INTERDEPARTMENTAL COMMITTEE ON SPACE

Fourth Annual Report
9 April 1973

Your file Votre référence

Our file Notre référence

April 9, 1973

The Hon. Mme Jeanne Sauvé,
Minister of State for Science & Technology,
Confederation Building,
Room 405,
Ottawa, Ontario

Dear Mme Sauvé:

Interdepartmental Committee on Space
Annual Report - 1972

I have the honour to submit to you the Annual Report of the Interdepartmental Committee on Space for the year 1972.

Yours sincerely,

J.H. Chapman,
Chairman,
Interdepartmental Committee
on Space

Encl.

100 Metcalfe Street
Ottawa, Ontario
K1A 0C8

100, rue Metcalfe
Ottawa, Ontario
K1A 0C8

ANNUAL REPORT

INTERDEPARTMENTAL COMMITTEE ON SPACE

ANNUAL REPORT - 1973

1. Introduction

The Interdepartmental Committee on Space has met formally only once during the year. Its members have, however, cooperated in the handling of a number of problems facing the Federal government in the field of Space Technology. The future of the Committee and its relation to the Ministry of State for Science and Technology remain to be finally decided, but it appears probable that, with some minor revisions to its membership and terms of reference, it will continue as a coordinating body, advisory to the Minister of State for Science and Technology.

The Sub-Committee on International Aspects of Space has continued to be active and to serve an indispensable role in organizing and presenting Canada's position at International Space Meetings primarily those of the UN Committee on the Peaceful uses of Outer Space, its Sub-Committees and working Groups.

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

2. International Space Activities

Canada particiapted in the Fifteenth Session of the UN Committee on the Peaceful Uses of Outer Space. Among the matters considered at that session were a draft Moon Treaty, a draft Resolution on Direct Television Broadcasting from satellites submitted to the UN General Assembly by the USSR, and a Canadian draft Convention on the Registration of Objects Launched into Space. In the Legal Sub-Committee, which met in April in Geneva, the Canadian delegation tabled a draft Convention on the Registration of Objects Launched into Outer Space and worked to combine it with an earlier draft submitted by France to produce a joint text which was given detailed consideration by a working group of the whole.

In the Scientific and Technical Sub-Committee, which met in New York in May, Canada participated actively in discussions of remote sensing from space and assisted the UN Secretariat in the preparation of a background document on the subject.

On the recommendation of the Committee on the Peaceful Uses of Outer Space, the UN General Assembly agreed, at its 1972 session, to a Canada/Sweden proposal that the Working Group

on Direct Broadcast Satellites should be reconvened in 1973 to review new developments in the field.

Other international activities have included an exchange of notes between the Government of Canada and the European Space Research Organization concerning cooperation on advanced space technology, and an exchange of notes providing for the establishment and operation of a temporary space tracking facility by the United States Government in Newfoundland for use in connection with NASA's SKYLAB project.

3. The Post-Apollo Situation

The problem of what paticipation, if any, Canada should have in the space shuttle program continues to confront us. Other countries face the same situation. The U.S. has now designated North American Rockwell as the prime contractor for the program.

During the past year efforts have focussed on a proposal by SPAR Aerospace Products Ltd., teamed with Dilworth, Secord, Meagher and Associates Ltd. (DSMA) to develop and manufacture the Shuttle Attached Manipulator System (SAMS) of the Space Shuttle Orbitor Vehicle. It is clear that the Post-Apollo program will rely heavily upon remote manipulation. It is also apparent that remote manipulators will see increasing use in non-space areas such as nuclear power generation, oceanology, mining and in surgery and prosthetics.

4. Space Communications (Domestic)

The first phase of the satellite program culminated with the successful launching of the Telesat Anik-1 Satellite from Cape Kennedy on 9th November 1972. Injection into circular orbit was accomplished on 13th November with the firing of the Apogee Motor in response to a command from the Satellite Control Center in Ottawa.

The satellite arrived at its designated location of 114°W longitude on 24th November and communications tests indicated satisfactory performance. During this period, final acceptance tests were being conducted on the second Telesat spacecraft, Anik-2, which is scheduled for launching in mid-April 1973. The third Telesat satellite is also expected to undergo final acceptance testing in April 1973.

Steady progress was made in 1972 towards the completion of the initial network of thirty-five ground stations and by the end of the year all stations were essentially completed and ready for service. Beyond the initial 35 earth station network, a major expansion activity is foreseen through the

.../3

implementation of the thin route system. This system is designed to provide up to eight voice channels to small remote communities utilizing single voice channel per carrier frequency division multiple access techniques.

5. Space Communication (International)

The Canadian Overseas Telecommunication Corporation (OTC) has now two fully commercial satellite communication earth stations operating on both the East and West Coast of Canada. The new station located near Lake Cowichan on Vancouver Island is now operating via Intelsat IV satellite over the Pacific Ocean and is presently in direct communication with Australia, Japan, Hong Kong and the Philippines with plans in the near future to include 3 more destinations.

The recently up-dated station on the East Coast of Canada, the Mill Village earth station complex, is presently operating with Intelsat IV over the Atlantic and is in communication with 11 countries.

6. Communication's Research

The Department of Communications in cooperation with NASA in the U.S.A. and ESRO in Europe is developing the Communications Technology Satellite (CTS). The general objective of the project is to advance the state-of-the-art in spacecraft and related ground-based technologies in Canadian industry, relevant to future communication and to other satellite applications systems. Of particular importance will be the investigation of capability of a high-power repeater satellite to provide two-way voice communications and FM broadcasts for communities with low-cost ground terminals, particular in remote areas in Canada.

The Department of Communication is responsible for the design construction and test of the spacecraft and the subsystems. NASA will provide the launch vehicle and certain other spacecraft components and will carry out the launch. ESRO will provide a number of the spacecraft components. The launching into geosynchronous orbit is scheduled for late 1975.

7. Remote Sensing

In 1972-73, the principle space-oriented activity of the Canada Centre for Remote Sensing has been the ERTS program. This involves the readout of Canadian imagery from the United States' National Aeronautice and Space Administration's Earth Resources Satellites, the first of which, ERTS-1, was launched on July 23, 1972. The satellite contains two

imaging systems: a 3-Camera Return Beam Vidicon System (essentially high resolution television), and a four spectral channel Multi-Spectral Scanner, both of which cover a swath along the ground 185 km wide and provide complete repetitive coverage every 18 days. To read out the Canadian data, an existing 85-foot parabolic dish antenna system at Prince Albert, Saskatchewan was converted with appropriate tracking and recording facilities. A ground Data Handling Centre which can process both ERTS and certain airborne remotely sensed data was established at Ottawa.

ERTS imagery is produced as both black and white and colour composite images each encompassing an area 185 km by 185 km. There are usually four orbits and 60-65 scenes per day over Canada, and the entire country can be covered in approximately 1100 images. Users can order copies of the imagery through a computer-based inventory and ordering system. It is expected that standing orders for ERTS imagery will exceed 250 in 1972-73, ranging in coverage requested from a small section of one province in one spectral band to the whole country in several. The reproduction and distribution of ERTS imagery is handled by the National Air Photo Library, whose Reproduction Centre is located in the same building as the Canada Centre for Remote Sensing.

In addition, ERTS-1 has the ability to re-transmit data which has been collected by remote data collection platforms, and there are currently 20 of these in Canada, deployed by user agencies in various disciplines and being operated on an experimental basis. Working both independently and in support of ERTS is the Airborne Sensing Program. This is operated through the Canadian Forces Airborne Sensing Unit, which utilizes four aircraft fitted out with a flexible complement of photographic and electronic sensors. It is expected that about 55,000-60,000 line miles will be flown for user agencies in both 1972-73 and 1973-74.

