ionosonde), which together with Dr. Creutzberg's photometers at Cape Parry, will make triangulation possible. Thus, we hope to have comprehensive and simultaneous ground-based optical, ionosonde, and direct rocket measurements. In addition, both ISIS-II and Atmospheric Explorer have favourable orbit configurations for supporting data, though precise coincidences are not a launch requirement.

Airglow Observations at Toronto

The initiation of regular airglow observations from the York Campus has been much slower than expected, but Fabry-Perot data for temperatures and winds in 5577 Å airglow are now being obtained. Routine supporting photometric observations on several wavelengths is to begin soon. Dr. 's Gault and Koehler should soon have their low resolution scanning wide angle Michelson interferometer ready for initial measurements.

Satellite Studies

The atomic oxygen red line (6300Å) photometer continues to operate satisfactorily in orbit in the ISIS-II spacecraft. Data acquisition continues on a routine basis, although there is now much more emphasis on

scheduling the spacecraft for specific studies. Nearly all of the first two years of data have been received at York, and incorporated into a catalog, which may be readily interrogated to find specific passes. Data processing has slowed somewhat, owing to time spent on the completion of specific studies, and on further improvement of software.

Rocket Studies

Rocket VB-34 was successfully flown in 1974, one of the largest and most complex auroral payloads to be launched at Churchill. Analysis of the data is proceeding. Rocket VB-41 was launched from Cape Parry (70°N, 125°W) in December, 1974, into the dayside magnetospheric cleft aurora. This was one of the first flights with the cleft as a specific objective, and the first in which optical 6300Å observations were used to define the cleft location.

Ground-based Observations

A ground-based photometer was operated at Cape Parry during late Nov. - early Dec., 1973, and information on cleft location relative to that point was obtained. During the forthcoming rocket launches Dr. Fokke Creutzberg will provide optical ground based support at Cape Parry, and we are sending a photometer to Sach's Harbour, to be operated by the University of Alaska. These two-station meridian scans will allow an estimate to be made of the altitude of the cleft emissions.

The Fabry-Perot interferometer is now operating on the York Campus, and is measuring 5577Å temperatures and winds.

Stratospheric Nitric Oxide Measurements

The Department of Chemistry has been engaged in a program to determine nitric oxide concentrations in the lower stratosphere as part of the Climatic Impact Assessment Program sponsored by D.O.T. of the U.S. This past summer the instrument was flown on two balloon flights from Fort Churchill. One was supported by NRC and the other successful flight was made as part of the Atmospheric Environment Service sponsored flight to determine simultaneously a number of trace constituent concentrations. In both cases NO was determined over the altitude range of 20-32 km and on the second flight the measurements included sunset. At present all the data analysis is not complete but the measurements are qualitatively consistent with photochemical models, the lowering of the tropopause with increasing latitude, and a number of balloon flights launched from New Mexico.

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. It continues to be used from time to time on special request.

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 A 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 casuses 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 pehnomena recorded by other instruments on board the spacecraft and on the ground.

ISIS II Operation

All experiments and spacecraft systems, except for the tape-recorder which failed about 8 months after launch, are working well and up to seven hours of data is acquired daily. One of the SPS channels failed in January 1973, but the remaining channel can be programmed for any mode for either electrons or protons.

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) and measurements of radio noise and interference have continued during 1974.

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. Sharma and Muldrew have found the occurrence of conjugate ducts to be almost an order of magnitude higher near the December solstice at American longitude and near the June solstice at Asian longitude than for the rest of the year. This is likely due to the non-coincidence of the magnetic and geographic poles. Studies on the occurrence of conjugate with height and L value are continuing. Studies of the quiet winter polar cap are in progress, using data from ISIS-1 and ISIS-2, in addition to ground-based sounders and in one case, an aircraft-borne sounder. The computer program for the reduction of topside ionograms to electron density profiles has been modified for more successful use at the very low densities encountered. Muldrew has observed a new line called the "lower line, on Arecibo ionospheric modification (heating) data. It occurs at the same frequency as the plasma line but originates a few kilometres below the height of origin of the plasma line. James has collected sounder data from Alouette-2, ISIS-1 and ISIS-2 when two of them rendezvous. Inter-satellite propagation of sounder transmissions in various modes have been identified, and data are being analyzed in the hope that they may provide more insight into how dipole antennas work in a magnetoplasma and how waves propagate. When satellite separations have been less than about 500 km, it has been possible to obtain some whistler-mode transmissions. The role of the electric dipole in launching the whistler-mode is of special relevence to present and future experiments in space. VLF records from Alouette and ISIS have been studied in connection with the 'VLF Saucer' phenomena. These natural auroral latitude emissions originate from small sources whose dimensions have been estimated. The dimensions, along with other evidence about the plasma parameters are used in identifying the instability.

Theoretical studies performed by G. Atkinson include the suggestion of two experiments. The first points out that accurate measurement of magnetic and electric fields in an auroral arc can provide information on the closure of the electric current in the outer magnetosphere, and the second points out that the cross-polar-cap potential could be monitored by radar backscatter techniques. A further theoretical study has shown that magnetospheric convective flow obeys the Laplace equation for uniform ionospheric conductivity. The dependence of the high latitude flow pattern on sector structure was calculated using this result.

Routine scaling of Alouette-1 is essentially complete, and ten Alosyn Data basics are being published.

F.H. Palmer is a member of the "Atmospheric, Magnetospheric, and Plasmas in Space" working group. This group is currently engaged in defining the basic experimental facilities to be available on board Spacelab, due to be launched routinely into orbit by the U.S. Space Shuttle in the early 1980's.

Studies of the lower ionosphere and of the neutral mesosphere by the partial reflection of MF and HF radio waves continues to be very productive. The research studies in this programme have been concerned with diurnal and seasonal changes in electron loss rates, and with possible change in mesospheric photochemistry which could give rise to the observed loss rates; and with electron loss rates at times of energetic particle precipitation (of the "particle drizzle" and "event" types.) The latter work is a co-operative effort with the Lockheed Palo Alto Research Group, who are providing data on particle precipitation measured on their satellite overpasses over Ottawa.

The major expansion of the partial reflection facilities at Ottawa begun several years ago are now nearing completion. These developments are aimed at allowing the measurement of differential phase and amplitude on a spaced receiver antenna system. It is hoped they will enable the measuring of mesopheric winds (in the 50-90 km height region) as well as a study of electron density irregularities known to exist in the region. The development to date has allowed the measurement of the amplitude fading in a spaced receiver antenna system, and initial "wind" measurements are presently being produced, along with the basic differential-absorption experiment to measure the electron density distribution.

HIGH FREQUENCY DIRECTION FINDING

An antenna system with a sampled aperture of 1.2 km length, and useable over the frequency range 2 to 30 MHz, is being employed to study radio wave propagation over oblique paths. The emphasis of the work is on travelling ionospheric disturbances, tilts and other ionospheric irregularities which are a limitation to present HF radio direction-finding systems. The experimental system includes an FM sounding capability which permits measurements to be made on a mode-resolved basis.

Important results to date include the measurement across the 1.2 km aperture of the detailed phase characteristic of the radio signal received after oblique propagation via the ionosphere, and the discovery that F-layer propagated signals sometimes split into a large number of components when travelling ionosperic disturbances are present. As many as seven components (implying seven distinguishable effective reflection points) have been noted.

Work is in progress to utilize the array at near vertical incidence to study ionospheric disturbances, drifts and other motions.

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 the statistics of precipitation attenuation at locations representative of the various climatic regions of Canada. A 13 GHz radiometer and associated data recording system has been installed at each of seven locations across Canada. 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. More than one year's data has been collected at each location, and analysis is underway.

As an extension of this program, radiometric measurements of site diversity improvement will begin at two locations beginning in early 1975. The predictions of site diversity improvement calculated from the analysis of 2.9 GHz weather radar data obtained at Ottawa during 1970 will be compared with the radiometric data to be obtained.

A series of propagation experiments at 12 and 14 GHz using the Communications Technology Satellite is planned. Precipitation attenuation at 12 and 14 GHz, differential attenuation in two orthogonal planes of polarization, depolarization and cross-polarization of linear polarized waves, and fluctuations in the time of arrival will all be measured and correlated with the relevant meteorological and ionospheric data.

McGill University is currently using digital records of radar data to calculate the elevation angle dependance of precipitation, and the characteristics of attenuation on terrestrial microwave systems, of various link lengths, orientations, and diversity spacings.

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. During the past summer, a co-operative experiment involving two groups at CRC, Telesat Canada and the Department of National Defence measured low-angle fading at 4 and 6 GHz at an elevation angle of approximately one degree.

This included the measurement of coherent bandwidth, and demonstrations of voice and wideband FM communications to the far north.

Transhorizon Propagation

Upper tropospheric structure and certain characteristics of transhorizon propagation are being analyzed from long-term measurements (of both received power and average Doppler frequency) obtained with a forward-scatter system which operated at 15.7 GHz over a 500 km path between Boston and Ottawa. Initial results show that scattering from the ice clouds of the upper troposphere occurs for significant percentages of the time, producing signal levels considerably higher at this frequency than those due to the usual tropospheric scatter mechanism. Investigation is continuing to determine the importance of cloud scatter as a mechanism for causing interference between terrestrial and space communication systems sharing the same frequencies. In a separate investigation being conducted primarily at the Air Force Cambridge Research Laboratories in Bedford, Mass., the accuracy of the scatter system for remotely measuring the average wind speeds of the upper troposphere is being determined on a statistical basis.

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-diversity 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 1973, 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.

DEPARTMENT OF ENERGY, MINES AND RESOURCES

Geological Survey of Canada

Participation in Apollo Lunar Sample Studies

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

The 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.

During the last twelve months we have concentrated on further studies of Apolle 16 samples, with emphasis on the identification and analysis of rocks, breccia clasts and soil components attributable to impact melting. Remarkable resemblances to anorthosite-rich melt rocks and breccias from the Lake Mistastin, Labrador, and Manicouagan, Quebec craters were noted in submissions to the Fifth Lunar Science Conference and are being pursued in recently completed petrologic and Ar 39/40 studies of Mistastin crater rocks. Further detailed studies of samples from these craters are in progress.

Also reported to the conference, in part in collaboration with German investigators, were the results of the application of experimental and natural terrestrial impact crater investigations to the problem of ejecta from lunar impacts. Small recent craters at the Apollo 14 and 16 sites were considered and further data relating to ejecta from South Ray crater has been acquired. Another recently completed study concerns the possible depth of origin of Apollo 12, 14 and 15 mafic glasses interpreted as ejecta from the Imbrium Basin. The interpretation is based largely on continuing structural analysis of large Canadian impact structures.

This research agreement with NASA will terminate February 1, 1975.

Electrical Rock Property Laboratory

Electrical measurements of lunar samples are being continued over the frequency range from 30 Hz to 1.5×10^8 Hz. The parameters that are being measured are the dielectric constant, dissipation factor and resistivity. The samples are measured in dry nitrogen atmosphere under room temperature.

There are 16 lunar samples (9 from Apollo 17, 4 from Apollo 16, and 3 from Apollo 14) in the custody of the Electrical Rock Property Laboratory at present. Measurement of 6 of these samples were completed in July 1974, and the measurement of the rest of the samples are expected to be completed by January 1975.

Mr. L.S. Collett (Principal Investigator) and Dr. T. J. Katsube (Co-investigator) will not be renewing any proposal to continue electrical measurements on lunar samples after February 1, 1975. A final report on the results of the samples on hand will be submitted to NASA on this date which will complete our commitments to that agency.

Earth Physics Branch

Division of Geomagnetism

Following installation of a digital magnetometer and strip-chart recorder at Yellowknife in July 1974, the Division of Geomagnetism now operates 11 permanent observatories, 10 of which record in digital form on magnetic tape at one minute intervals. Data from Yellowknife is available in analogue form for most hours beginning July and in digital form as of October.

Microfilm of copies of magnetograms are sent to World Data Centre A on a monthly basis; edited digital data are sent as available. The observatories and variation stations and the recording facilities are listed in the table.

The seventh magnetic variometer station along the meridian through Churchill will be installed at Herchmer, which is 150 km south of Churchill in November 1974. This station and three others along the Churchill line will be recording magnetic and auroral photometric data by a digital logger system.

Analysis of the data from the coordinated ground-based and rocket-borne (VB-33) observation during the January 15, 1972, event is nearly completed. The models indicate westward electrojets north of the arc and eastward currents inside the arc. Field-aligned currents flow downward outside the arc and upward within the arc. The field-aligned currents above the arcs probably exceed the critical limit of flow possible along the magnetic field lines. A similar analysis is underway for the February 28, 1974, event.

The effect of the July 10, 1972, solar eclipse on the ionosphere currents is being investigated.

The longitudinal extent of Pc5 geomagnetic pulsation which was

of an odd-mode sheat Alfven wave, was studied.

Ruska charts for 1967 are scaled to obtain Pc5 pulsation data from Victoria, Agincourt, Meanook, Great Whale River, Churchill, Baker Lake and Resolute Bay. Various morphological features of the pulsational activity are examined. Occurrences and the amplitudes of the pulsations maximise in the northern half of the auroral zone and the statistical periods increase with increasing latitude. In general the occurrences peak in the morning and in the evening hours but at auroral zone stations a midnight occurrence peak is also evident. Also at Great Whale River and Churchill the periods of Pc5 are found to be larger in the evening hours compared to the morning hours giving indications of the influence of diurnal variations in the height of the plasmapause. With magnetic activity increasing to moderately high value both the occurrences and the amplitudes of Pc5 increased. At some stations and especially at Baker Lake, a decrease in the period of Pc5 with increasing activity is noted.

Observatories

The Division of Geomagnetism of the Earth Physics Branch operates magnetic observatories at Mould Bay, Resolute Bay, Cambridge Bay and Baker Lake in the Canadian Arctic; at Yellowknife, Churchill and Great Whale River in the auroral zone; and at Victoria, Meanook, Ottawa and St. John's in southern Canada. All observatories except Mould Bay record three components of the magnetic field digitally on magnetic tape at one minute intervals. Photographic records in standard magnetogram format are produced at all observatories except Yellowknife, Cambridge Bay and St. John's, and are regularly deposited at World Data Centre A, Boulder, Colorado. In addition pen-and-ink fluxgate charts are available for the arctic station of Alert.