8. International Aeronautical Satellite (AEROSAT)

Jurisdictional problems within the U.S. administration have prevented any progress in this program during the year. It now appears, however, that the program will be re-started in modified form, and on the basis of a new memorandum of understanding between the U.S. and ESRO. Canada's participation will be re-considered in the light of these new developments. Meanwhile, a cooperative study program, jointly undertaken by the MOT and DOC in support of the Aerosat Concept has continued in 1972.

9. Programs of the NRC, Canadian Universities and Canadian Industry

The space and upper atmosphere projects of the NRC, Canadian Universities and Canadian Industry are covered in the NRC's Annual Report on "Space and Upper Atmosphere Programs in Canada", a copy of which is attached as an appendix. Since the NRC Report also covers Federal government activities in space, there is some overlap with the text of this report.

10. Summary of Expenditures

A summary of Federal government expenditures on space science activities is appended. This summary does not include expenditures by industry (e.g. Telesat).

Statement of Federal Government Expenditures on Space Activities

($ Millions), 1972-73 and 1973-74 (estimated)

Department of Communications	1972-73	1973-74
Spacecraft Technology and Satellite Operations	17.860	18.038
Satellite Communications Systems	2.244[1]	3.153[2]
Scientific Research Utilizing Satellites and Rockets	0.500	0.500
Earth Resource Technology Satellite Ground Station	0.466[3]	
TOTAL	21.070	21.691

Note 1 - including 0.278 recoverable from DRB

Note 2 - including 0.286 recoverable from DRB

Note 3 - including 0.447 O & M recoverable from EMR

Department of Energy Mines and Resources	1972-73	1973-74
Canada Centre for Remote Sensing and the Earth Resources Technology Satellite[1]	5.900	6.000

Note 1 - includes Airborne Program, Applications Program and Sensor Development Program

Department of Industry Trade and Commerce	1972-73	1973-74
Ground Stations for Satellite Communications Systems	0.250	0.300
Rocket Development	0.200	0.250
Reproducer for weather satellite pictures	0.020	
Space Environment Simulator and Test Equipment	0.010	
Study on Benefits of Post Apollo participation	0.022	
Program for Export Market Development	0.080	0.095
Remote Manipulator Technology Development		0.150
TOTAL	0.582	0.795

Ministry of Transport	1972-73	1973-74
Aeronautical Satellite Studies	0.150	0.150

National Research Council	1972-73	1973-74
Intra-mural Space Oriented Programs	3.500	3.350
Extra-mural Space Oriented Programs	0.800	0.800
TOTAL	4.300	4.150

Department of National Defence /DRB	1972-73	1973-74
Tactical Satellite Communications (1)	0.280	0.314
Studies related to Remote Sensing	0.226	0.265
Other Space related Research (2) (3)	0.173	0.189
TOTAL	0.679	0.768

DND Extra-mural Programs	1972-73	1973-74
Defence Industrial Research (4)	0.122	0.114
University Grants Program	0.283	Figures not available
TOTAL	0.405	0.114

1.068

Note 1 - This activity is conducted at the Communications Research Centre of DOC but funded by DRB on behalf of the Department of National Defence.

Note 2 - Some programs include non-space oriented components. The figures given here are for the space oriented components only.

Note 3 - Includes $46,000 in 1972-73 and $49,000 in 1973-74 which are recoverable from DOC

Note 4 - DIR Programs for 1973-74 are subject to further review and approval

TOTAL EXPENDITURES.....$33.1M $33.7M

TERMS OF REFERENCE

TERMS OF REFERENCE

INTERDEPARTMENTAL COMMITTEE ON SPACE

DEFINITIONS:

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

ORGANIZATION:

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

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

2. Observer status shall be accorded representatives of:

   Science Secretariat
   Treasury Board Secretariat
   Department of External Affairs

3. The Chairman shall be named by the Committee.

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

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

DUTIES:

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

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

..2

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

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

MEMBERSHIP

INTERDEPARTMENTAL COMMITTEE ON SPACE

MEMBERSHIP

Dr. J.H. Chapman (Chairman)	Dept. of Communications
Mr. D. Armstrong	Ministry of Transport
Dr. L.W. Morley	Energy Mines & Resources
Dr. H. Sheffer	Defence Research Board
Mr. F.R. Thurston	National Research Council
Dr. S. Wagner	Dept. of Industry, Trade & Commerce
	Dept. of External Affairs

OBSERVER

Dr. J.R. Whitehead	Ministry of State for Science and Technology

SUB-COMMITTEES

International Aspects of Space Policy

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

Space Vehicles and Propulsion

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

Satellite Applications and Technology

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

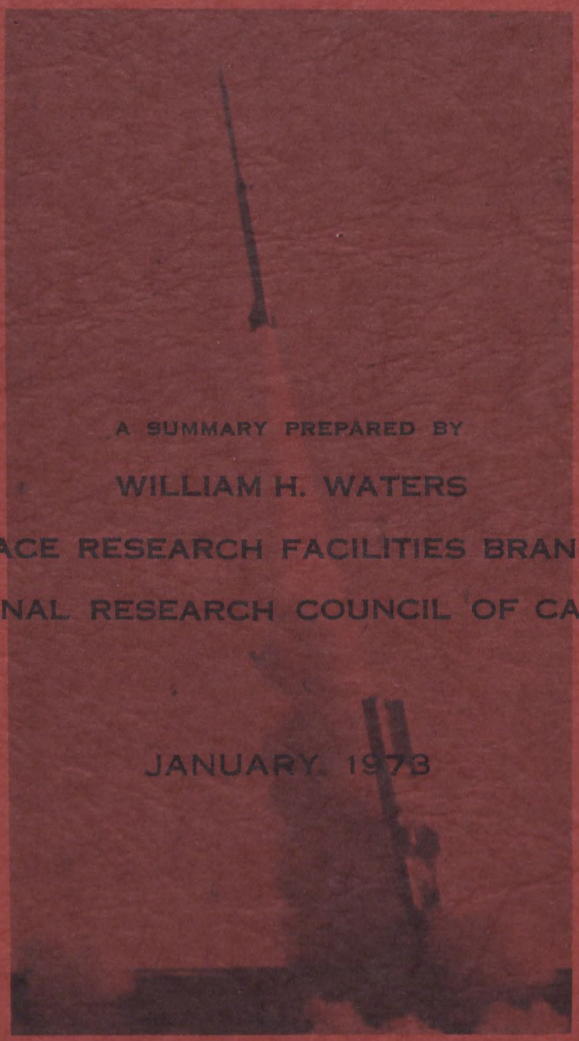
Scientific Research

Dr. R.E. Barrington (Chairman) Dept. of Communications

SRFB 071

Space And Upper Atmosphere Programs in Canada

1972



A SUMMARY PREPARED BY

WILLIAM H. WATERS

SPACE RESEARCH FACILITIES BRANCH

NATIONAL RESEARCH COUNCIL OF CANADA

JANUARY 1973

National Research Council Canada
Conseil national de recherches Canada

SPACE AND UPPER ATMOSPHERE PROGRAMS IN CANADA

1972

A Summary Prepared By
WILLIAM H. WATERS
SPACE RESEARCH FACILITIES BRANCH
NATIONAL RESEARCH COUNCIL OF CANADA

JANUARY 1973

FOREWORD

This report is published yearly to keep interested scientists, government departments and other informed regarding Canada's space programs. Contributions from participating and associated agencies are solicited and form a major portion of the publication. These contributions are in general up-to-date as of the end of December each year.