Canada Centre for Remote Sensing

The Canada Centre for Remote Sensing was established in April, 1971 as the lead agency for the co-ordination of a Canadian program of airborne as well as spaceborne remote sensing. The Centre's spaceborne remote sensing activities include the readout of ERTS-1 and NOAA-3 satellite data of Canada, the processing of these data to imagery, as well as research, development, and promotion of techniques for using those data. The Centre is also involved in research with data derived from the Skylab S-191 and S-192 experiments.

Satellite imagery of Canada is available in several formats. Band 5 or band 6 ERTS-1 "Quicklook" as well as NOAA-3 "Quicklook" imagery are very valuable to users requiring imagery in the briefest delay subsequent to satellite passes over Canada. Distribution of "Quicklook" imagery is the responsibility of Donald Fisher and Associates, Prince Albert, Saskatchewan, contractor to the Centre. While "Quicklook" imagery is

distributed by mail to most users, several experimental methods of communicating satellite imagery data for Arctic navigation were demonstrated during September and October, 1974. ERTS-1 "Quicklook" and NOAA-3 "Quicklook" imagery data were transmitted by facsimile via telephone lines from Prince Albert Satellite Station to the Communications Research Centre in Ottawa. The imagery data were then retransmitted to the Arctic using two methods: Firstly, the imagery data were retransmitted to survey ships via high frequency radio link. Secondly, the imagery data were retransmitted via the US high frequency military satellite, LES-6, to the HMCS Preserver. Similarly, ERTS-1 "Quicklook" and NOAA-3 "Quicklook" imagery data were transmitted from the Prince Albert Satellite Station via the ANIK satellite to Resolute, for use by Geophysical Service Incorporated. Further, ERTS-1 "Quicklook" and NOAA-3 "Quicklook" imagery data were transmitted by facsimile via telephone line to Ice Central, Ottawa for use in compiling ice forecast maps. Finally, ERTS-1 "Quicklook" and NOAA-3 "Quicklook" imagery data were transmitted from the Prince Albert Satellite Station to Calgary by facsimile via telephone lines, and then retransmitted to Inuvik via microwave repeater network.

The centre's Ottawa ground data handling facility provides users with the more widely know format, that is the radiometrically and geometrically corrected ERTS-1 imagery. Imagery is available for all 4 individual spectral bands of the ERTS-1 multispectral scanner as well as in 3-band false colour composites. ERTS-1 imagery, at a scale of 1:1,000,000, is reproduced, archived, and distributed by the National Air Photo Library, Ottawa. Because the numbers of users capable of processing satellite imagery data is rapidly expanding, the Centre is supplying an increasing number of computer compatible tapes. Samples of satellite imagery can be examined at the Centre's Imagery Browse Facility, located at 717 Belfast Road, Ottawa. Furthermore, at the request of users, the Centre provides searches of its satellite imagery files, as well as searches of RESORS, an automated bibliographic service, that incorporates airborne as well as spaceborne remote sensing literature; searches are carried out using user-supplied key words.

Some of the potential benefits of spaceborne remote sensing depend on the ability to quickly and automatically classify features of the environment. To this end, the Centre is continuing to develop computerized classification techniques. The automated methods currently being developed to classify ERTS-1 imagery can be applied to various surveys such as the inventory of land use, forests, lakes, crops, and surficial materials.

Supervised classification is one such automated classification method, and it requires that ground truth data be input into classification programs. Supervised classification of ERTS-1 imagery is being actively developed, and a modular interactive classification analyser support package known as MICA can be used at the Centre by user agencies. The MICA package classifies on the basis of the maximum likelihood decision rule. This computing

package has been used for the automated classification of surficial materials in the Pelly Bay area of the Northwest Territories. The surficial materials classified include glacial till, marine silt, sand and gravel, bedrock, turbid water, and clear water. As well, the MICA package is being used for the classification of prairie crops such as wheat and barley, rapeseed, and summer fallow. Furthermore, this package is being used in forest inventory mapping of burned areas, logged areas, as well as vegetation types such as spruce or pine. Current work on the package includes the development of faster classification techniques.

In early 1975, the Centre will make an interactive multispectral analyser hardware known as the Image 100 available to users. The Image 100 will quickly produce classifications from ERTS-1 digital data. The Image 100 provides quick response to user action, and it is well suited to users having little computer experience.

On the other hand, unsupervised classification does not require that ground truth data be available prior to classification. Rather, classes are identified by the computing program using given statistical rules. After classification is completed, an interpreter determines the significance of the classes identified by the computing program. This method is currently at the research stage. An application of this method to the Pelly Bay area of the Northwest Territories has yielded impressive results which compare well with supervised classification methods.

Work in progress includes feasibility studies of a program of textural (spatial) analysis, as well as a program of optical processing of satellite imagery.

Cost benefit analysis of remote sensing in Canada indicates that major potential benefits will be derived from the applications of remote sensing in the North. As an example, such benefits would result from operational systems for retransmitting satellite imagery to the Arctic for use in ice forecasting and ship navigation. Major benefits would also result from the operations and use of all-weather remote sensing devices installed on-board satellites as well as aircraft. Consequently, a study of a potential Canadian Arctic all-weather satellite has been initiated, and preliminary results have recently become available.

ENVIRONMENT CANADA

Atmospheric Environment Service

Experimental and Theoretical Studies

Experimental and theoretical studies continue in the Atmospheric Environment Service to aid in the interpretation of the dynamic processes in the stratosphere, with particular reference to possible anthropogenic effects.

Two flights of the AES stratospheric balloon gondola were conducted in July from Churchill on 4.3 and 11.6/cubicfoot/million balloons in the annual Skyhook series. Ten experiments were flown, with five from AES and five from Canadian universities under contract to AES. Ozone, nitric oxide, nitrogen dioxide, water vapour, nitric acid, hydroxyl emissions and solar ultraviolet flux were measured simultaneously. Analysis of the data is in process and comparison with model simulations will be made in order to verify representations of stratospheric photochemical schemes. The program will be continued in 1975 with further flights and additional experiments on the gondola to measure chlorine constituents in the stratosphere.

The analysis of the data from rocket VB-37 produced a water vapour mixing ratio profile over the range 15 to 50 km. The mixing ratio received from 3 PPMV in the 25 km region up to 5 PPMV at 45 km due to the oxidation of methane. Absorption photometers to measure water vapour and nitrogen dioxide will be flown on rocket VB-41 in December from Cape Parry, and on rockets in Kiruna, Sweden in March.

Further measurements of NO_2, in a cooperative experiment with the University of Toronto, were carried out in a series of flights on a Jetstar of the Ministry of Transport. An aircraft experiment to observe the time variation of NO_2 during an eclipse will be conducted on December 13.

Global analyses of total ozone values derived from the Nimbus 4 backscatter ultraviolet experiment were used in studies in relation to nuclear explosions in tropical latitudes to clarify the effect of anomalous NO_x production on the ozone budget. The results suggested that no significant depletion in ozone resulted from the introduction of a local intense injection of short duration. The problem of isolating the effect of the NO_x was attributable in part to the fact that both advection and dispersion change with height and could not be reliably specified with available data, the net effect conceivably being to cancel out depletion occurring in one or more specific levels. A subsequent attempt to study this by means of ozone profiles derived from the NIMBUS data failed as information was unsuitable for computing profiles for the

construction of cross sections on all but two orbits of the period of interest.

Numerical experiments have been carried out by incorporating HO_x (oxides of hydrogen) and NO_x (oxides of nitrogen) as dependent variables in a steady-state two-dimensional radiative. Photochemical-transport model, to assess the possible effect of increased amounts of the above trace gases, due to potential fleet operation of SST's on the ozone balance and the temperature structure of the stratosphere. The model is now being extended to study the impact of chlorofluoremethanes (Freons) on the atmospheric ozone budget. Also under development is a two-dimensional time-dependent model which incorporates radiative heating and cooling and the principal photochemical processes in the atmosphere, from the surface to the lower mesosphere.

Daily surface-based measurements of total atmospheric ozone, made with the Dobson ozone spectrophotometer, continue at Churchill, Edmonton, Goose, Resolute and Toronto. The vertical ozone profile from the earth's surface to about 30 km is measured by balloon sounding with the Brewer-Mast electro-chemical sonde each Wednesday at the first four of the above noted stations.

The visual and photographic programs for noctilucent clouds are continuing.

Weather Satellite Activities

The Meteorological Services Research Branch, Satellite Data Laboratory at AES Headquarters, Downsview, Ontario, routinely acquires and distributes imagery received directly from the Automatic Picture Transmission (APT) mode from orbitting U.S. meteorological satellites. Routine daily receptions over the past year have been taken from ESSA 8, NOAA 2 and NOAA 3.

Equipment to remove the distortions inherent in the Scanning Radiometer system in both the Infrared and Visual outputs is being tested. The removal of the distortion will facilitate the use of these data for meteorological and other environmental applications.

Two APT mode receiving stations at Halifax and Vancouver continue to acquire weather satellite data for operational utilization. Plans for upgrading the real-time distribution of this data to major weather offices across Canada via broad band circuits are in progress. The Satellite Data Laboratory continues to archive all the received data on magnetic tape and to distribute requested data to government and private agencies, universities, etc. Approximately 30,000 copy photos are distributed to these agencies each year.

Equipment to acquire the Very High Resolution Radiometer (VHRR), now available from the NOAA spacecraft, has been purchased and will shortly be installed at AES Headquarters. This will include a 10-foot solid dish auto-track antenna housed in a fibreglass shelter, an S-band receiver and preamplifier. The acquired signal will be computer processed in a dedicated computer facility and outputted through a computer fax interface so that present photographic facsimile equipment can be used to reproduce imagery from the high resolution system and other systems in full detail or with reduced resolution or enhancement as required for research and operational applications. It is anticipated that the ground station will have the capability to reproduce imagery from the APT system, the Scanning Radiometer system, the Very High Resolution Radiometer, plus data received via the WEFAX retransmission system on the Geostationary Meteorological Satellites (SMS 1 and SMS 2).

In addition to the capability to provide data in image form, the system will provide digitized VHRR data on computer compatible tapes for research and development purposes. Plans have also been made to provide digital data in real-time to users with specified requirements to allow real-time processing, transmission and archiving of selected data sets. It is also anticipated that the ground station will directly acquire Vertical Temperature Profile Recorder data from the NOAA spacecraft and by means of the computer facility reduce the raw radiances transmitted into a data form suitable for research and operational purposes.

DEPARTMENT OF NATIONAL DEFENCE

Aerospace Engineering Test Establishment (AETE) CFB Cold Lake, Alberta

Synoptic Rocketsonde Program

As a participating station in the USAF Environmental Rocket Sounding System (AFERSS), the Aerospace Engineering Test Establishment (AETE) at Cold Lake, Alberta, continued routine launchings of Loki-Dart meteorological rocketsondes at Primrose Lake Evaluation Range on Monday, Wednesday and Friday of each week. Over the year, to mid-December, a total of 67 Loki's were fired. Of these, 48 were successful in providing data on temperature and wind to 51 km or better. (Average apogee exceeded 60 km). A further 6 soundings provided limited data or one parameter only and were classified as "partials". The balance of 13 were recorded as failures for a variety of reasons. The highest sounding achieved was 71.7 km (235,000 ft), on 17 May. Conjunctive radiosondes are flown to complete the soundings from the ground up to the base of the rocket sounding at about 30 km.

This program began at CFB Cold Lake in April 1967, and is continuing. Total of launches to date has reached 745, of which 300 were Arcas rockets; the balance Loki's.

For the second year the rocket sonde program included a series of special launches to co- incide with satellite over-passes, to provide "ground-truth" comparisons with data derived by remote sensors on spacecraft. Of the 79 special launches requested, 28 were carried out. Eleven of these were successful.

Data is transmitted by teletype the same day for worldwide dissemination. Combined with similar data from other rocketsonde stations and other rocketsonde networks, the program provides a fund of research data, a climatic record of upper atmosphere temperature and wind, and up-to-date reports approximating real-time conditions of the upper atmosphere for immediate operational use. The data is later published by the National Oceanic and Atmospheric Administration, Washington.

Support to the Max Planck Institute of Germany

In November 1974 a visiting team of scientists from the Max Planck Institut Für Physik and Astrophysik (Institut Für Extraterrestrische Physik) established an operation at Primrose Lake Evaluation Range (PLER) to make photographic observations of barium ion clouds released by rocket over Greenland at altitudes of about 500 km.

MINISTRY OF TRANSPORT

Telecommunications and Electronics Branch

Aeronautical Satellite Development

In support of Canadian air traffic service over the North Atlantic a study is being carried out of suitable characteristics for a satellite system. Related to this study is an experimental program for the determination of critical design parameters of special interest to Canada as well as to the international aviation community.

A system design study is in preparation for the implementation of a satellite system for evaluation in an aeronautical environment. An international project to launch such a system of satellites over the North Atlantic has been agreed. The system comprises two satellites over the North Atlantic allowing surveillance of aircraft within the mutual coverage area of the satellites. Each satellite would have about six voice channels and one surveillance channel and would operate with aircraft antennas having a minimum G/T of minus 24 db. Satellite launch is scheduled for mid 1978 with experiments being carried out until 1983.

The related experimental programme comprises a study of the parameters of a communications link between satellites and aircraft. Aspects being studied are voice modulation techniques and the evaluation of a Canadian design for an economical, high gain, linear phased array aircraft antenna.

Division of Physics

Auroral Particle Studies

Direct measurements of thermal ionospheric ion distribution functions have been continued. In two sounding rocket experiments ion flows perpendicular (convective) and parallel to the geomagnetic field were observed at altitudes from 200 to 840 km. The equivalent electric fields were observed to vary between a few tens of mv/m to over 150 mv/m and were highly correlated with energetic electron precipitation.

High velocity (up to 2 km/sec) parallel ion flows were observed at various times and also found to be correlated with auroral electron precipitation.

A correlation analysis of perpendicular (or equivalent electric fields $E_{\perp}$) and parallel ion flow velocities with energetic electron intensities (I) was carried out. It was found that the form of the $E_{\perp}$ versus the logarithm of I relationship was approximately linear over most of the observed $E_{\perp}$ range.

Magnetospheric Studies

Particle detectors on the ISIS satellites have continued to be used to study a number of magnetospheric problems.