This is the fifth annual edition, with the first (SRFB 024) having been published in January 1969. The introduction, and brief histories of space activities will be included in subsequent editions in order to make these reports as complete as possible. Yearly changes and amendments will be continued to bring the record up-to-date.

All previous editions of Space and Upper Atmosphere Programs in Canada are out of print except for SRFB 061F (January 1972) French edition. Copies of the above and current editions may be obtained by applying to the Space Research Facilities Branch, National Research Council of Canada, Ottawa, Ontario, Canada, K1A 0R6.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

TABLE OF CONTENTS (Cont'd)

TABLE OF CONTENTS (Cont'd)

TABLE OF CONTENTS (Cont'd)

TABLES

INTRODUCTION

This document contains information regarding Canada's activities in space and her contribution to the international effort. It has been prepared as a result of written and verbal requests for such information and should not be construed as containing a complete digest. The activities described are carried on by means of balloons, sounding rockets, satellites and ground-based research laboratories.

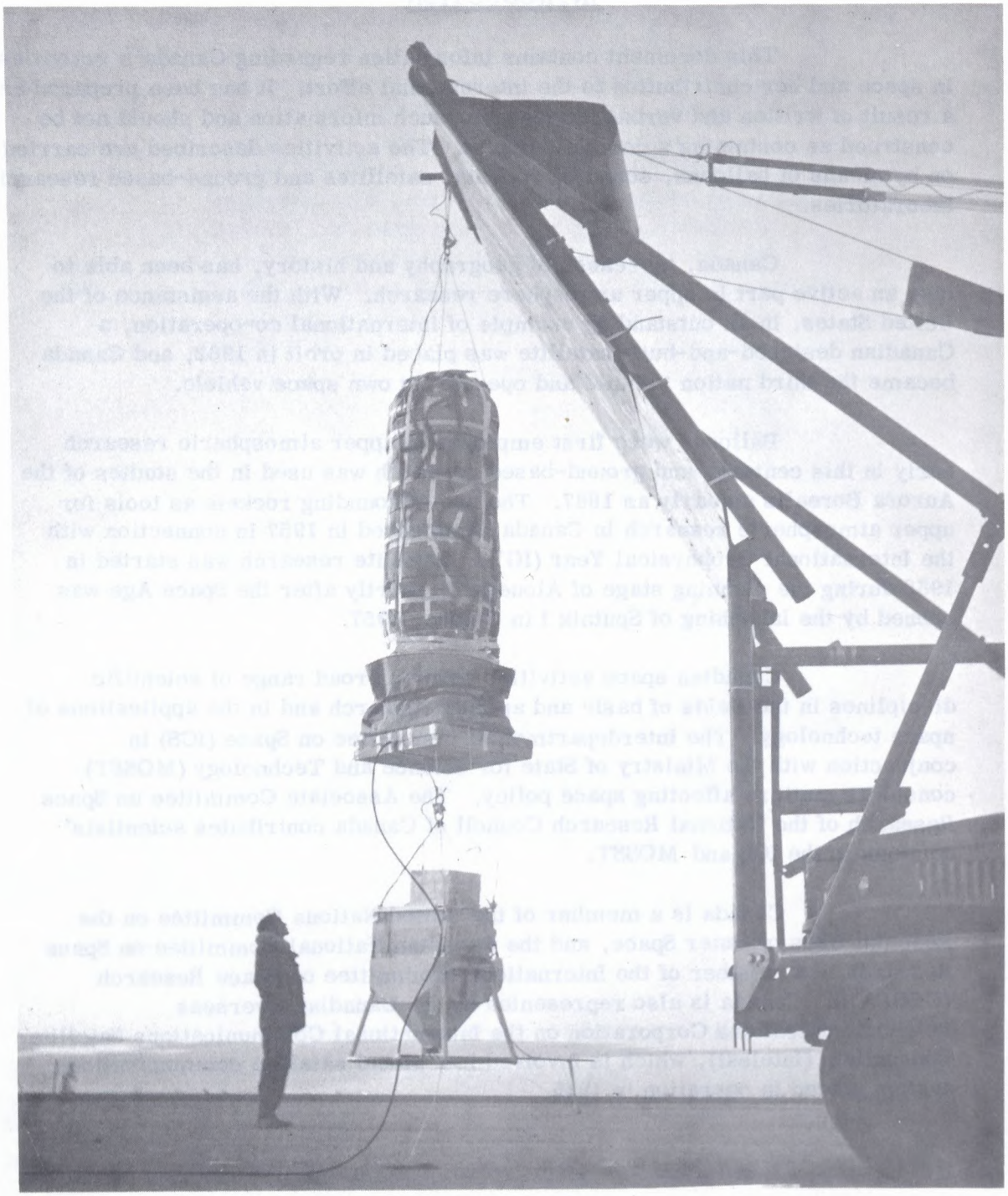
Canada, by reason of geography and history, has been able to take an active part in upper atmosphere research. With the assistance of the United States, in an outstanding example of international co-operation, a Canadian designed-and-built satellite was placed in orbit in 1962, and Canada became the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

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

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

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

A BALLOON PAYLOAD READY FOR FLIGHT



BALLOONS

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

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

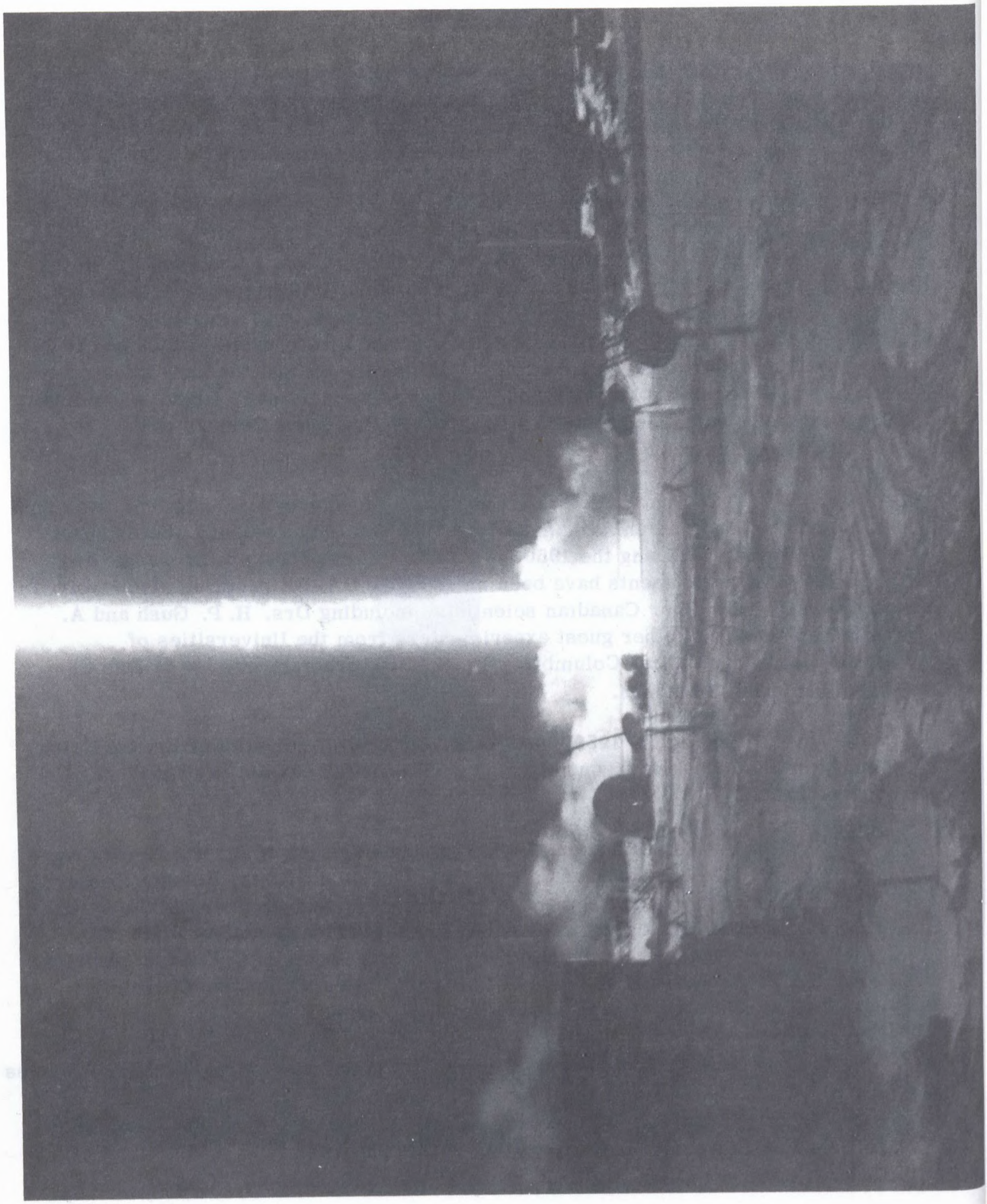
The first large scale Canadian balloon program, however, was that instituted by the Canadian Armament Research and Development Establishment (CARDE), Quebec, during the 1950's. Numerous important spectroscopic and photometric measurements have been made. The CARDE program also involved co-operation with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

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

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

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

LAUNCHING A BLACK BRANT IIIB ROCKET



ROCKETS

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

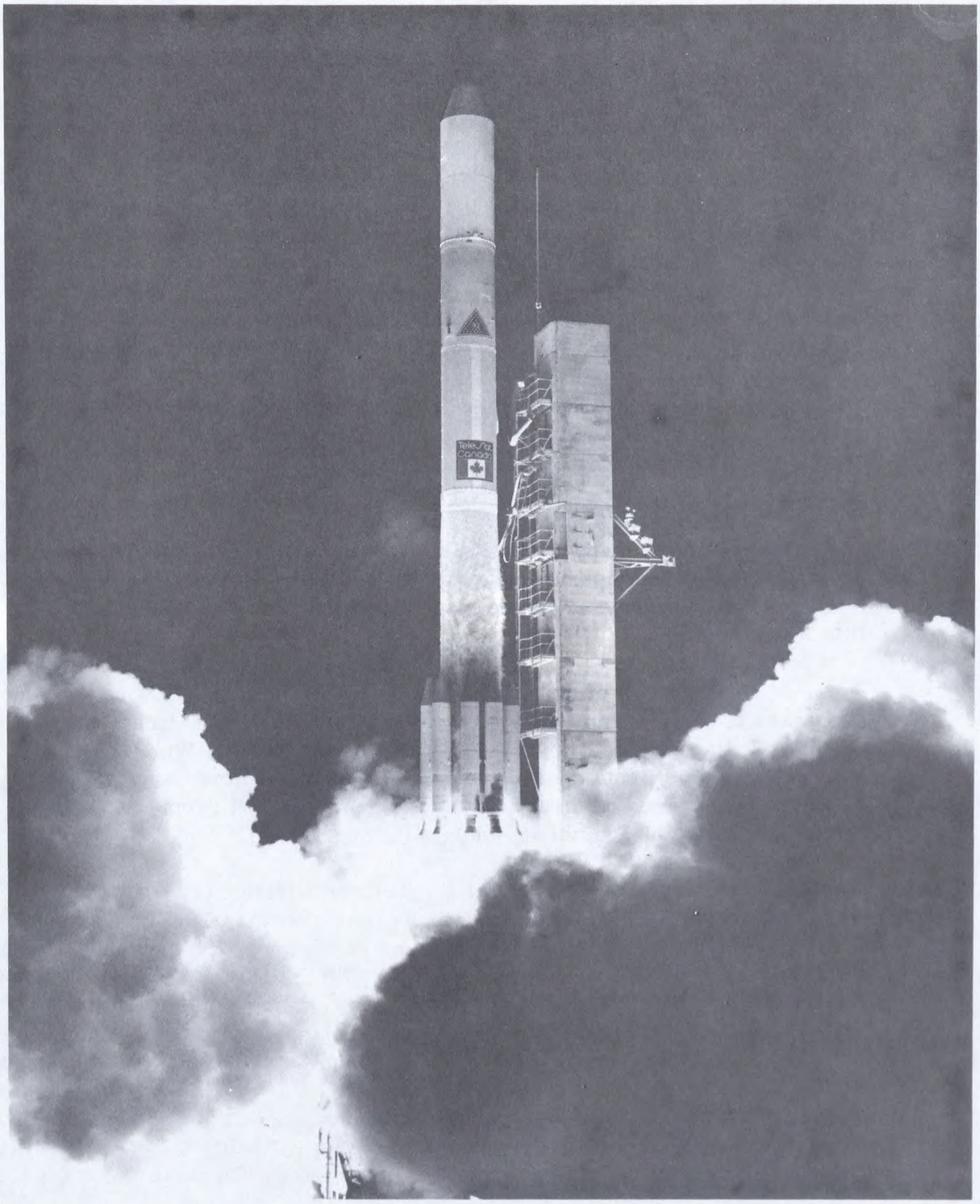
At DREV, direct high-altitude measurements began in 1957 - 1958 with rocket-borne measurements of the sodium airglow and hydroxyl profiles. More recent rocket flights were used to release nitric oxide into the atmosphere in order that ground-based observations of the resulting luminescence could be used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

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

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

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

LAUNCH OF ANIK I ON A THOR-DELTA ROCKET 9 NOVEMBER 1972



SATELLITES

Alouette I

This was the first satellite to be designed and constructed in Canada. It was launched from the Western Test Range, California, U.S.A., on 29 September 1962 and is now the oldest active vehicle in space. On command it still transmits data back to earth.

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 command this vehicle continues to transmit data back to earth.

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, which is at present producing degraded data, are performing as planned.

ISIS II

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

ANIK I

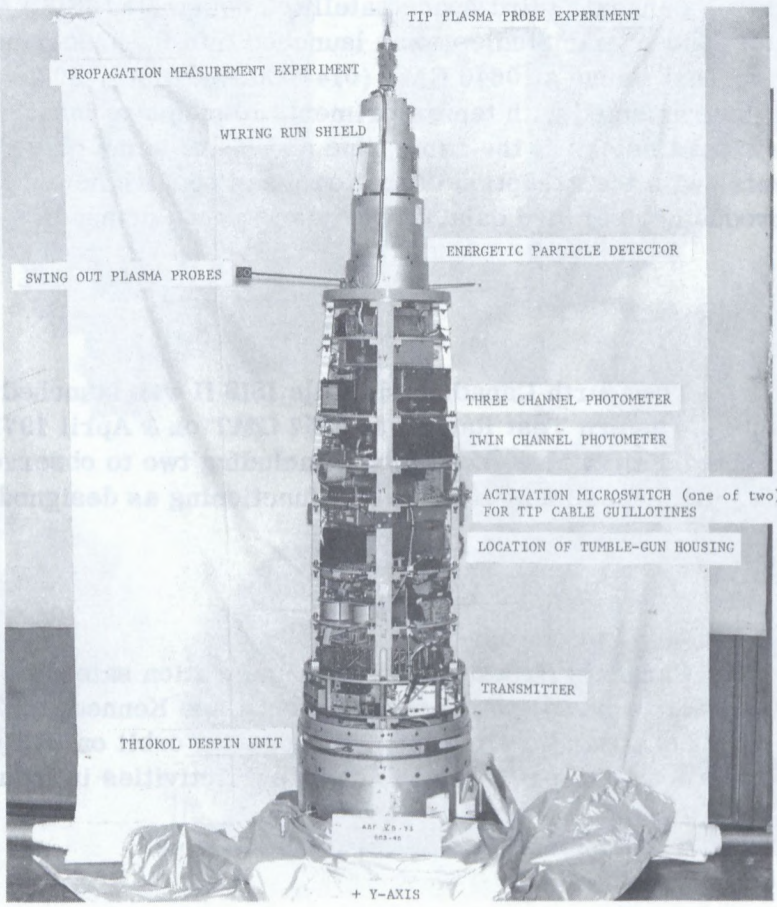
Canada's first domestic communication satellite, ANIK I (an Eskimo word for brother), was launched from Cape Kennedy at 2014 EST, 9 November 1972 and was inserted into its operating orbit on 24 November 1972. Details will be found under Telesat Canada and Activities in Industry.