One of the studies determined the average intensity and energy of electrons above 150 eV as a function of magnetic local time and invariant latitude. It was found that at any local the average electron energy was a minimum at or near the latitude of the average position of the trapping boundary for 35 keV electrons. The measurements suggest that magnetosheath particles enter the closed field region of the magnetosphere at all local times and that typically there is some energization associated with this entry. Entry is least likely at local times before noon and energization is greatest at local times before midnight. It is further suggested that at least two processes, convection and possibly a diffusive mechanism, are involved in the entry of magnetosheath plasma to the magnetosphere.

Another study examined 'inverted V' structures in the evening sector. It was found that, frequently, the fluxes of electrons in the 'inverted V's' peaked at ~90^{o} pitch angles. The measurements suggested that acceleration processes other than that due to parallel electric fields are mainly responsible for the formation of at least some of the observed 'inverted V'

substructures and that such 'inverted V' events probably occur on closed field lines in the magnetosphere.

Cosmic Ray Studies

The NRC Cosmic Ray Group continued to operate the cosmic ray monitor stations at Deep River, Alert, Inuvik, Goose Bay and Ottawa.

Monte Carlo computer studies of the trajectories of individual cosmic ray particles as they undergo scattering in the interplanetary magnetic field were continued during the past year. The studies were extended to investigate the motion of electrons, protons and helium nuclei in a sectored magnetic field. It was found that even in a field comprised of 90^{o} sectors latitudinal drift is important, and that a substantial fraction of the particles' energy loss (which largely determines the intensity modulation) takes place at solar latitudes greater than 30^{o}.

Operation of the prototype ($4m^2$ area) proportional counter array to monitor the intensity of near-horizontally incident cosmic ray muons has demonstrated the practicality of the large ($48m^2$) proposed array. Construction of the large array is under way.

Astrophysics Branch

The Canada-France-Hawaii Telescope

The National Research Council of Canada and the Centre National de la Recherche Scientifique of France are building jointly a 144 inch (3.6 meter) optical telescope to be installed on Mauna Kea, Hawaii. The University of Hawaii is providing the site and support facilities through its Institute for Astronomy. The three research agencies have joined in a non-profit corporation to build and operate the telescope and will share its observation time. The project is due to be completed in 1978.

Mauna Kea at an altitude of nearly 13800 feet (4200 meters) is one of the best sites in the northern hemisphere for optical astronomy. Its high altitude is particularly suitable for infrared observations. It will be the first telescope of its size available to Canadian astronomers and will enable them to study objects, particularly extragalactic objects, beyond the reach of existing telescopes in Canada.

AURORA OVER CHURCHILL RESEARCH RANGE

Upper Atmosphere Research Section

Auroral Spectra and Photometry

The auroral spectrum in the 3100 to 4700 Å region was studied with the 1/2 metre spectrometer at a slit width of 3 Å from the Ft. Churchill Auroral Observatory in February, 1974. Specific emissions in the 7000 to 9000 Å region were also investigated with this system. The 11-channel photometer was run during the same period largely in the meridian-scanning mode. Synthetic spectra were matched quantitatively to the 3100 - 4700 Å spectra. This work which is being prepared for publication constitutes, in conjunction with the 4500 - 8900 Å paper referred to below, a complete quantitative atlas to the auroral spectrum (except for the S-1 and rocket regions).

The O_2 1.27 μ three-channel photometer was also operated during that period and enhancements (a factor of two or less) were again observed during several strong auroral displays. The analysis of the 1.27 μ emission observed by us indicates an O_2 ($^1\Delta$) excitation rate corresponding to about 3 per cent of the incident energy flux. Direct electron impact could account for at least an important fraction of the excitation.

The analysis of the 6000 - 9000 Å spectra gave the result that progressions of the O_2 atmospheric system with $v' \leq 5$ are clearly present. It was concluded that the $O(^1D)$ - O_2 energy transfer mechanism may be inadequate and that a $N(^2D)$ - O_2 energy transfer could be important.

Extensive ground-based measurements were made in February 1974 at Gillam, Manitoba with meridian scanners and an all-sky camera in conjunction with ISIS-II passes in an attempt to gain a better understanding of the morphology of the diffuse aurora and to define the relation between the quiet-time hydrogen arc and the diffuse emission region as observed by the spacecraft. Excellent data were obtained which are now being prepared for publication.

Measurements were also made at Cape Parry, N.W.T. using the same instrumentation during December 1974. Observations were made mainly in the day sector, and particular attention was paid to emissions associated with the cleft of the magnetosphere. Observing conditions and the phase of the moon were generally unfavourable for obtaining good H-beta measurements, but excellent red-line data were obtained within one hour of magnetic noon.

Auroral Rocket Photometry

Photometers were flown on one rocket in 1974. Good data were obtained. Auroral emissions currently being studied are the N_2^+ING (O, O) band, the N2IPG band system in the spectral region of 6400 - 6900 Å and the atomic oxygen transition at 5577 Å. Data are reduced to provide vertical emission rate profiles.

Radio Aurora

Our studies of the relationships between radio aurora, visual aurora and magnetospheric-ionospheric current flows during several substorms are nearing completion. Although the requirement of simultaneous data from the radar network, the all-sky camera network and the temporary magnetometer chain through Churchill limited us to only a few substorm events, several of these were very interesting magnetically. Midlatitude and satellite magnetometer data were used to study the presubstorm magnetospheric current flow and to determine the longitudinal extent of electrojet current flow and the variations in same (sometimes dramatic) during the course of a disturbed period. The other data are being used to study the latitudinal structure of the ionospheric portion of the current flow and to determine the relationships between this current and spatially adjacent visual and radio aurora.

Rocket Measurements of Auroral Plasma

Plasma measurements with electrostatic probes were obtained from four rockets flown in January and February 1974. These launches occurred in nighttime aurora at Churchill.

Plasma probes were also carried on the two rockets launched into the dayside magnetospheric cleft at Cape Parry in December 1974.

Infrasound from Meteors

In the meteorite observation and recovery project, fireballs can be detected only during periods of darkness and clear skies. It is known that the atmospheric flight of large meteoroids generates sound waves by explosions or shock wave phenomena. Although the higher frequency (audible) sound waves are attenuated to the extent that they are seldom heard beyond a 50 mile radius, waves having periods of tens of seconds propagate over longer distances. This suggests the possibility of detecting meteorite entry on a 24-hour basis.

An intensive program of instrument development and field testing has been carried out during the past year. A detector using a commercial piezoelectric microphone has sensitivity well below atmospheric noise and adequate frequency response. Since wind turbulence is the major source of noise much work was focussed on methods of reducing it. Spatial averagers consisting of 1000-ft. lengths of plastic pipe with capillary inlets every 10 feet have been found to reduce noise of wave periods about 10 seconds by 3 to 5 times. At quiet times, sensitivities of < 0.5 dynes/cm^2 were achieved in the detection of pressure waves. At higher frequencies (~ 1 Hz) a simple hole in the ground seems to be the most practical noise reducer.

An array of 4 detectors has been established at Springhill Meteor Observatory and is being operated a few days per month in conjunction with an all-sky camera and the meteor radar.

In conjunction with, and in support of the experimental program theoretical studies are being carried out to improve our understanding of the sound source mechanisms. This, combined with additional research into the attenuation and propagation of weakly nonlinear disturbances in a realistically modeled atmosphere will enable predictions of the nature and range of values of wave amplitude and period available at the ground from a meteor event.

Some of the source mechanisms being considered are:
1) Blast wave, that is, hypersonic boom in the presence of ablation, and
2) emission due to turbulence generated in the wake of the body. The altitude range of these mechanisms is dependent on the entry dynamics for a meteor body with a certain shape, density, velocity, etc. These models will then be coupled into existing computer programs for calculating both attenuation and ray path with respect to a specific source and its location from a ground-based infrasonic detection system.

Cosmic Dust Studies

We have had two flights of Magellan, the balloon-borne, micrometeoroid collecting experiment. Both flights were launched from Palestine, Texas during the spring and winter turnaround periods. Main and control exposures for the two flights were 17 hours and 45 minutes and 34 hours and 3 minutes respectively. Results are encouraging and the determination of the composition of the collected particles is continuing.

The optical scanning of the surfaces flown on rocket AAF-VI-04 is also progressing. Many puzzling particles and features have been located. It is hoped to examine these in detail in an electron microscope in the near future.

Meteor Research

The program of routine observation of meteors was continued at Springhill Meteor Observatory and at Shiels Meteor Station. Emphasis this year has been on the cooperative program with Dudley Observatory (Albany, N.Y.) and Smithsonian Astrophysical Observatory (Cambridge, Mass.). Observations made with a sensitive, closed-link TV system are combined with those of our normal grating spectrographs and two backscatter radars. The Dudley group have acquired a high-sensitivity vidicon system. For observations of the Perseid meteor shower in August we were joined also by two S. E. C. vidicon systems operated by the Meteor Physics group from NASA, Huntsville, Alabama. Some 150 spectra were obtained in about 11 hours and cooperative reduction and study of these spectra is proceeding.

A Super-Schmidt camera (f/0.7, 55^{o} field) is now in operation at Springhill.

Analysis of radar meteor data in cooperation with Czechoslovakian meteor groups resulted in a number of publications on the Geminid meteor shower. Our patrol radar observations have been useful in delineating large year by year changes in the meteor flux. These are explainable if there is a 2:1 variation in the number distribution of meteoroids around the orbit. Similar studies on the Quadrantid meteor stream are in progress.

Previous computer studies of the ablation of meteorites in the lower atmosphere (<90 km) were applied to determine conditions under which a meteorite that has a purely-geometric trajectory which would miss the earth (by <90 km), will be captured by atmospheric drag and ablation. This has application to some recent fireballs on very flat trajectories.

Springhill meteor radars were operated at the time earth crossed closest (.03 a.u.) to the orbit of Comet Kohoutek. Since this was about 2 months ahead of the comet no meteors were really expected and none were detected.

Meteorite Recovery

The 12 camera stations of the MORP network have been in operation during the year. One major event late in the year appears to be of special interest. Considerable progress has been made in determining the lens distortion corrections.

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 at 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 low 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. In addition to sporadic large flares observed during sunspot minimum flow patterns are being studied around single stable sunspots. Instrumental additions have been made to the photoheliograph in order to 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).

FORT CHURCHILL

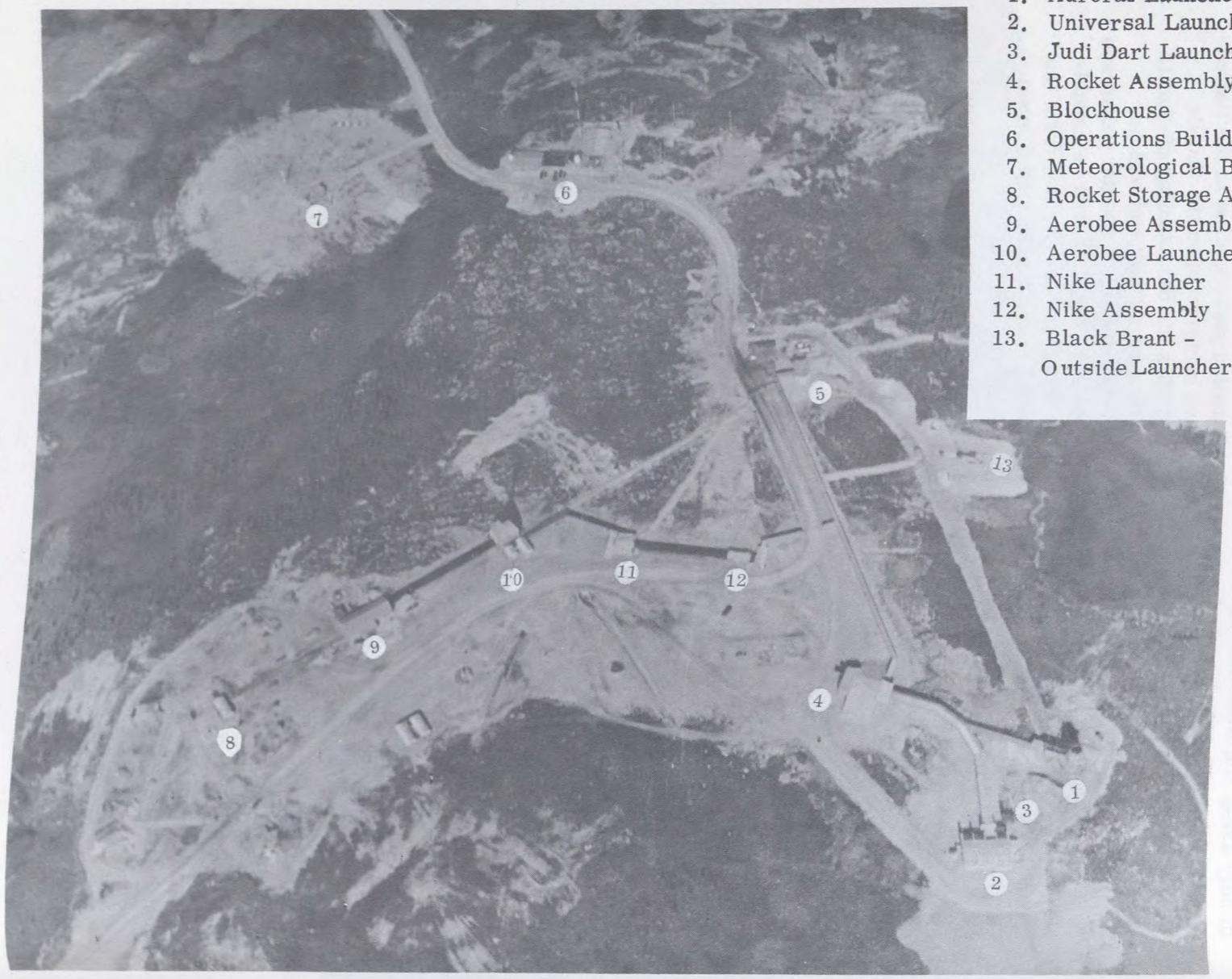
National Aeronautical Establishment (NAE)

As part of an expansion of Canada's space policy, announced in July 1974, the National Aeronautical Establishment has been conducting negotiations with NASA to explore possible Canadian participation in the United States Space Shuttle program. Discussions have centered upon the Shuttle Attached Remote Manipulator System (RMS) suitable for the handling of shuttle payload. The RMS will be installed in the Shuttle payload bay and will be operated from the Shuttle crew compartment. With the aid of special guideways and payload retention devices installed in the orbiter, the RMS will be capable of performing several operations, such as (a) removing the payload from the cargo bay and deploying it in a stabilized condition, (b) attaching itself to a stabilized payload in the retrieval zone and moving the payload into its position in the cargo bay, and (c) removing a crewman from the area of the side access door or the airlock door of a disabled orbiter and transferring that crewman to a rescue orbiter.