Further Details

Further details of these satellites, including instrumentation and experiments, will be found under the ISIS Satellite Program and Telesat Canada. The first four Canadian satellites listed above were designed and constructed by the Communications Research Centre of the Department of Communications, RCA Limited and Spar Aerospace Products Limited.

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

PAYLOAD LAYOUT IN A BLACK BRANT VB ROCKET



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 in the past 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. Additionally, and in conjunction with the United States Bristol Aerospace Limited has developed a meteorological rocket which is capable of lifting a useful payload of 3 to 5 kg to a height of 84 km. A vehicle designed to lift heavier payloads, which could be used as a satellite booster, has been considered, using clusters of Black Brant motors. Further details of the capabilities of these rockets will be found under Activities in Industry - Bristol Aerospace Limited.

The British Skua II rocket is a 12.7 cm diameter, solid propellant vehicle, measuring approximately 254 cm. 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 a 11.4 cm diameter, solid propellant vehicle with a booster stage, measuring about 405 cm in length. It is capable of lifting payloads of more than 9 kg to heights of over 105 km.

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

By December 1972 the National Research Council of Canada had participated in 118 rocket launchings which carried aloft 838 different experiments. Thirteen of these rockets carried experiments from the United States, Sweden, the Federal Republic of Germany, Czechoslovakia, the United Kingdom and Belgium, in addition to the Canadian experiments. By the end of 1972, Canada had launched more than 185 scientific sounding rockets.

UPPER ATMOSPHERIC ROCKET AND BALLOON RESEARCH IN 1972

Prior to 1972, the Space Research Facilities Branch arranged for 81 scientific rocket launchings. These vehicles carried a total of 512 experiments from the National Research Council of Canada, the Communications Research Centre of the Department of Communications, and the Universities of Calgary, Saskatchewan, Western Ontario, Toronto, York and Montreal. In addition, 20 experiments from other countries were included in nine of these vehicles.

During 1972, 17 Black Brant rockets sponsored by the National Research Council of Canada, carried 90 experiments to heights ranging from 80 to 800 km to make measurements under quiet and disturbed conditions. With the exception of five vehicles, one from Gillam, Manitoba and four from East Quoddy, Nova Scotia, 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 1972. During this program, 24 balloons were launched from four sites carrying experiments from six U. S. and one Canadian university, Goddard Space Flight Center and the U. S. Naval Research Laboratory. Canadian agencies and ground stations participated in this program.

Canadian Experiments Carried in Canadian Rockets

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

National Research Council of Canada

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

Communications Research Centre, Department of Communications

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

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 detectors, acoustic detectors, day and night glow spectrometers, infrared airglow photometers and spectrometers.

Simon Fraser University

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

York University

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

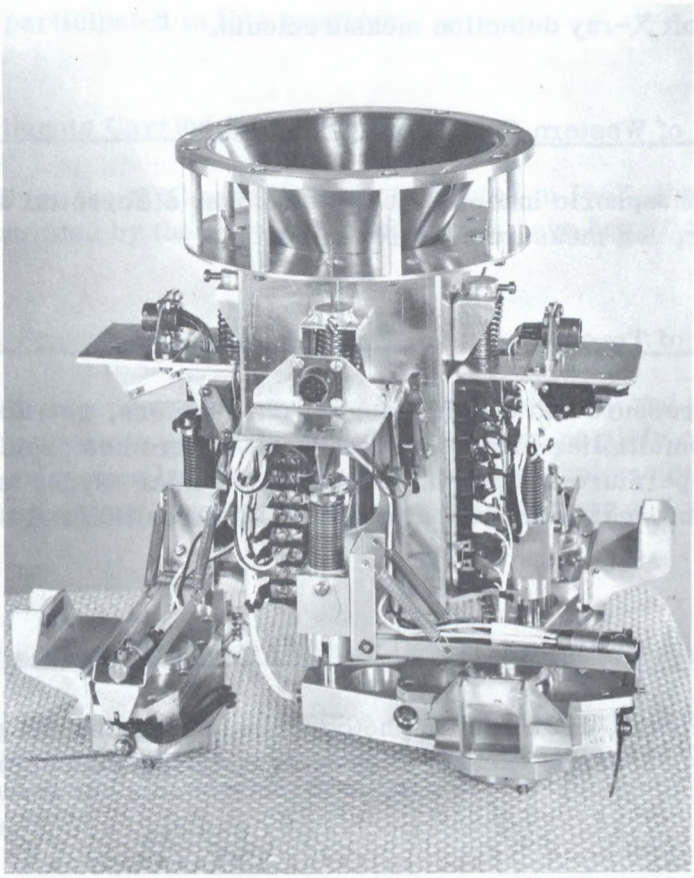
University of Montreal

Thermal electron measurements and multi-grid velocity analyzers.

Experiments Carried for Other Countries in Canadian Rockets

In addition, electric field probes, acoustic micrometeoroid detectors, OH dayglow instruments, barium cloud, ozone measuring instruments (above 55 km), solar X-ray, Lyman alpha, spectrometer and photometer experiments were carried in 13 of the above rockets for the United States, Sweden, Federal Republic of Germany, Czechoslovakia, the United Kingdom and Belgium. Some of these experiments were ejected from rockets during flights, while others remained with the parent vehicles.

COSMIC DUST COLLECTOR MECHANISM TO BE FLOWN ON BALLOONS



ACTIVITIES IN UNIVERSITIES

UNIVERSITY OF ALBERTA

Institute of Earth and Planetary Physics

For the past three years, the Killam Earth Sciences group has operated a meridian line of three component fluxgate magnetometers in western Canada. At present sufficient digital data has been acquired so that the efforts of the group are now directed towards analysis of the data and its correlations with data from other experimental groups.

Studies have recently been completed on two major aspects of geomagnetic activity. It has been shown that micropulsations may occur in localized L-shell regimes, and the periods of the pulsations Pc4 and Pc5 are latitude dependent. At present ISIS 1 and ISIS II data are being correlated with the station line data to establish the character of the oscillating L-shells. A definitive study of the modelling of polar magnetic substorm current systems has revealed that it is possible to localize the region of disruption in the ionosphere associated with substorms. Recent studies are dealing with the electrojets associated with convective flow in the magnetosphere. In addition all-sky camera data are being used to study the character of auroral arc motion associated with substorms.

New studies are being commenced dealing with the character of Pi 2 micropulsations during the development of a substorm expansive phase. Co-operative efforts are also in progress correlating the VELA and ATS-5 satellite data with the station line data. The character of magnetic activity in the region of the polar cusp is also the subject of investigation, and cusp activity during both quiet and active times may be used as a tool to describe the character of the solar terrestrial interaction.

Studies have been carried out on the propagation of narrow band amplitude modulated waves of finite extent, using a technique which allows the propagation of non-time-harmonic disturbances in a dispersive medium to be studied by Fourier synthesis from the ray solutions of time-harmonic problems.

Within the Geophysics group in the Department of Physics, a strong program investigating the effects of induction in the Earth on the character of the magnetic and electric fields at the Earth's surface is under way. The experimental program involves array studies using three component magnetometers, and magnetic depth sounding techniques are used to determine anomalies in the subsurface conductivity structure. Theoretical investigations center around the perturbation patterns associated with vertical discontinuities in conductivity associated with dikes, coastlines, and islands.

In addition to the induction studies, research into space plasmas is being carried out centered on the problem of anomalous resistivities in a current-carrying turbulent plasma which may be associated with the heating of auroral particles during substorms.

UNIVERSITY OF BRITISH COLUMBIA

Department of Physics

An instrument to measure the spectrum of the cosmic background radiation in the wavelength region of 1 mm to 0.1 mm has been developed which is suitable for rocket use. It consists of an interferometer cooled with liquid helium at a temperature of 4°K coupled to a bolometer detector cooled to 1°K. One interferogram (from which the spectrum may be deduced by a Fourier Transform) is recorded every ten seconds. A prototype instrument was launched in February 1971 and a slightly modified version was launched in November 1972.

UNIVERSITY OF CALGARY

Department of Physics

The university has been concerned mainly with analysis of scanning auroral photometer data from the ISIS II satellite during the past year. Initial results have revealed the presence of a uniform belt of diffuse aurora which extends around the auroral oval and is characterized by a sharp equatorward boundary typically at about 66° invariant latitude in the midnight sector and also shows the existence of an intense spiral pattern of auroras well inside the polar cap on December 18, 1971 during the recovery of a major magnetic storm.

The diffuse belt is probably the earthward projection of the plasma sheet and the polar spiral pattern is highly suggestive of convection. They are also examining data that shows a very high incidence of polar cap discrete and diffuse auroras for several days following the above storm. Analysis of the 5577 airglow limbs has provided altitude profiles of this emission. The E region and F region components are resolvable so latitude variations of these components for several December 1971 passes have been obtained.

One student is completing his Ph. D. thesis, which describes some very interesting variation of the 5577 Å/3914 Å emission ratio in type B and pulsating auroras as determined by means of a ground based high speed scanning photometer, with special attention given to correction for scattered light.

Plans for the future will emphasize comparisons of the satellite scanner data with ground based auroral and satellite particle and other measurements. It is hoped that data from this instrument will help to synthesize the great bodies of optical, particle, and magnetospheric data already in existence.

Solar Terrestrial Relations

An International Conference was organized at Calgary, by Dr. D. Venkatesan as Chairman, during August 28 to September 1, 1972. This was inaugurated by Prof. E.N. Parker, Enrico Fermi Institute, University of Chicago. The conference was attended by about 110 delegates.

The conference had a new format. Invited papers and panel presentations and discussions by three or four people on specifically chosen topics formed the dominant theme of the conference. There were a limited number of papers for formal presentations.

The conference covered the areas of Solar Physics, Interplanetary Medium, Cosmic Ray Propagation, Magnetospheric Physics, Aurora and High Latitude Phenomena. The proceedings will be published early in 1973.

Solar Particle Events

(a) The study of the interplanetary propagation of low energy solar flare particles has continued. The study confirms that the propagation of protons of energy $\gtrsim 55$ MeV is adequately explained by the isotropic diffusion model invoked by Parker and Krimigis. The propagation of low energy solar flare particles in general is not diffusion like. An attempt has been made to discuss the propagation of low energy particles on the basis of Liouville's theorem. A thesis for Ph.D. was submitted on this work.

(b) A study of onsets of relativistic electron events as a measure of the high frequency component of the interplanetary field power spectrum is in progress. This is in collaboration with Bell Laboratories, New Jersey and University of Kiel, Germany. It is found that the several estimates of electron mean free paths are quite consistent with the mean free paths calculated for rigidities P $\sim$380 MV by Sari from the interplanetary field power spectra, when Sari's values are extrapolated to the electron rigidities (P $\sim$1MV). A paper is being written up on the work.

(c) A detailed study of the November 18, 1968 solar particle event and propagation of low energy protons and alpha particles is in progress. (University of Calgary, Bell Laboratories and Kiel University.)

Cosmic X-rays

A proving rocket flight, Black Brant IV in May, 1972 from Churchill, carried two newly developed multi-anode, multi-layer proportional counters. The counters and electronics performed satisfactorily. Some minor problems were encountered. Work is in progress for a flight in 1973 in conjunction with Simon Fraser University, with modifications, to obtain a four point spectra in the range 0.1 - 20 keV.

Auroral X-rays

Work in collaboration with the Division of Physics, NRC, Ottawa, and the University of Houston, Texas, is nearing completion. This deals with the analysis of rocket data and attempts to establish a relationship between the auroral electrons precipitating in the upper atmosphere and the bremsstrahlung x-rays emitted by these electrons. It is found that the auroral electrons precipitating in the atmosphere have a steeper differential electron spectrum for energies greater than 20-25 keV. For an exponential parent electron differential spectra, the bremsstrahlung produced x-ray differential spectrum at the top of the atmosphere is also exponential for x-ray energies greater than $\sim$ 20 keV. A paper is being written up. An auroral x-ray package for a meteorological type rocket, to be launched in conjunction with the rocket measurement of auroral electrons is planned for early 1974.

Cosmic Rays

The Sulphur Mountain and Calgary super neutron monitors continued to operate. Data from the Sulphur Mountain laboratory is piped to Calgary via telephone lines.

Various aspects of cosmic ray intensity modulation in interplanetary space are investigated with the aid of super neutron monitors, and meson monitors at Calgary and Sulphur Mountain.

The cosmic ray modulation during the period of August 2-15, 1972, resulting from the unusual solar activity during this period is being studied in detail. The records of Calgary and Sulphur Mountain for the solar flare increase of 7 August 1972 have provided the first evidence for the injection of relativistic particles even before the H_α maximum of the flare. The primary proton and α - particle spectrum during the Forbush decrease of this period has been measured and is being studied.

The low energy end of primary spectra is measured by balloon-borne charged particle telescopes, after special solar events.

Balloon Experiment for the Detection of Cosmic Ray Electrons

The experimental package consisted of a gas Cerenkov counter, two plastic scintillator counters and a lead glass Cerenkov counter. After conversion to digital form the signals from these counters are transmitted by PCM telemetry. The aim of the experiment was to detect and measure the energy spectrum of cosmic ray electrons in the energy range 10 MeV to 1 GeV. This information is important for the study of the solar modulation of the galactic spectrum.

Although a three million cubic foot balloon had been allocated by the Office of Naval Research, the Department of the United States Navy; it was decided to share a 10 million cubic foot balloon with Professor Earl of the University of Maryland in order to improve the exposure time at ceiling and to gain a higher maximum altitude. The balloon was launched from Fort Churchill, Manitoba at 2030 GMT on July 29, 1972, and reached a float altitude of approximately 130,000 feet (3 mb) by 2300. Telemetry reception by CRR was satisfactory until about 0400.

A number of magnetic tapes with the PCM data are presently under analysis. First indications are that the whole package functioned properly with the exception of the lead glass Cerenkov photomultiplier which may have been damaged in transit to Churchill. This was the first time this particular experiment was flown and the first time this Calgary group had used PCM telemetry. Another flight with a similar package is planned for 1973.