NASA has recently conducted a technical evaluation of Canada's capabilities of carrying out the necessary research and development for producing the manipulator. Negotiations on a Memorandum of Understanding between the National Research Council of Canada and NASA for a cooperative program are now underway and it is hoped that they will be successfully concluded by March 1975. It is intended to procure all the necessary RMS research, development and production from a suitable composed team of Canadian industrial companies.

In the field of Aerothermodynamics the cooperation with NASA is continuing on the wind tunnel studies of dynamic stability of aircraft at high angles of attack. This research programme, which was considered relevant mainly to high performance military aircraft, is also of interest for the reentry flight of the shuttle orbiter. A series of dynamic experiments was conducted in the NAE 30 inch intermittent wind tunnel using the new dynamic wind-tunnel apparatus constructed last year, and it was shown that, under certain combinations of angles of attack and sideslip, large and sudden variations could occur in several static and dynamic stability derivatives. It was also shown that, in those conditions, some of the "never-before-measured" dynamic cross-coupling derivatives could attain values that may be significant enough to warrant the inclusion of cross-coupling terms in the stability analysis of an aircraft. A separate feasibility study was also carried out, under a NASA contract, of a high-load dynamic cross-derivative apparatus, that would be compatible with some of the large wind tunnels at one of NASA's research centers.

CHURCHILL RESEARCH RANGE LAUNCH SITE



1. Auroral Launcher
2. Universal Launcher
3. Judi Dart Launcher
4. Rocket Assembly
5. Blockhouse
6. Operations Building
7. Meteorological Bldg.
8. Rocket Storage Area
9. Aerobee Assembly
10. Aerobee Launcher
11. Nike Launcher
12. Nike Assembly
13. Black Brant - Outside Launcher

Space Research Facilities Branch

General

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

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

Because of recent scientific interest in the Magnetospheric Dayside Cusp phenomenon, which occurs in the polar regions of Canada SRFB established a temporary rocket launching site at the Dew Line station at Cape Parry, NWT. Four Black Brant rockets were scheduled to be launched from this site during December/January 1974/75. Two of these rockets carried experiments for Canadian scientists, while the other two will carry American experiments. This was the first time that the larger diameter (43.2cm) Black Brant rockets have been launched from a temporary site, confirming the capability of launching the whole family of Black Brant vehicles from any suitable remote location.

The Canadian scientific program which SRFB supports is based on projects which have been approved by the Canadian Sounding Rocket Planning Group (CSRPG) 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 and outside NRC-supported scientific programs, on a cost recoverable basis. Cost recovery also applies in the case of support to non-Canadian users of SRFB facilities, carried out under various inter-governmental agreements between Canada and other countries.

Range Section

The range section is responsible for the operation of NRC operated sounding rocket ranges. This includes liaison with foreign government agencies regarding their use of range facilities. At present, there are three ranges in use: Churchill Research Range (CRR) in Manitoba, the expeditionary range facility at Cape Parry, NWT, and a small facility at Resolute, NWT. Other temporary launch sites have been established in the past to fulfill specific requirements.

Churchill Research Range has the capability of launching greater numbers of 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. In order to arrange launch scheduling and technical and financial matters an NRC/NASA Churchill Research Range Working Group was established in January 1971 under the provisions of the 1970 Canada/U.S. agreement governing the support of U.S. 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 CRR. An agreement exists with Belgium and experiments have been launched for that country in Canadian rocket payloads.

Churchill Research Range (CRR)

This range is manned by 50 to 55 contractor personnel and operations are controlled by a resident staff of four NRC personnel. It can be used to launch numerous types of sounding rockets to track by radar, and to recover and record data at a telemetry ground station.

The range has the capability of launching 20 to 25 major sounding rockets per year and of supporting a continuing 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.

Cape Parry (NWT)

During 1973 the Canadian Sounding Rocket Planning Group

(CSRPG) approved the launching of two Black Brant rockets in December 1974 to investigate the characteristics of the Magnetospheric Dayside Cusp phenomenon in the high arctic region of Canada. SRFB investigated a number of potential launch sites and finally selected the Dew Line Station at Cape Parry as the most suitable location. During the summer of 1974 a rocket launcher, telemetry trailer and other launch support facilities were installed and two Canadian instrumented Black Brant rockets were launched from this location in December. On completion of the Canadian expedition the site was made available to the United States Los Alamos Scientific Laboratory for the launching of two U.S. instrumented Black Brant rockets.

Resolute (NWT)

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 United States launchings have taken place there.

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 foreign scientists. NRC also 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 provision 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.

During 1974 seven Canadian scientific rockets were launched from CRR. A wide variety of photometers and spectrometers to measure auroral radiation in the visible to vacuum ultraviolet regions together with particle detectors and plasma probes were carried on four major rockets. Some of the payloads ejected self-contained packages to measure electric and magnetic fields at altitude.

For the first time the newly developed Black Brant VI rockets were utilized to carry small experiments. Two were employed to lift cosmic dust collectors to an altitude of 80 kilometers and one was used to measure cosmic x-rays at the same altitude.

Most of the payloads launched at CRR are now recovered using appropriate parachute assemblies. In February 1974 one payload was launched

and recovered for the third time. It is anticipated that the recovered experiments will be reflown in 1976 with minor modifications.

Of particular interest this year was the firing of two rockets into the Dayside Cusp region of the magnetosphere. On 6 December a Black Brant VB was launched at Cape Parry, followed on 11 December by a Black Brant IV. Both carried photometers, spectrometers and particle detectors to investigate the Dayside red aurora phenomenon. In the first rocket, experiments were also carried for the Universities of Liege and Tokyo.

In early 1975 a Black Brant V with an electron beam fluorescence probe and an aerodynamic spectrometer, together with other complementary detectors will be launched at CRR. Nine other rockets are planned for launch there in late 1975 and early 1976.

The possibility of launching a payload specially equipped with an attitude control system to make measurements of cosmic x-rays and of the moon's reflectance from Woomera, Australia is being considered. This launch is planned to take place in October or November 1975.

The analog to digital translation system designed and built by the Data Systems Section of REED to handle both telemetry and radar data has now been installed at SED Systems Limited in Saskatoon. Facilities have also been added to provide for the reformatting of digitally encoded data. Final computer operations are carried out on the NRC IBM 360 computer in Ottawa or by the scientists using their own computers.

In future all but the smallest rocket payloads will be designed with digitally encoded data transmission systems. Experimenters have found that this method enables them to handle their data in a computer with a minimum of difficulty.

As soon as possible after each rocket flight SRFB publishes a brief engineering report. The scientific results are published in the appropriate journals by the experimenters 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 1974 Canada participated actively in the work of the Committee on the Peaceful Uses of Outer Space, playing a major role in the deliberations of its subordinate bodies including the Scientific and Technical Subcommittee, the Working Group on Remote Sensing and its Task Force on Dissemination of Remote Sensing Data, the Legal Subcommittee and the Working Group on Direct Broadcast Satellites.

The Legal Subcommittee, at its thirteenth session in May, completed the Draft Convention on Registration of Objects Launched into Outer Space, having reached an acceptable compromise on the issue of voluntary marking of space objects. This Draft Convention was endorsed by the parent Outer Space Committee, and approved by the 29th Session of the United Nations General Assembly through Resolution 3234 of November 26, 1974. This important Convention is the fourth instrument in the development of Outer Space Law. Together with the Agreement on the Rescue of Astronauts, The Return of Astronauts and the Return of Objects Launched into Outer Space, and the Convention on International Liability for Damage Caused by Space Objects, the Registration Convention constitutes an essential addition to the 1967 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space including the Moon and other Celestial Bodies. Canada has ratified the Outer Space Treaty and now intends to accede to the Agreement on the Return of Astronauts, the Liability Convention and the Registration Convention.

No progress was made on the Moon Treaty in 1973, largely because of the continuing difficulty in reaching a compromise on the question of proprietary rights in the resources of the Moon. Negotiation based on the significant concept that the Moon's resources should be described as the common heritage of all mankind was by agreement adjourned pending the outcome of similar deliberations at the Caracas Law of the Sea Conference on the scope of this novel and as yet undefined concept as it might apply to the resources of the seabed.

In attempting to formulate draft legal principles governing direct broadcast by satellite the Working Group on Direct Broadcast by Satellites considered a new joint Canada/Sweden Working Paper which summarized the basic assumptions underlying the draft legal principles which Canada and Sweden had submitted at the previous session of the Working Group. While the Subcommittee was able to agree on certain draft principles, considerable disagreement persisted on more contentious issues, particularly

on the principle of prior consent.

The subject of Remote Sensing continued to receive close attention in 1974 in the Working Group on Remote Sensing and its Task Force of Data Dissemination. The Task Force considered members' views on data dissemination and utilization of environment and resource data and the Working Group summarized the replies to a questionnaire which surveyed member states' remote sensing activities and general views on legal and organizational aspects. The Working Group submitted its final report to the Scientific and Technical Subcommittee which also reviewed the report of the United Nations Expert on Space Applications. The Subcommittee felt that, although the Working Group's task was completed, its work should be continued within the Scientific and Technical Subcommittee and recommended that the Secretary-General commission studies on financial and operational aspects of various phases of the ground segment of global and regional remote sensing programs. The Subcommittee also agreed to circulate another questionnaire seeking the views of members regarding their interest, priorities and specific types of assistance needed and sought in the field of space applications for development.

1974 witnessed the expansion of the United Nations Program on Space Applications. This program included several panels and seminars, and was largely responsible for increased coordination within the UN system of activities relating to space applications.

The Outer Space Committee briefly considered the question of the use by satellites of positions in geostationary orbit in view of the growing number of satellites planned to utilize such orbit. Because some of this concern had already been met by the ITU's amended Radio Regulations which came into force in January 1973 and which included provisions for satellite position shifting, the Committee requested the ITU and other UN agencies with related interests to provide the Scientific and Technical Subcommittee with up-to-date information on this subject.

In 1975 the Legal Subcommittee will convene in February in New York to consider as matters of equal priority the drafting of principles governing Direct Broadcast by Satellite, the drafting of a Moon Treaty, and the question of Remote Sensing by Satellite. The Scientific and Technical Subcommittee will meet in April and the parent Outer Space Committee will meet in June. The Working Group on Remote Sensing has completed its task and was dissolved and the Working Group on Direct Broadcast Satellites may reconvene in the future if the Outer Space Committee deems it useful.

THE INTERDEPARTMENTAL COMMITTEE ON SPACE (ICS)

During 1974 the Interdepartmental Committee on Space was reorganized to reflect changes in departmental structure which have taken place since the committee was originally organized in 1969.

The committee is responsible for reviewing Canada's space activities in terms of national interests, needs and opportunities, and for making recommendations concerning appropriate policies and plans, the optimum use of resources and the coordination of space activity.

The committee reports to the Minister of State for Science and Technology and is composed of senior officials representing:

Department of Communications
Department of Energy, Mines and Resources
Department of the Environment
Department of External Affairs
Department of Industry, Trade and Commerce
Ministry of Transport
Ministry of State for Science and Technology
Department of National Defence
National Research Council

Observer status is accorded to representatives of:

Treasury Board Secretariat
Department of National Health & Welfare (Health).

The committee is supported by a Secretariat in the Ministry of State for Science and Technology and is assisted by sub-committees in three areas of special interest:

Sub-committee for the International Aspects of Space Policy

Sub-committee for the Industrial Aspects of Space Policy

Sub-committee for the Scientific Research Aspects of Space Policy. (This committee acts in a dual capacity since it also functions as the NRC Associate Committee on Space Research).

THE ASSOCIATE COMMITTEE ON SPACE RESEARCH (ASCR)

The Associate Committee on Space Research serves as the national committee adhering to COSPAR and also is the Research sub-committee of the ICS.

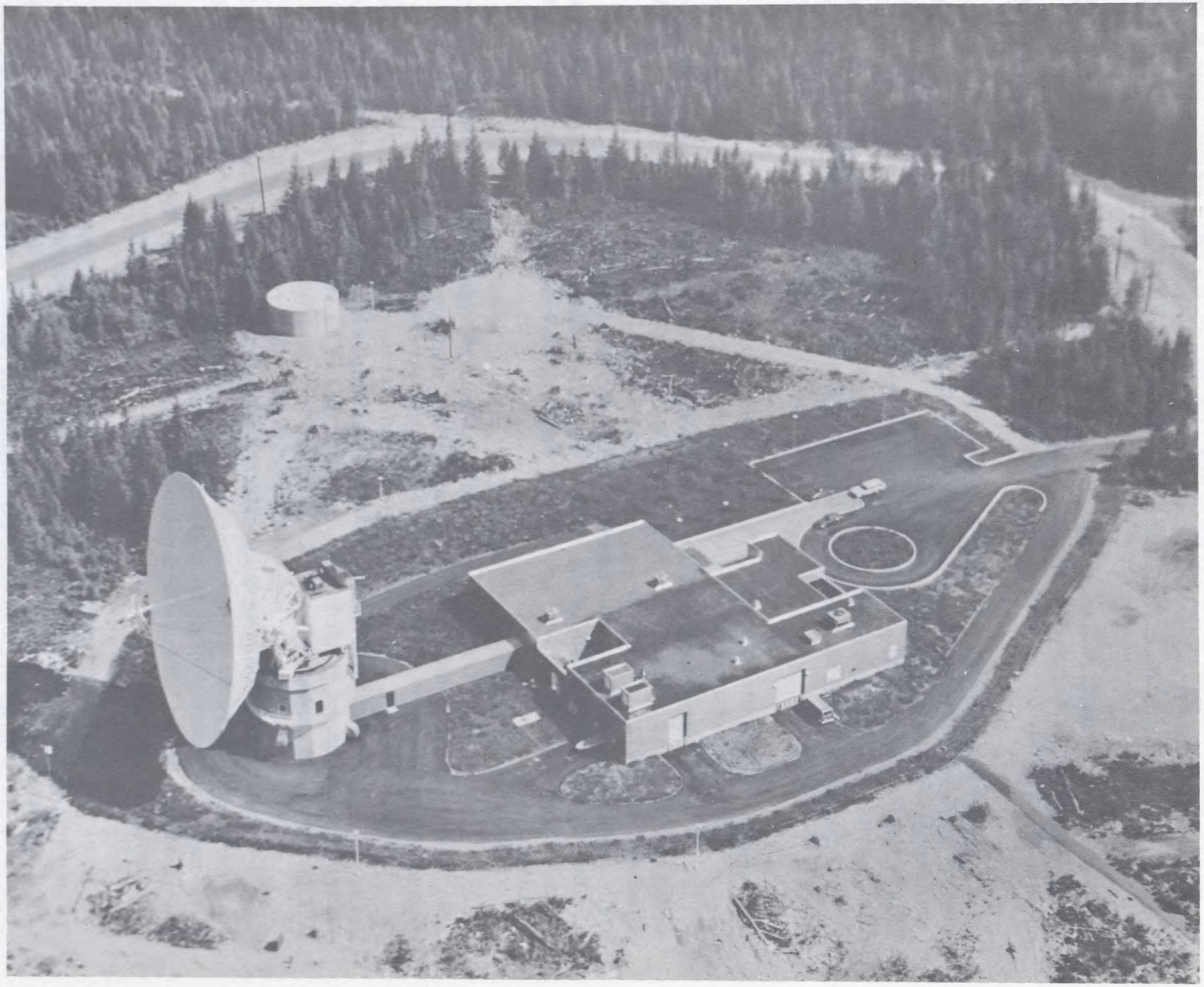
One of the prime concerns of the committee has been the coordination of Canadian participation in the International Magnetospheric Study. A recommendation has been made to the National Research Council that a secretariat be established to coordinate the relevant Canadian activity and to represent the Canadian interest in the international program. Dr. B.W. Currie has been appointed as the IMS coordinator, and he is studying the requirements for, and the organization of the proposed secretariat.

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 (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.

COTC EARTH STATION AT LAKE COWICHAN



CANADIAN OVERSEAS TELECOMMUNICATIONS CORPORATION

ACTIVITIES IN SPACE RADIO COMMUNICATION

The Canadian Overseas Telecommunication Corporation has three fully commercial satellite communication earth stations operating via Intelsat IV satellites on both the East and West Coast of Canada.

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. The West Coast earth station located near Lake Cowichan on Vancouver Island operates via the Intelsat IV satellite over the Pacific Ocean.

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 control 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 cassegrainian 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 Organization) of which COTC is a member.

The station is equipped with three transmit chains (2 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 16^0 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 to accommodate traffic growth scheduled for operations mid 1975.

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 the United Kingdom. Due to rapidly growing international traffic in the Atlantic Region requirements, COTC has undertaken 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 is now complete.

Mill Village No. 1 employs an 85 ft. cassegrainian 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/^{o}K at elevation angles greater than 15^{o}.

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 is equipped with three transmit chains operating on a (1+1) basis (i.e. one operational and one standby) using 3 three KW and 2 eight KW Klystron type amplifiers on a (2+1) and (1+1) basis.

Two low noise amplifiers with a 16^{o}K noise temperature and a bandwidth of 500 MHz at 4 GHz operating on a one for one basis from the front end of the receive chains in conjunction with 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, Trainidad, United Kingdom. Early in 1974 communication was 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. cassegrainian 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 3 transmit chains, 2 telephony, 1 TV video, 1 TV sound, 1 SPADE and 3 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.

76 Olympics

Work is currently in progress to provide television coverage over the Atlantic via the Intelsat network during the 1976 Olympic games. It is anticipated that four separate video carriers will be required during the games. In order to provide these facilities COTC plans to temporarily establish two transportable earth stations in the Montreal vicinity.

11/14 GHz Propagation Study

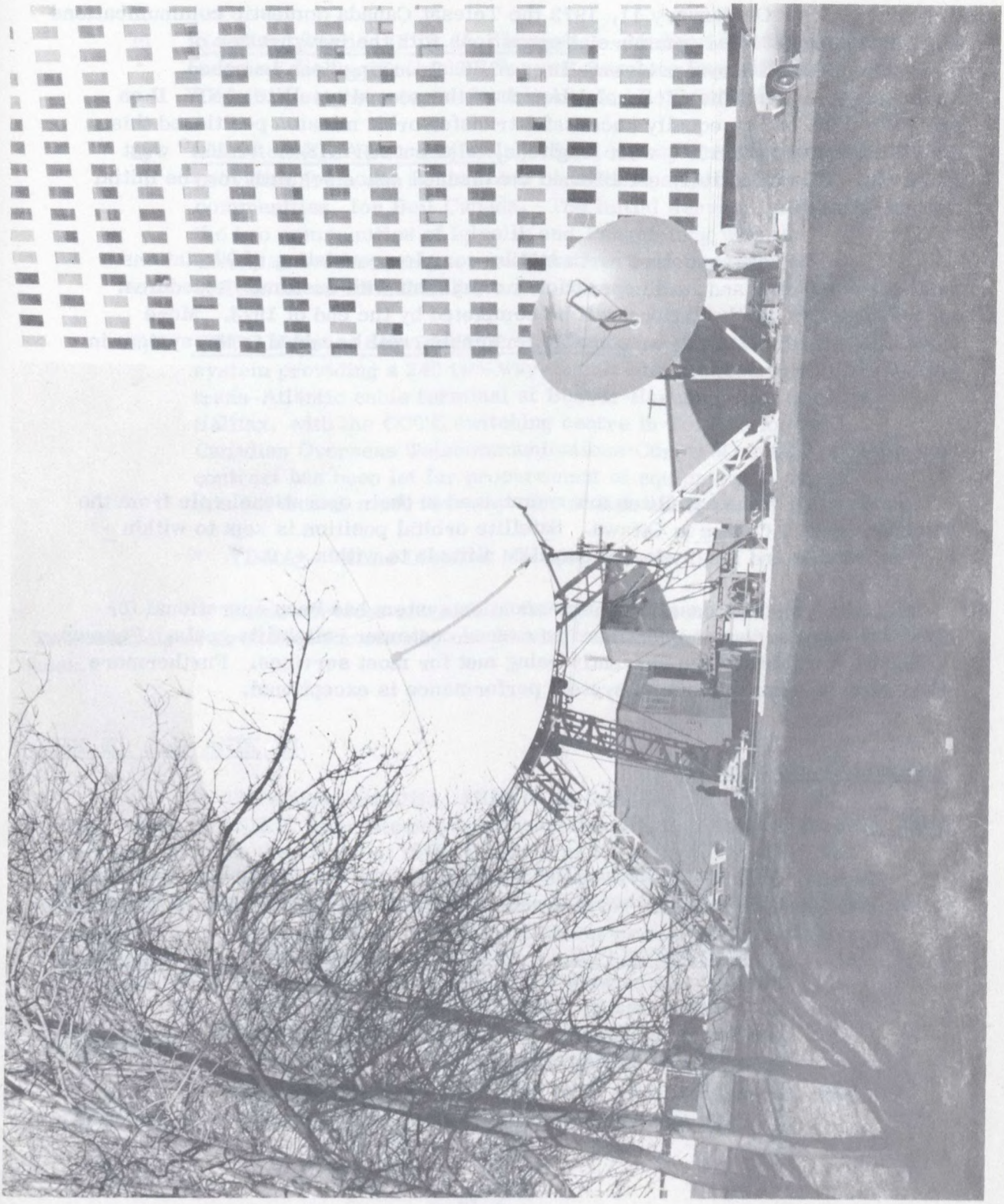
In anticipation of the eventual expansion into high frequency bands, COTC is currently undertaking studies to investigate propagation characteristics in the 11/14 GHz bands of the earth to space communication paths from Canada.

The study will be divided into three parts (a) literature research on available and useful data and to draw meaningful conclusions therefrom and (b) to carry out actual radiometer measurements to obtain more data for diversity system feasibility studies and (c) concurrently with (a) and (b), to study other systems aspects including depolarization effects.

It is expected that the study will extend into 1976/77.

TELESAT CANADA TRANSPORTABLE TELEVISION STATION

OTTAWA, ONTARIO



TELESAT CANADA

Telesat System

On January 11, 1973 the Telesat Canada domestic communications satellite system started commercial operations with the inauguration of telecommunication services by satellite, ANIK 1 having been launched November 9, 1972. 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 baseline earth station complex consisting of 37 stations has been completed and made operational consistent with customer schedules. An additional 19 earth stations will be completed by the end of 1974. More earth stations, including transportable terminals, will be added to the system in 1975.

Operation

The satellites are maintained in their operational role from the Satellite Control Centre in Ottawa. Satellite orbital position is kept to within $\pm$ 0.1° in latitude and longitude and satellite altitude to within $\pm$ 0.1°.

The baseline communication system has been operational for almost two years now and continued to exceed customer reliability goals. Figures of 99.99% availability are currently being met for most services. Furthermore the quality of communications system performance is exceptional.

Communications Services

ANIK I

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

a) TV Distribution (4 R. F. Channels) - High quality television transmit and receive service from any of two Heavy Route and six Network Quality Television stations, and receive only service at an additional 26 locations, for the Canadian Broadcasting Corporation (CBC).

b) Heavy Route Trunk Message (2 R. F. Channels) - High quality 960 two way telephone circuits, 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) - Low density message service, providing from one to six voice circuits to small northern communities, for Bell Canada. The initial service linking the two communities of Igloolik and Pangnirtung with the Canadian southern terrestrial links has been expanded to include 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.

* TDMA - Time Division Multiple Access

These services use nine of the satellites's twelve R. F. channels. Two channels are retained for standby use leaving one channel for lease or other uses.

ANIK II and ANIK III

The second satellite, ANIK II, is fulfilling its role as an in-orbit spare to ANIK I, guaranteeing continuous service to Telesat's current customers, and with the launch of ANIK III early in 1975 providing additional capacity for future system growth. Currently, some of ANIK II R. F. channels have been committed to provide interim service to RCA Globcom enabling them to provide U. S. domestic satellite communication service in advance of the start of operations of U. S. domestic satellites.

Earth Stations

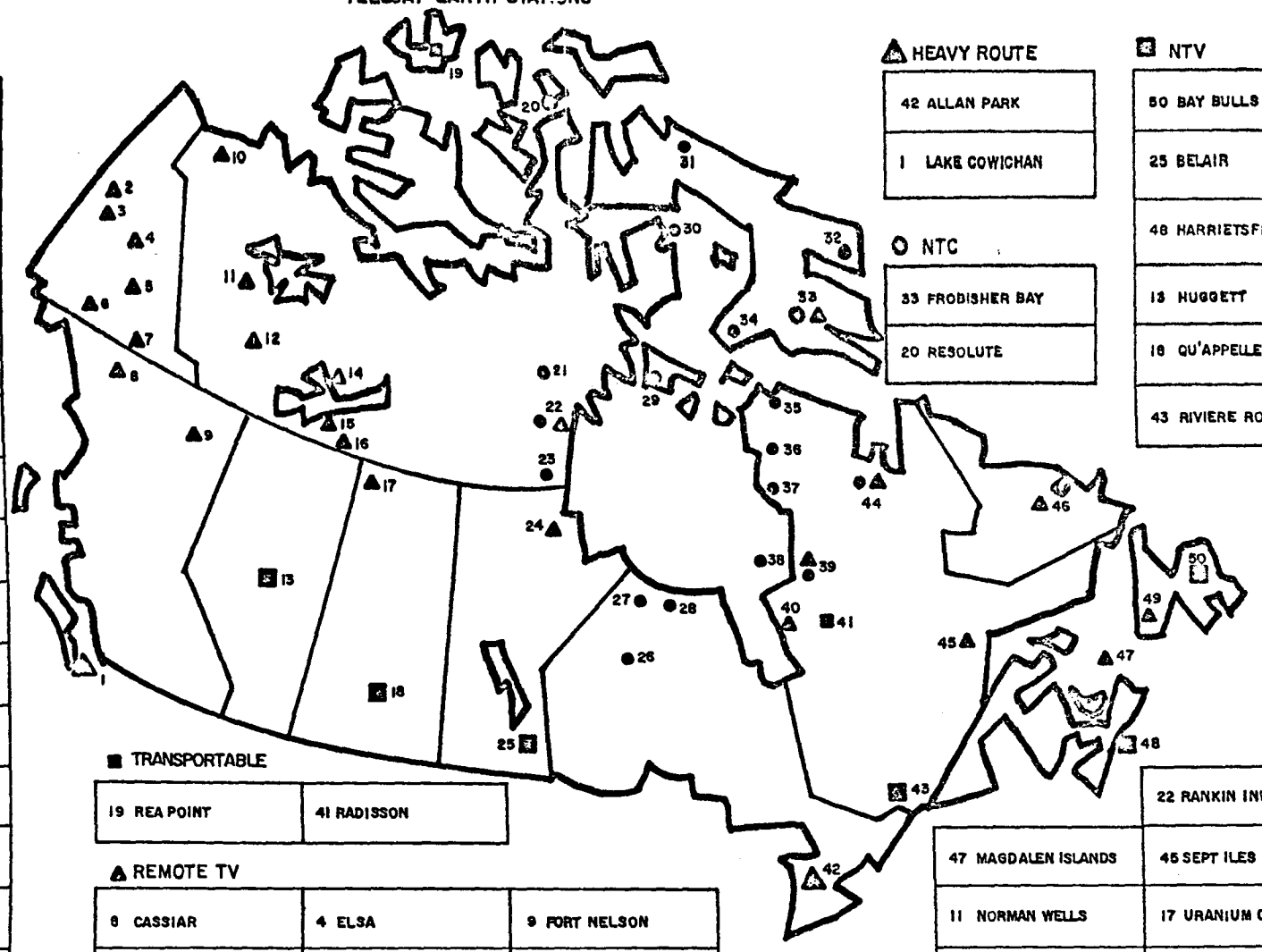
The initial planned deployment of 37 earth stations is being expanded and may be summarized as follows: (see map page 83)

TYPE	PLANNED (1974)	OPERATIONAL (at 18 Nov 1974)
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**	12
Transportable Television	2	2
Transportable Thin Route	1	1
Total	56	51

* Co-located with one Heavy Route Station

** Includes service at three Remote TV Stations

TELESAT EARTH STATIONS



● THIN ROUTE

21 BAKER LAKE	
26 BIG TROUT LAKE	
34 CAPE DORSET	
29 CORAL HARBOUR	
23 ESKIMO POINT	
44 FORT CHIMO	
27 FORT SEVERN	
30 IGLOOLIK	
32 PANGNIRTUNG	
31 POND INLET	
37 PORT HARRISON (INOUCDJOUAC)	
39 POSTE de la BALEINE	
36 POVUNGNITUK	
22 RANKIN INLET	
35 SAGLOUC	
38 SANIKILUAQ (BELCHER IS.)	
28 WINISK	

▲ HEAVY ROUTE

42 ALLAN PARK	
1 LAKE COWICHAN	

○ NTC

33 FROBISHER BAY	
20 RESOLUTE	

■ NTV

50 BAY BULLS	
25 BELAIR	
48 HARRIETSFIELD	
13 HUGGETT	
18 QU'APPELLE	
43 RIVIERE ROUGE	

■ TRANSPORTABLE

19 REA POINT	41 RADISSON

▲ REMOTE TV

8 CASSIAR	4 ELSA	9 FORT NELSON		22 RANKIN INLET	
24 CHURCHILL	5 FARO	12 FORT SIMPSON		47 MAGDALEN ISLANDS	45 SEPT ILES
2 CLINTON CREEK	44 FORT CHIMO	16 FORT SMITH	46 GOOSE BAY	11 NORMAN WELLS	17 URANIUM CITY
3 DAWSON	40 FORT GEORGE	33 FROBISHER BAY	10 INUVIK	15 PINE POINT	7 WATSON LAKE
				49 PORT AU PORT	6 WHITEHORSE
				39 POSTE de la BALEINE	14 YELLOWKNIFE

ACTIVITIES IN INDUSTRY

AIR INDUSTRIES ASSOCIATION OF CANADA LIMITED

SPACE SUBCOMMITTEE REPORT, 1974

The activities of the Space Sub-Committee brought improved awareness within industry and government agencies of the enlarging role of the satellite systems for Canada's forward development of the benefits to the country by Canadian industry participation in future Canadian satellite projects.