UNIVERSITY OF MANITOBA

Department of Physics

The Cosmic Ray group consists of Dr. G.A. Smith, Dr. R.W. Flint, and Dr. S. Standil. The work to date has been mainly concerned with time variation and intensity studies of the sea level muon component. A number of scintillation telescopes, including a meson megatelescope, has been operated. Present studies include an experimental investigation of delayed particles following air showers.

The Antenna Laboratory, Department of Electrical Engineering

Analytical and experimental work with a 35 GHz scanned microwave radiometer was continued in connection with a wide range of applications extending from arctic reconnaissance to oil pollution, mineral exploration, offshore drilling, ice-thickness, surveying, detection of subsurface water and permafrost level, weather forecasting, etc.

It is expected that Canadian satellites will soon employ multifrequency scanned microwave radiometers as basic tools for surveying agriculture, ice and water levels, mineral resources and for surveillance of arctic and coastal regions of Canada.

MCMASTER UNIVERSITY

Principal Investigator	-	Dr. H.G. Thode
Co-Investigators	-	Dr. W.B. Clarke
		Dr. C.E. Rees
		Dr. H.P. Schwarcz

Determinations of sulphur concentrations and isotope abundances in returned lunar samples are continuing. Experiments on lunar soil samples in particular are being performed in order to separate components with different sulphur concentrations and $^{34}S/^{32}S$ values. Identification of these components is important to the understanding of the processes by which the soils have been formed.

UNIVERSITY OF SASKATCHEWAN

Institute of Space and Atmospheric Studies

Rocket investigations of the aurora and airglow have been undertaken in an attempt to provide new information on the interaction of the atmosphere with the incident solar flux and auroral particles. These in situ investigations have also been complemented by independent ground based studies of the interaction effects using various experimental techniques.

Observations with a soft electron spectrometer (20 eV - 18 keV) have shown that an extensive Type-A red aurora resulted from the precipitation of electrons with a Maxwellian energy distribution and characteristic energy of about 300 eV. The low energy spectra (20 - 100 eV) detected are being used to provide a comparison between the observed and calculated optical emissions. Optical measurements to improve the knowledge of spatial and temporal fluctuations of the auroral brightness have also been made. To provide further information on the interaction of the incident solar flux with atmospheric constituents a series of rocket experiments were made during the 1972 solar eclipse. These measurements provided knowledge of the temporal variation of the O_2 ($^1\Delta$) and OH emission profiles during the eclipse and are being compared with existing theories and the measured nightglow height profiles. The height profiles have also been used to estimate minor constituent concentrations which are difficult to determine by other techniques.

Other rocket investigations have been concerned with the measurement of electric and magnetic fields from ejected probes. The observations have indicated that the E-W auroral electrojet is a Hall current and that the parallel conductivity is limited. The presence of field aligned and horizontal currents has also been established although the inferred current density is much lower than that expected from usual models of conductivity. Techniques for the analysis of Doppler shifts in VLF transmissions have been developed to determine the local electron density from measurements with a rocket borne VLF receiver.

Ground based studies of atmospheric and related phenomena have measured the vertical electric field and horizontal magnetic field in the frequency range 3-18 Hz. The coherency of the measured signals indicates that the origin of these fields is a large number of independent sources and that during auroral disturbances the activity in this frequency band is high. Polarization studies, at 42 MHz, are also being used to determine Stokes parameters for auroral back-scatter and are being extended to include measurements from individual meteor trails.

Ground based optical studies are being used to derive further information on the relevant atmospheric parameters. The helium emission at

1.08μ is being extensively investigated and observations of the oxygen emission at 1.27μ are being used to derive the mesospheric ozone concentration. Auroral emissions are also being studied to complement the particle fluxes measured from the ATS-E satellite and are being compared with the measured heights of particle reflections.

An extensive series of ground based studies using radio waves has been undertaken to determine atmospheric parameters in the height range 60-120km. These studies have been able to measure the mean vector and zonal winds on a regular basis and these are available to other investigators. More recent observations of the mesospheric winds have indicated the presence of gravity waves in the height region 80-95 km. These investigations are important for complete descriptions of the photochemistry and energetics of the atmospheric region between 60 and 120 km.

SIMON FRASER UNIVERSITY

The active research program in low energy x-ray astronomy has been continued. The first rocket flight of the new detector system developed at Simon Fraser University took place in May 1972. The detector, which involves many novel features, appears to have functioned satisfactorily; however, due to the occurrence of a magnetic disturbance with accompanying particle precipitation at the time of the flight, little useful astronomical data is expected. The flight did, however, prove the reliability of the vapour pressure regulating system and the performance of the thin window. A paper describing the detector and its flight performance is in course of preparation. A preliminary report on the vapour pressure system has been published.

A second flight is now being prepared for launch from a non-auroral site. The object of the flight is to study the spectrum of the diffuse background.

A proposal to use the novel features of the Simon Fraser University detector on a stabilized platform has been submitted. (The importance of a stabilized platform to further work in x-ray astronomy cannot be over emphasized). Considerable effort is therefore being devoted to evaluating and improving the techniques tested on SFU-1. It is anticipated that a method of programmed efficiency changes in-flight will uniquely identify celestial soft x-rays from other background ionizing events. Combination of data from detectors with differing x-ray absorption edges (e.g. C K 284 eV, Cl L $\sim$204 eV) will then yield spectral information down into the region where interstellar absorption becomes dominant. This is then a powerful new way of studying both the interstellar media and diffuse x-ray sources.

In other areas, a study of the effects of various astronomical phenomena on the ionsphere has been published and upper limits on the x-ray and optical flux associated with gravitational events have been established. Radio data on the giant pulses from NPO532 have been collected in order to search for a correlation with x-rays. This analysis is incomplete.

UNIVERSITY OF TORONTO

Institute for Aerospace Studies

Atmospheric Composition and Temperature Determination Using Electroluminescence

A previous rocket-borne experiment has shown the electron beam fluorescence technique to be a powerful new tool in the measurement of rotational temperature and nitrogen density over the 65-150 km region. Subsequent flights have provided further information on the densities of N_2 and O_2 and rotational temperature, to more than 200 km.

A laboratory analysis of the emission spectra produced by 2.5 K_{ev} electron excitation has been completed for N_2, O_1, O_2 and A in the visible range. On the basis of this work, suitably located spectral regions have been selected which provide good prospects for determining the concentrations of the species mentioned unambiguously and accurately.

Compact flight instrumentation has been developed providing 10 discrete spectral channels and the capability of rejecting high levels of ambient radiation.

Aerodynamic Spectrometer

This instrument, which has been investigated theoretically by Visentin is capable of determining the ambient temperature and density of the major constituents of the neutral upper atmosphere in the free molecular region (>90 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 gas species, their temperatures and known parameters associated with the velocity and attitude of the vehicle. Ions created in a small, well defined region behind the slit are collected and this current is analyzed for temperature and density information.

Two versions of the instrument have been flown; the first employing a 150v magnetically confined cylindrically shaped electron beam and the second using a Bayard Alpert type electrode arrangement for delineating the probe region.

In the first flight attempt anomalously high ion currents were recorded and electrostatic shielding has been incorporated on a subsequent attempt. The latest flight data shows good correlation between the outputs of both instrument types and densities which conform to expectations.

In the latest version of the aerodynamic spectrometer (to be flown in late 1973) the neutral gas will be mechanically chopped at the slit and the signal synchronously detected.