Under the direction of AIAC Space Subcommittee Chairman, John MacNaughton, Vice President, Marketing and Planning of SPAR Aerospace Products, a number of circles to effect this heightened awareness and promote the need for a formal Government Space Policy. The Subcommittee contended that a policy could compel firstly, the blue-printing of forward prospective satellites, and, secondly, an industry business planning response in the form of resources and developments to achieve technological readiness at the time the programs emerge for implementation.

Presentations to the Ministry of Science and Technology and the Science Council were major reflections of the industrial viewpoint. These were well and gratefully received.

In order to plan soundly for significant Canadian industry participation in early new communications satellite projects, the Space Subcommittee sponsored the application to the Department of Industry, Trade and Commerce for a $100,000 in-depth feasibility study for design and fabrication of a typical new commercial communications satellite in Canada. The resulting contract, awarded to the Toronto consulting firm of Dilworth, Secord, Meagher & Associates, involved the participation of five major aerospace companies, (RCA, Northern Electric, SPAR Aerospace, Bristol Aerospace and Canadair) and PH Lapp Limited for special technical analysis and D. Clough of Waterloo University for economic impact analysis associated with the study. The study completed at the end of 1974 gave a clear inventory of current facilities and skills in Canada for the work, and importantly, the deficit facilities and skills for each satellite subsystem to perform the typical project in a cost and schedule effective manner.

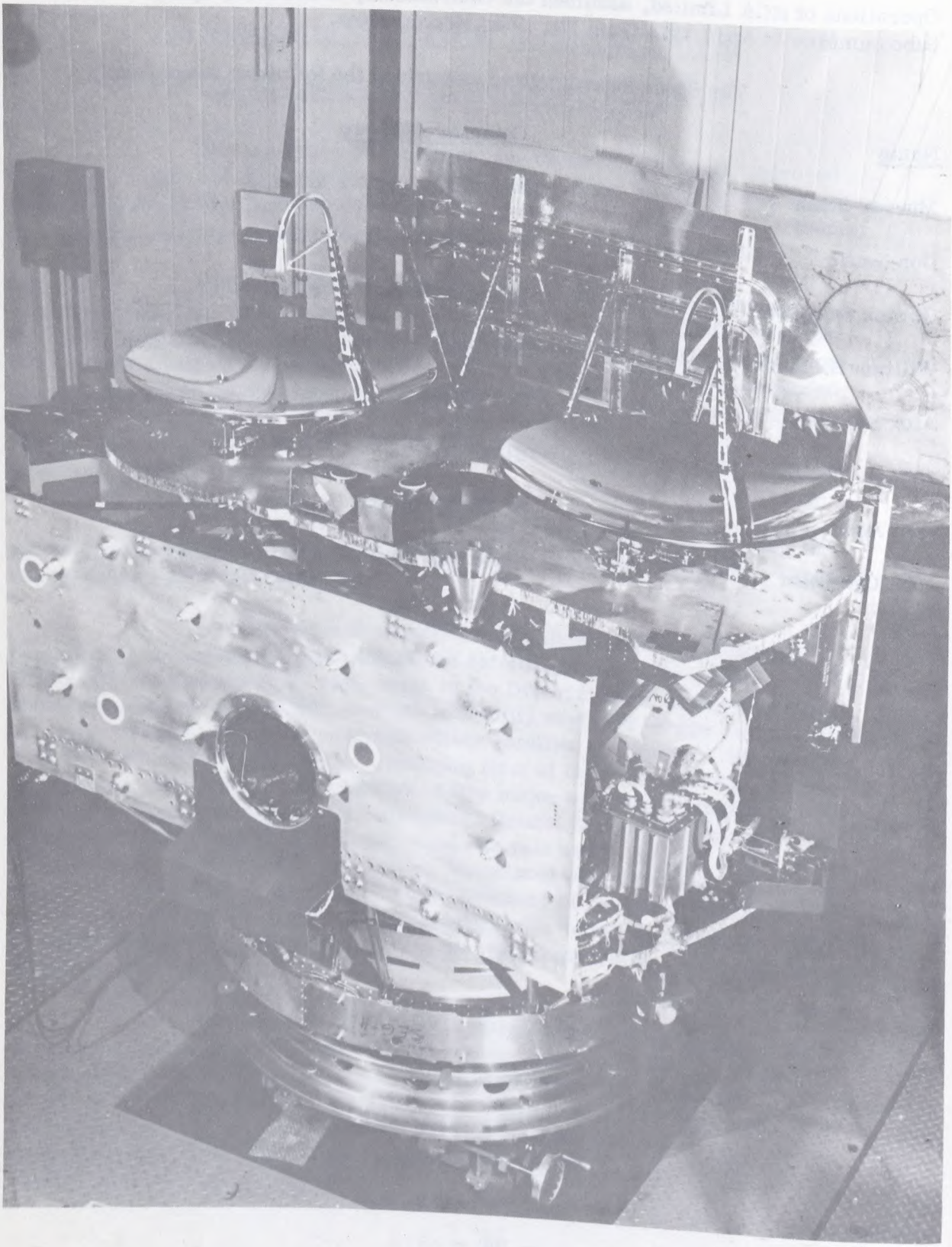
The feasibility contract - government funded, industry performed - represents a prototype in Canadian Government/Industry co-ordination and cooperation and as such was a major accomplishment of the Subcommittee. The report is expected to be very helpful both to industry and government in formulation of strategies and policies to retain, build upon and consolidate present Canadian industrial space capabilities to fulfill Canadian needs and as well as those of other countries.

John A. Collins, Manager of Program Development of Aerospace Operations of RCA Limited, assumed the chairmanship of the AIAC Space Subcommittee in April 1974 from Mr. John MacNaughton.

The Space Subcommittee comprised the following membership

Name	Company Affiliate
Murray Sloan	Bristol Aerospace Limited
Don Kettle	Northern Electric Limited
Gordon Sampson	Fleet Industries Limited
William H. Barrie	Northern Electric Limited (AIAC Rep.)
Alex Kavadas	SED Systems Limited
John A. Collins	RCA Limited
Ivan Agar	SPAR Aerospace Products Limited
John Chisholm	United Aircraft of Canada Limited

A BENCH VIEW OF THE COMMUNICATION TECHNOLOGY SATELLITE



BRISTOL AEROSPACE LIMITED

Bristol Aerospace manufactures the Black Brant family of sounding rockets, and also produces a meteorological rocket. The nine Black Brants were developed specifically for high altitude scientific research, and have been used extensively for over ten years, demonstrating high reliability and proven performance. Users range from various North American agencies to European space groups, and firings have taken place world-wide.

In addition to the production of rocket vehicles and their solid propellant, Bristol also manufactures a complete line of rocket telemetry equipment and payload support systems. The latter include various para-recovery units, despin and separation mechanisms, and different types of deployable nose fairings. Payload integration, checkout and environmental testing are carried out in the facilities of the Rocket and Space Division. Experienced range crews are available to provide field services for both vehicle and payload systems.

The following represents a summary of the activities and achievements of 1974:

- the total number of Bristol designed and built rockets launched reached 449.
- there were 20 Black Brant launchings, plus 31 metrocket firings, for a total of 51 flights.
- the global application and operational flexibility of the Black Brant was again demonstrated, this time by customer use of the two stage BB IV which was flown from locations in Norway, Peru, Greenland and Cape Parry, N.W.T. Additionally, the BB V has been launched from Churchill, White Sands (New Mexico), Alaska, Wallops Island (Virginia), and Cape Parry.
- the year saw the first scientific use of the extended length payload capability Black Brant IVB Mod 1, both by NRC and DFVLR (West Germany).
- the Peruvian BB IV firing represented the first launch of any rocket by that country, and took place at a minimum-facility remote site on the Pacific coast, south of Lima. The operation was a complete success, with excellent data acquisition by the Aerospace Corp. payload.
- in December a BB IVB and a BB VB were launched from Cape Parry, N.W.T. in support the the NRC "Polar CUSP" auroral program. Following these shots range activities commenced for the U.S. Sandia Corp., who are planning to fire two BB IVA vehicles from the same facility over the New Year period.
- NRC continued their use of the new Black Brant VI low altitude sounding rocket; three firings were made, two of which produced good data

(the third vehicle experienced a flight failure, which was corrected by a motor insulation design change).

- the highly successful BB VC "CALROC' program, in support of the NASA Skylab project, was completed.
- the U.S. Air Force launched three BB VC vehicles, each of which employed a new 46 ft. main chute para recovery system (for use with heavier payloads and/or reduction of impact velocity). All flights were 100 percent successful.
- secondary activities included development of a new high velocity (10 fps) payload separation system; design and first operational use of a recloseable payload door (to protect recovered payload sensors from damage during re-entry); and the successful first customer use of a payload "turnabout" system, for prevention of impact damage to nose tip mounted recovered payload units.
- Nike-VC development continued, with the first rescheduled for mid 1975.

In summary, 1974 saw the launching of one BB IVÀ, three BB IVB, three BB VB, ten BB VC, three BB VI and thirty-one metrockets; seven of these Black Brants were to support NRC programs with others for NASA, the U.S. Air Force, and various North American and European users.

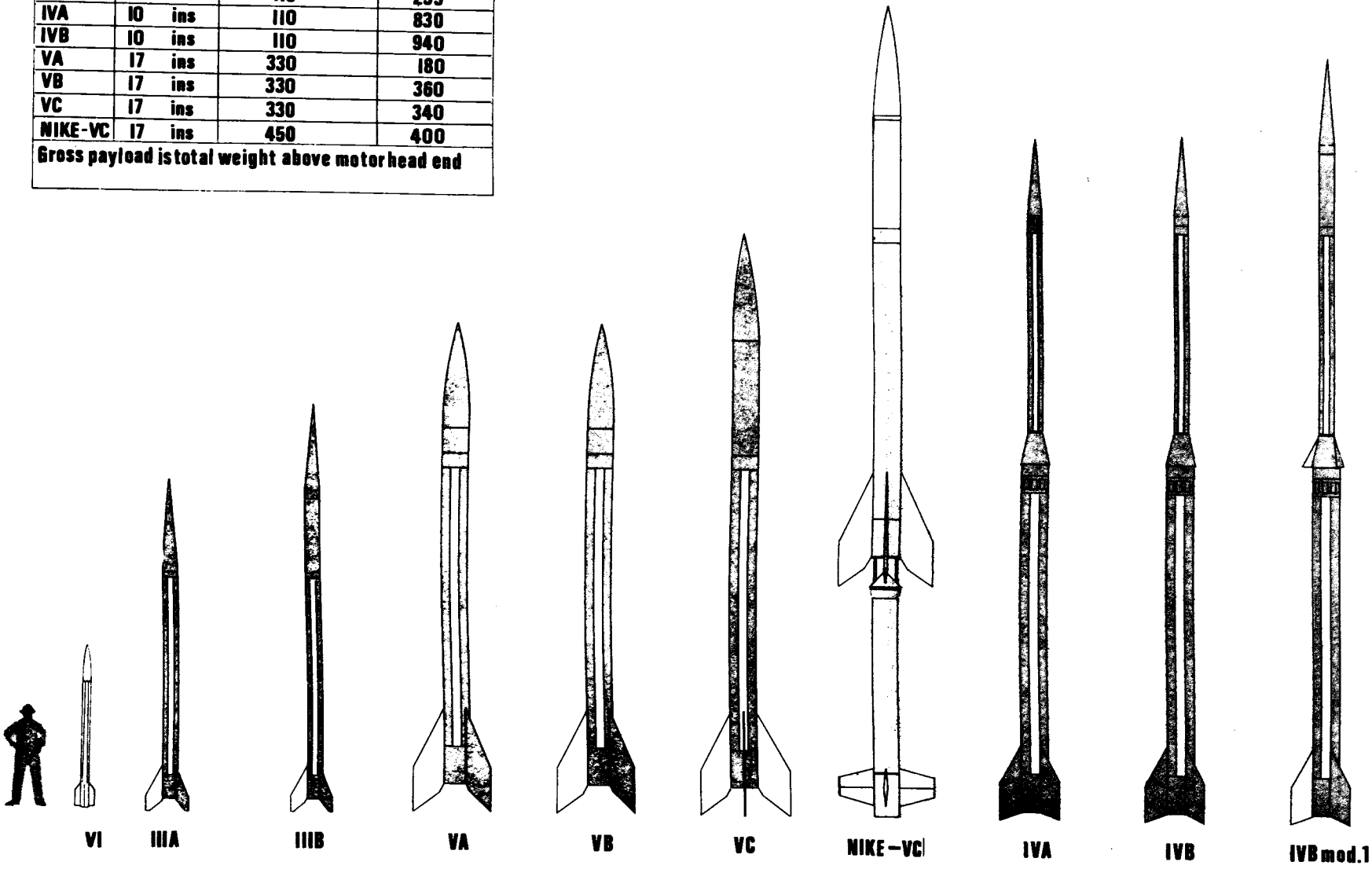
In addition to the rocket activities, Bristol is also engaged in the production of satellite components. Two major projects are now in progress. They are the design and manufacture of the command decoder and power switching unit for the Communications Technology Satellite. These units were designed and qualified through a rigid test program to meet comprehensive environmental requirements including thermal cycling, electromagnetic interference and vibration.

For the RCA Globecom U.S. domestic communication satellite system Bristol fabricated the upper deck support structure, microwave plumbing and feed horns. These components are made from advanced composite materials such as graphite epoxy and Kevlar 49 which combine properties such as high strength and light weight as well as providing dimensional stability over the wide range of temperature encountered in a space environment.

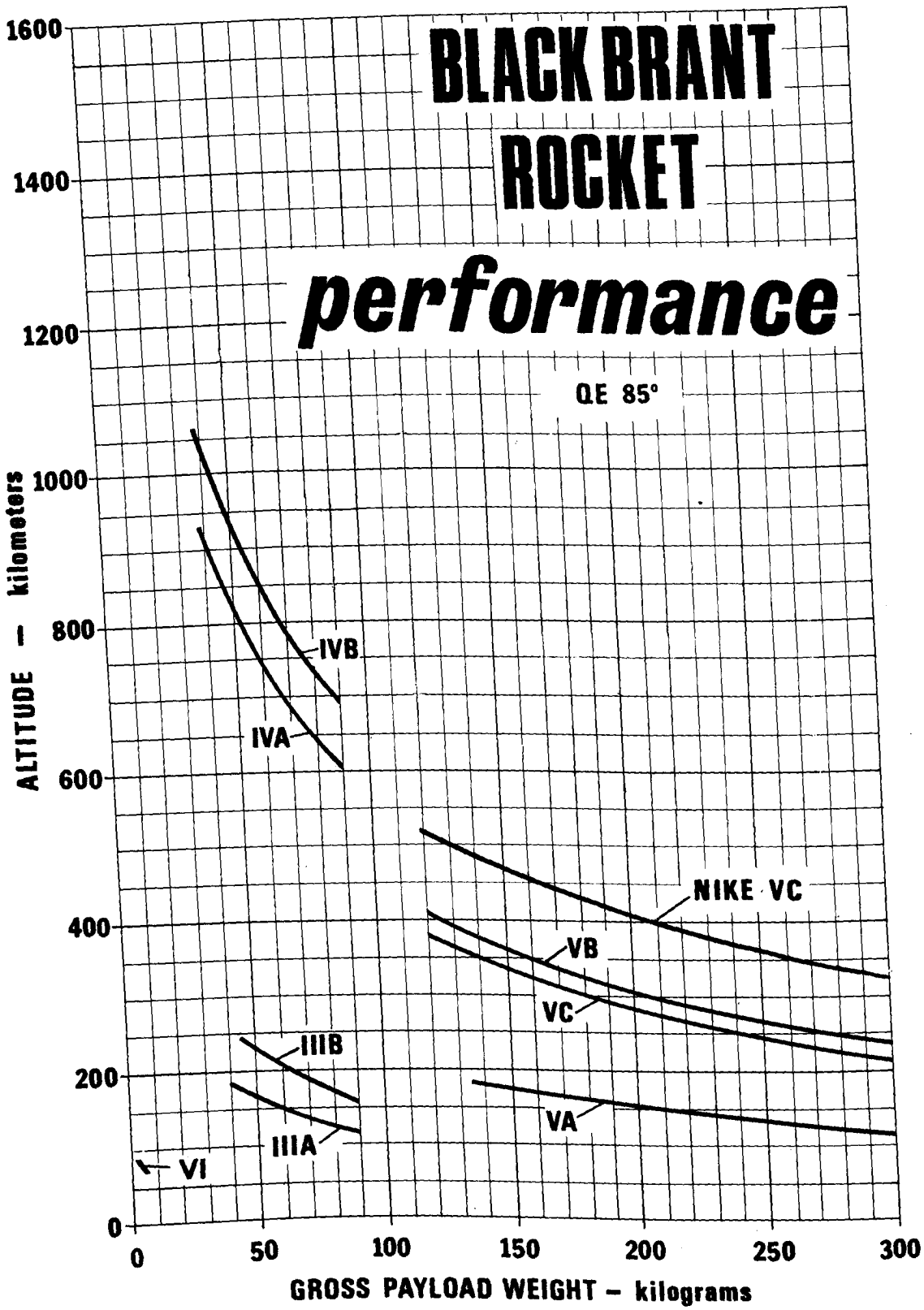
BLACK BRANT ROCKET SYSTEMS

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


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

LEIGH INSTRUMENTS LIMITED

Leigh Instruments Limited, Avionics Division, has been interested in Search and Rescue techniques, as it applies to the Canadian environment since its founding in 1961.

Since 1961 we have developed a wide range of avionic products to enhance flight and ground safety. The Company designs and manufactures emergency locator transmitters, crash position indicators, flight data recorders, and recorder locators. Our airborne data acquisition systems together with the necessary computer controlled equipment provide after-flight analysis capabilities.

The initial users of the Leigh Crash Position Indicator were bush pilots operating in Northern Canada. To date approximately 3,000 Crash Position Indicator/Flight Recorder Locator Systems have been delivered to the United States Air Force, United States Navy, Canadian Forces, The Federal Republic of Germany, and, a host of other military and commercial customers including private operators.

Leigh Instruments has also developed altimeters, radar digitizers and extractors for airtraffic control, mechanical strain and special recorders, and helicopter ice detector. The Company is interested in developing products for requirements in transportation and communications.

Progressing from our beacon capabilities Leigh has conducted a number of studies to determine the feasibility of the use of geostationary satellite(s) for Search and Rescue activities.

The conclusions reached in one study were based primarily on the requirement for location of downed aircraft in all parts of Canada, and, those parts of Canada, and of the Atlantic and Pacific Oceans assigned to Canadian responsibility by ICAO.

The Engineering Study for a Canadian Satellite Alarm and Position Reporting System showed that systems using a geostationary satellite(s) in conjunction with survivor type emergency locator transmitter for SAR purposes are feasible, and, may be capable of supporting practical systems which could increase the effectiveness of Search and Rescue operations.

The actual level of effectiveness achievable for both automatic deployable, and, survivor type beacons is however not readily definable, and requires further investigation and experimental studies.

Leigh Instruments Avionics Division, will continue in the future to contribute its capabilities to the field of telecommunications by

satellite. The future growth of the satellite will involve many factors. The political, social, and economic factors in the next quarter of a century will dictate communication needs, which, in turn will determine the role of satellites. One thing is certain, satellites in the future will affect the lives of all Canadians.

Leigh Instruments Limited, is prepared to make its contributions to the significant role that satellites will play in communications of the future.

NORTHERN ELECTRIC COMPANY LIMITED

General

The space activities of Northern Electric are carried on at the Lucerne, Quebec facility. Ground communication equipment used in satellite earth station systems is manufactured in the transmission manufacturing facilities in Montreal.

Canadian Domestic Satellite

The electronics "payload" of two ANIK spacecraft for Telesat were operating successfully in orbit and the third tested in preparation for a planned February 1975 launch.

U.S. Domestic Satellite Systems

Two of four satellites for Western Union were operating successfully in orbit and an additional two sets of electronics completed for future launches into the Western Union System.

Spacecraft telemetry and travelling wave-tube amplifiers were also produced for the ATT/COMSAT U.S. Domestic System.

Intelsat Satellites

A large amount of equipment for the Intelsat IV-A satellites is also being produced at Lucerne. This equipment consists of digital telemetry, travelling wave-tube amplifiers and microwave receivers.

Satellite Earth Station Equipment

Broadband 4 GHz parametric amplifiers were designed and manufactured for use in the Telesat Thin Route Earth Stations. Considerable effort has been expended on studies to reduce the cost of these low noise amplifiers.

Earth station multiplex equipments, echo suppressors and back-haul microwave were designed and supplied to Canadian, U.S. and foreign systems.

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

Introduction

RCA Limited maintains separate business centers for satellite activities and satellite earth stations, each with dedicated engineering, manufacturing and marketing functions for sales to the domestic and export markets. The Communications and Space Technology Laboratory of the company's R & D Laboratories at Ste-Anne de Bellevue provides research support to both business centers.

Satellites

Space segment work at RCA Limited started in 1961 with the design and supply for RCA Astro Electronics of the transponder system for the NASA-sponsored pioneer RELAY communications satellite; and matured in the 1962 to 1970 period by major engagement on a succession of scientific satellites - Explorer XX, Pegasus, Alouette I & II, ISIS I & II. The Alouette and ISIS satellites were jointly funded NASA/Canada programs for upper atmosphere exploration wherein RCA Limited was the prime contractor for the ISIS series. RCA Limited specialization in design and supply of the transponder and antenna subsystems of new generation communications satellites established a strong growth pattern of the company's space activities throughout the 1970 decade. Two of these satellites were the NASA/Canada/ESRO 12/14GHz Communications Technology Satellite (CTS) and the RCA Satcom 24-channel, 3-axis stabilized satellite for 4/6GHz U.S. domestic service by RCA Globcom/RCA Alascom. Approximately $50 million of satellite work has been performed by the company to the end of 1974.

RCA Limited's satellite facility, located at Ste-Anne de Bellevue, Quebec, engages a staff of 320, of which 175 are scientists, engineers and technicians. The RCA participation of the CTS program included the design and integration of the transponder subsystem based upon ESRO supply of the parameter amplifier (GTE Milan) and 20 watt travelling wave tube amplifier (Thomson-CSF) and NASA supply of the 200-watt amplifier (Litton); and design and supply of the TT&C, communications antenna, power conditioning and attitude control electronics subsystem.

A feature of the company's transponder product is the use of light weight graphite fibre epoxy composite material for input and output multiplexer units, waveguide components and antenna feed tower structural members. The company pioneered the use of a dual polarized frequency re-use antenna system using gridded reflectors in a commercial satellite program. The 24-channel, 4/6 GHz transponder produced by RCA Limited has an advanced design using a solid state amplifier driving all TWTA's.

RCA Limited, individually and in co-ordination with its associated space facility, RCA Astro Electronics of Hightstown, N.J., has forwarded plans for participation in a variety of future space communications projects.

Satellite Earth Stations

RCA Limited is one of the world's major contractors for the supply of satellite earth stations - 40 complete stations and major subsystems in 47 other stations in the span of the last 11 years, representing a dollar output of products and services in excess of $72 million. The company represents the RCA Corporation in the design, manufacture, installation and marketing of commerical satellite earth stations for the world market and engages a technical work force for this work of over 100 engineers and technicians.

Following completion of two 30-meter terminals for the Peoples Republic of China in 1973, the company in 1974 completed the 30-meter intelsat terminal in Bangladesh, an 11-meter TV receive terminal for Haiti, and an extensive augmentation program of C.O.T.C.'s Mill Village, No. 1 earth station facility in Nova Scotia, and commenced work on an intelsat terminal for Haiti.

The company commended work on supply of 18 12/14GHz terminals for operation with the Communications Technology Satellite in 1974. The program represents fulfillment of 12/14GHz earth station development work carried out over several years. The terminals are a mixture of 1-meter and 3-meter antenna diameters for radio programming and TV reception respectively with facilities for telephony in both types of terminals.

The development of and first production run of a line of Ground Communications Equipment (GCE) using micro-electronics circuitry was completed in 1974 and incorporated in several earth stations.

Antenna feed system work was directed to low cost systems for application to domestic satellite systems. Emphasis was placed on refinement of frequency re-use feeds for application to 24-channel systems such as being built for RCA Global Communications and AT & T.

Research

The RCA Limited Research Laboratories in Montreal have been active in aeronomy and space physics for many years. This work has continued during 1974. The following is a brief summary of the major projects carried out by the laboratories.

Personnel from the laboratories have contributed to early systems and trade-off studies for Satcom, RCA's US Domestic Communication Satellite. A trade-off study comparing transistor amplifiers and the driver TWT for use in the transponder was carried out. Changes in the transponder configuration were recommended to optimize the system with the transistor amplifier. In addition 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. Work on UHF satellite systems continued during 1974 with a system study on moderately inclined orbits and a trade-off study on a new transponder concept.

A number of projects have been carried out during 1974 to investigate multiple access techniques, modulation and demodulation techniques and data switching techniques that would be suitable for thin route satellite communications systems in general and UHF satellite communication systems in particular.

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 ground 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 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.

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.

A research program has been carried out on a low intermodulation mode of operation of a transistorized amplifier. This mode was discovered by the Research Laboratories. By properly adjusting the input and output impedance and the bias, the intermodulation noise level can be sharply reduced with only a slight penalty in efficiency compared to a class C amplifier. This effect has been demonstrated for 2 GHz at the one watt level and for 300 MHz at the 50 watt level. Extensive measurements were carried out to compare the performance of low intermodulation and class C operation. Systems calculations were performed in order to determine the conditions in which a low intermodulation transmitter will out perform a class C transmitter in a satellite transponder application. This work is being continued.

SED SYSTEMS LTD.

SED Systems is an electronics and space engineering corporation wholly owned by the University of Saskatchewan.

The Company is engaged in CTS ground control software development and is training a team for the attitude acquisition operation of the CTS satellite. Under construction now for the CTS program are two transportable earth stations.

SED has also contracted to build 6 remote television earth stations and 6 television receive systems for existing earth stations for Telesat Canada.

For rocket payloads and balloon payloads a variety of products have been developed:

- DC-DC Converter Systems
- PCM Telemetry Systems
- Extend-Retrack Devices for Experiment viewing control
- Deployable boom systems, electrical and hydraulic control
- Payload skins, nose cones and clamshells, custom designed to optimize payload requirements
- Telemetry receivers, FM demodulators and analog to digital converters compatible with the PCM telemetry systems allow experiments that were ejected from the payload to radiate telemetry signals back to the payload for retransmission via the payload main telemetry PCM link to ground. Expected advantages will be an improved signal. No requirement for remote telemetry PCM link to ground. Expected advantages will be an improved signal. No requirement for remote telemetry receive stations and enhancement to data reduction.
- Payload design, instrumentation, checkout and launch support capabilities (have crew will travel) balloon projects
- Azimuth and Zenith payload control systems for balloon projects
- Ram Sensors
- TDS Telemetry data reduction capabilities

Projects planned for the coming year include:

- VB-43 - Launch from CRR - January 1975

- VB-42 - Launch from Australia - October 1975

- VB-44 - Launch from CRR - January 1976

- VB-45 - Launch from CRR - January 1976
  (This is the fourth flight for this payload. It was previously flown as ADD-II-114, 127 and 128 and was recovered three times.)

- AES Balloon - Flown twice in tne summer of 1974 and will be flown three times in August 1975 from Yorkton, Saskatchewan.

SPAR AEROSPACE PRODUCTS LTD.

Spar Aerospace Products Ltd. 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, Japan and Norway. More than 500 space mechanisms have been launched aboard satellites and sounding rockets from most of these countries.

Almost half of Spar's business in 1974 can be attributed to space programs. A good portion of the work was associated with Canada's Communications Technology Satellite (CTS) program as summarized below. Other noteworthy programs include American experimental satellites, sounding rockets, and the Space Shuttle.

1. Research & Development

(a) Composites

A current study is analyzing high performance composites including thin graphite filament rein-forced resin structures. Methods for joining composite structures is being investigated.

(b) Solar Arrays

Spar is conducting a design study of deployable, rigid solar arrays for three-axis stabilized spacecraft. These arrays are in the 500-1000 watt power range which is typical for small satellites launched aboard Thor Delta 2914/3914 launch vehicles.

Spar and AEF- Telefunken, Germany, are developing a 5 KV deployable solar array for the German Government (GFW). Spar's responsibilities include the deployment system.

2. Communications Technology Satellite

Spar is responsible for the design, hardware fabrication and integration of major CTS subsystems:

Structure
Thermal Control
Attitude Control
Solar Array Power Generation

(a) Structure

Following vibration tests of the dynamic model, design and fabrication alterations were made to reflect the revised flight payload layout. The Engineering Model and Proto/Flight hardware has been delivered to the Communications Research Centre (CRC) for integration. Vibration of the complete spacecraft to flight levels is scheduled for March 1975.

(b) Thermal Control

Following the Thermal Model tests, the thermal control system was revised in response to the latest heat dissipation data of the various components. The thermal blankets' design and fabrication methods were maximized to achieve ultimate performance.

The south panel was tested for thermal balance at NASA with the 200 watt Transponder Experimental Package and Heat Pipe system. Test results confirm the design of the south panel and its thermal blanket. Final hardware preparations are underway for the Engineering Model Thermal Balance tests early in 1975.

(c) Attitude Control

The Engineering Model has completed its qualification testing and has been installed in the Engineering Model spacecraft. Currently, flight hardware is being delivered to CRC where acceptance testing is underway.

(d) Solar Array

Vibration and thermal vacuum tests were carried out at the system level at CRC and NASA-Lewis Research Center. The qualification model will be installed into the Engineering Model spacecraft for further vibration tests in early 1975.

Flight hardware construction is nearing completion with thermal vacuum tests scheduled for February 1975.

(e) Integration and Flight Support

Spar is providing engineering support to CRC for the spacecraft integration and flight phases of the program.

3. Remote Manipulator Systems (RMS)

Conceptual studies, conducted in conjunction with NASA-GSFC on the Special Purpose Manipulator System (SPMS) for the EOS (Earth Observatory Satellite) series of spacecraft, reached an advanced stage. A full scale working model of the manipulator was built and checked out with the spacecraft at NASA-GSFC, prior to being shipped to California for integration into the Shuttle orbiter mock-up where it will undergo astronaut evaluation tests.

Spar undertook further systems and design studies relating to the anthropomorphic Remote manipulator System to be installed on the Shuttle orbiter for the purpose of deploying and retrieving payloads. These studies are related in part to possible Canadian participation in the U.S. Shuttle program. In this work, Spar has received considerable technical assistance from its team made up of CAE Electronics Ltd., RCA Ltd., and Dilworth, Secord, Meagher & Associates.

Technologies gained from these programs are being applied to future requirements in underwater, mining, and nuclear fields.

4. MJS-77

Spar is supplying 30 ft. deployable antennae to the University of Colorado for their Radio Astronomy Experiment which will be launched aboard the MJS (Mars-Jupiter-Saturn) Flyby in 1977.

5. Sounding Rockets

Spar continues to supply a large quantity of orthogonal STEM (Storable Tubular Extendible Member) antenna arrays to NASA-GSFC for their Javelin and Nike-Tomahawk sounding rocket programs.

TABLE 1

DETAILS OF ROCKET LAUNCHINGS AND EXPERIMENTS - 1974

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
AMD-VB-34	340.8	CRR 0006:50 CST 23/1/74	87.0	207	T+230.2	2.0 approx.	Normal	At night 15-20 kilo-rayleighs aurora	Photometers (8) Resonance Absorption Photometer Spectrometer Spin Probes Spectrometer Plasma Probes Electromagnetic Probe UV Photo Detector Photometer	G. G. Shepherd R. A. Young F. R. Harris E. Ziph A. Kavadas D. J. McEwen A. G. McNamara " J. E. Mentall E. J. Llewellyn	Good data obtained SRFB 084
AAF-IVB-31	86.6	CRR 2201 CST 13/2/74	83.5	662	T+422	3.6/0.3 approx.	Normal	At night with quiet auroral arc on trajectory	Energetic particle detector Electric Field Probes (2) Plasma Probes (3)	B. A. Whalen A. Kavadas A. G. McNamara	Good data obtained SRFB 085
ADD-II-128	228.5	CRR 2300 CST 21/2/74	79.9	132	T+174	0.65	Normal	Solunar darkness with 20 kilorayleighs of aurora or more	Vacuum Ultraviolet Spectrometer Electron Spectrometer Forward-Looking VUV Photometer Up and Down Looking Photometer MK4 Auroral Scanner Forward-Looking Photometer Side-Looking Photometer Ejected Plasma Probe Swing Out Plasma Probe Side Plasma Probe Forward Looking Photometer Downward Looking Photometer	D. J. McEwen " " " C. D. Anger E. J. Llewellyn " A. G. McNamara " " G. G. Shepherd D. J. McEwen	Good data obtained SRFB 086
AKF-VB-39	265	CRR 2053 CST 27/2/74	78.6	246	T+250	4.45/ 0.94	Normal	Solunar darkness with 2-11 kilorayleighs of aurora	Auroral Scanner Energetic Particle Detector Electric & Magnetic Field Probes Plasma Probes (3) Electron Beam Fluorescent Probe Ionization Gauge Aerodynamic Spectrometer Soft Electron Spectrometer Secondary Photometer Ground Based at Gillam Neutral Hydrogen Spectrometer	C. D. Anger B. A. Whalen A. Kavadas J. Koehler J. Robar A. G. McNamara J. de Leeuw W. E. R. Davies J. de Leeuw D. J. McEwen G. G. Shepherd F. Creutzberg W. Bernstein	Good data obtained SRFB 087

TABLE 1

DETAILS OF ROCKET LAUNCHINGS AND EXPERIMENTS - 1974 (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
AAF-VI-02	3.2	CRR 1056 CST 22/3/74	85.2				Normal until T+10 sec	Daytime conditions suitable for recovery	Dust Collector	R. Wlochowicz	No results due to failure of the rocket at T+10 sec. SRFB 088
AAF-VI-04	3.2	CRR 0930 CST 26/3/74	84.2	80.7	T+130		Normal	Daytime conditions suitable for recovery	Dust Collector	R. Wlochowicz	Some data obtained SRFB 088
AAF-VI-03	12.28	CRR 2231 CST 22/4/74	82.6	59.8	T+115	25	Normal	At night during lunar darkness and auroral activity	Auroral X-ray Detector	D. Venkatesan	Limited data obtained SRFB 089
AMF-VB-41	190 approx	Cape Parry 2322 GMT 6/12/74	DETAILS NOT YET AVAILABLE					Dayside aurora	Auroral photometers Spectrophotometer Electron Temperature Probe Soft Electron Spectrometer (Lyman Alpha) Plasma Probes Twin Photometer Energetic Particle Detector	G. G. Shepherd W. F. J. Evans K. Hirao D. J. McEwen A. G. McNamara G. Monfils J. C. Gerard B. A. Whalen	In conjunction with AAF-IVB-32 Good data obtained SRFB 092
AAF-IVB-32	75 approx	Cape Parry 2249 GMT 11/12/74	DETAILS NOT YET AVAILABLE					Dayside aurora	Energetic Particle Detector Plasma Probes Secondary Photometer	B. A. Whalen A. G. McNamara G. G. Shepherd	In conjunction with AMF-VB-41 Good data obtained SRFB 093

TABLE 2

ROCKETS AND EXPERIMENTS PLANNED FOR 1975 & 1976

Vehicle No.	Pr. Scientist	Engineering	Launch Period	Conditions	Experimenters	Experiments	Remarks
AED-VB-43	DeLeeuw	SED	Early 1975 CRR	Less than 10 KR of aurora and moon	DeLeeuw Visentin Harris Koehler Wlochowicz	Electron Beam Fluorescence Probe Ion Probe Aerodynamic Spectrometer Photometer Spin Probes and Ram Sensors Ejected Acoustic Detector	Recovery
APD-VB-42	Wilson	SED	Late 1975 Woomera	Full moon and quiet conditions	Wilson Nicholls Koehler McNamara	Cosmic X-rays Lunar Reflectance Ram Sensor Plasma Probes	(COSRAY 75) Attitute Control System and Recovery
AMD-VA-35	Young	SED	Late 1975 or Early 1976 CRR	Quiet and solunar darkness	Young Shepherd Zipf McNamara McEwen	Stimulated Fluorescence Photometer Mass Spectrometer Plasma Probes VUV Spectrometer	Recovery
AAF-IVB-33	Whalen	BAL	1st quarter, 1976 CRR	Early evening auroral arc	Whalen Koehler McNamara	Particle Detector Spin Probes Plasma Probes	
AND-VB-44	Gush	SED	1st quarter, 1976 CRR	Quiet, solunar darkness	Gush	Cosmic Infrared Detector	Recovery
ADD-VA-45	McEwen	SED	1st quarter, 1976 CRR	Visual aurora intensity II or greater	McEwen Koehler Llewellyn McNamara Anger	Spectrometers and Photometers Spin Probes Photometers Plasma Probes Optical Measurements	Recovery Refly of ADD-II-128
AQF-VI-05	Forsyth	BAL	1st quarter, 1976 CRR	Visual aurora	Forsyth	Coherent Pulse Radar	
AQF-VI-06	Forsyth	BAL	1st quarter, 1976 CRR	Visual aurora	Forsyth	Coherent Pulse Radar	
AKF-VI-07	Venkatesan	BAL	1st quarter, 1976 CRR	Active conditions	Venkatesan	Auroral X-rays	Repeat of AKF-VI-03
AKF-VI-08	Venkatesan	BAL	1st quarter, 1976 CRR	Active conditions	Venkatesan	Auroral X-rays	Repeat of AKF-VI-03
AED-VB-46	DeLeeuw	SED	2nd quarter, 1976 CRR	Less than 10 KR of aurora and moon	DeLeeuw Harris Koehler Visentin	Electron Beam Fluorescence Probe Ion Probe Photometer Spin Probes and Ram Sensors Aerodynamic Spectrometer	Refly of AED-VB-43

ABBREVIATIONS

ACS	Attitude Control Systems
AECL	Atomic Energy of Canada Ltd.
AES	Atmospheric Environment Services
AFCRL	Air Force Cambridge Research Laboratories (U.S.)
AIAC	Air Industries Association of Canada
AIW	Auroral Infrasonic Waves
ANIK	Eskimo name for brother
ARCOM	Arctic Communications Station
AU	Astronomical 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
BCD	Binary Coded Decimal
CAE	Canadian Aviation Electronics
CANTAT	Canadian Atlantic Telephone Cable
CARDE	Canadian Armament Research and Development Establishment
CCRS	Canadian Centre for Remote Sensing
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
CTS	Communications Technology Satellite
DBS	Direct Broadcast Satellites

Abbreviations (Continued)

DCBRE	Defence Chemical & Biological Research Establishment
DFVLR	Deutsche Forschungs-und Versuchsanstalt fur Luft-und Raumfahrt
DNA	Defence Nuclear Agency (U.S.A.)
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)
EMR	Department of Energy, Mines and Resources
EOS	Earth Orbiting Satellite
ERTS	Earth Resources Technology Satellite
ESRO	European Space Research Organization
ESSA	Environmental Science Services Administration (Now NOAA)
EW	East West
GMT	Greenwich Mean Time
GPL	Gross Payload
GSC	Geological Survey of Canada
GSFC	Goddard Space Flight Center
IAGA	International Association of Geomagnetism and Aeronomy
IGY	International Geophysical Year
IMP	Interplanetary Monitoring Platform
INTELSAT	International Communications Satellite Consortium
IQSY	International Year 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

Abbreviations (Continued)

Laser	Light amplification by stimulated emission of radiation
LES	Lincoln Experimental Satellite
Maser	Microwave amplification by stimulated emission of radiation
Met	Meteorological
MORP	Meteorite Observation and Recovery Program
MTS	Meteoroid Technology Satellite
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
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
RMS	Remote Manipulator Systems
S^3	Small Scientific Satellite
SEC	Secondary Electron Conductor
SED	Space Engineering Division
SKYLAB	Space Laboratory
SN	Super Nova
SPADE	Single PCM Multiple Access Demand Equipment

Abbreviations (Continued)

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
TDMA	Time Division Multiple Access
TELESAT	Telecommunications Satellite
TIROS	Television Infrared Observational Satellite
TOS	TIROS Operations System
TRIAD	Navigational Satellite
TT&C	Telemetry Tracking and Command
TWT	Travelling Wave Tube
UNGA	United Nations General Assembly
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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