Department of Physics

Geophysics

$^{40}Ar/^{39}Ar$ age determinations have been carried out on lunar samples returned by the Apollo 14 and 15 missions. In this technique, the rocks are irradiated with neutrons and then heated to successively higher temperatures in an ultra-high vacuum system. The $^{40}Ar/^{39}Ar$ ratios in the evolved gas enable one to determine corrections for argon-loss which has occurred on the moon. More precise ages may thus be found than is usually the case when the conventional K-Ar method alone is employed. Ages thus found indicate that the Imbrium basin was most probably excavated about 3.9 billion year ago. Mare filling may have occurred as late as 3.3 billion years ago. The conclusions now seem inevitable that, in contrast with the earth, the moon became tectonically quiescent about 3 billion years ago, its surface features being modified subsequently mainly by relatively mild meteorite impacts and erosion by small particles. The origin of the moon by either a capture process or by fission from the earth must have occurred very early, about 4.5 billion years ago.

David Dunlap Observatory

Four expeditions were sited in the Maritime provinces along the path of the eclipse of July 10, 1972, those in the easterly sections being the more successful in obtaining prominence and coronal photographs during totality.

Work on applications of image tubes, which was originally begun by Dr. R. F. Garrison under a contract with the Department of Energy, Mines

and Resources, has continued into the experimental and utilization stages. Excellent results are being obtained with an image tube now in use on the 24-inch telescope in Chile.

Dr. Robert Garrison has submitted an advance proposal to NASA for scientific use of the International Ultraviolet Explorer satellite (IUE). Low resolution spectrograms in the far ultraviolet will be used to establish a two-dimensional spectral classification scheme (temperature and luminosity) for some 1300 of the brightest stars. These results will be correlated with optical spectral data already on hand at DDO and elsewhere. The launch could take place in Fiscal Year 1976.

One of the major scientific results of orbiting satellites has been the discovery of many celestial X-ray sources and the determination of reasonably accurate positions for them. At the Dunlap Observatory and the Algonquin Radio Observatory a great deal of effort has been expended in the last year in observing these objects both optically (Cyg X-1) and by radio (Cyg X-3). Cygnus X-1 is almost certainly a Black Hole, from radial velocity observations made by T. Bolton at DDO and spectroscopic observations made by N. Walborn at Kitt Peak. Cygnus X-3 had a major outburst on September 2, 1972, an unprecedented event which was discovered at ARO by Gregory. The phenomenon was subsequently observed at many frequencies by radio astronomers around the world, and the whole event was of course of great theoretical interest.

UNIVERSITY OF VICTORIA

Department of Physics

Twilight Airglow Studies

Observations of twilight lithium emission have been continued at Victoria, B.C., using the birefringent photometer. No unusual event was recorded during the past year until around October 17, 1972 when the evening intensity reached a value of 240 rayleighs. This is to be compared with the usual value of 20-40 rayleighs. As in the case of previous enhancements the duration was about five days. There were no known chemical releases just prior to the above time so that the cause of the enhancement is unknown.

A comparison study of upper atmospheric sodium intensity variations and the times of occurrence of stratospheric warmings has been carried out using data from Victoria and Saskatoon. The times of occurrence of the warmings and the corresponding effects in the vicinity of 90 km have been interpreted in terms of a frontal motion. The relatively low coherence between Victoria sodium abundances and arctic stratospheric temperatures suggests that the arctic winter circulation regime does not extend to this location at 90 km heights.

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 summarised 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 bistatic system with highly stable and coherent frequency sources is used to study the frequency spectra of the scattered signals which have revealed the presence of ion-acoustic waves. Magnetometers are employed to monitor the ionospheric currents associated with these waves. Recent results (Forsyth and Hofstee) indicate ion-acoustic waves propagating as much as 6° away from the direction of the unperturbed geomagnetic field direction. An analysis of the angular spread of wave vector under conditions of intense auroral disturbance has also been made (Moorcroft). Also the possibility of using satellite-borne transmitters in bistatic systems to examine radio auroral scattering is now being explored (Forsyth and Sinclair).

Wind Motions

Winds are being measured at meteor heights by employing bistatic systems to analyze the signals scattered from meteor trails (Fulford, Forsyth, Hanff). Following successful operation of a pilot system giving one component of velocity, a more sophisticated system to give two horizontal components and to achieve greater height resolution is now being built. This involves two bistatic systems and will incorporate digital automatic data analysis.

Ionospheric Irregularities

The Minitrak system is being used to monitor the phase scintillations and angles of arrival of the beacon signals from the ISIS I and II satellites (Forsyth); this permits some deductions on the detailed structure of F-region irregularities. A semi-portable version of the angle of arrival equipment has gone to Laurentian University to be operated by Hofstee whilst new portable systems are being built (Hajkowicz) to be operated at Lakehead University and at a site in the West Indies. These should give extended latitude coverage.

The role of cross-field instabilities in the formation of E-region irregularities has been investigated (Moorcroft, Beer). It is concluded that this phenomenon can explain the presence of low and mid-latitude, night-time, constant height sporadic-E.

Travelling Ionospheric Disturbances

A phase locked continuous following polarimeter has been recording the signal from the geostationary satellite ATS-3 (Lyon, Webster) to yield changes in electron content along the ray path. Periodic fluctuations attributable to T.I.D.'s are present for most of the time. A comprehensive power spectrum analysis of the data indicate the predominance of larger period waves (about 1 hr) in contrast to the reports of other workers. This may reflect biases in the method because of the combined effect of the geomagnetic field and preferred directions of atmospheric waves; further investigation is proceeding.

A new program of H. F. Doppler forward scatter measurements has been started. The Doppler shifts are interpretable as changes in the height of scattering. The system, presently under development, will monitor three C.W. signals from Ottawa.

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 Corporation to further the project and hopefully eventually operate the facility. The earliest operating date for the facility, depending on funding, is early 1975.

Probe Studies

The behaviour of rocket and satellite-borne probes are under investigation (Tunaley). The Langmuir probe, for example, which is often used for electron density measurements suffers from surface contamination. The effects of contamination with respect to probe characteristics and statistical fluctuations are being studied theoretically. Some success has been achieved in identifying possible mechanisms.

The influence of photoemission from the probe and vehicle on the measurements is also under investigation.

Absorption Studies

A new system of absorption measurement has been developed. This system uses a matrix of electronically driven attenuators to compare amplitudes of signals scattered at three different frequencies from the individual meteor trails. Comparative studies of measurements by this method and by riometers at the path mid point have been completed (Abdu, Vogan). Not surprisingly the riometer is evidently incapable of measuring absorption accurately when this is inhomogeneously distributed and it appears that the variation in absorption from meteor to meteor is a measure of the inhomogeneity of the absorbing ionization.

Meteor Physics

The main effort centres on the use of a low-light television system to study the luminosity distribution and light curves of faint meteors. This is coupled with forward scatter studies of meteor mass distribution (Jones, Collins). The effect of wind shears on radio meteor echoes has been studied (Jones, Read). On back scatter radar observations at 10 m or so, the major source of error in the measurement of the ambipolar diffusion coefficient is found to be most probably due to cosmic noise, while the forward scatter observations at a similar wavelength are mainly influenced by wind shear effects.

YORK UNIVERSITY

Centre for Research in Experimental Space Science

Laboratory Astrophysics and Laboratory Aeronomy

Intensity Measurements and Molecular Spectra

Intensity measurements have been completed on CO_2^+ spectra of importance in the spectrum of Venus. Not only was a vibrational population of inversion found but also the general trend of electronic transition moment. Band strengths were inferred. This work was supported by theoretical work on Franck-Condon Factors of polyatomic molecules.

Measurements were also completed on the C_2 Swan band system and a definitive set of band strengths were obtained for this band system.

Absolute absorption intensity measurements were carried out on the Cameron system of CO, the NO beta system, O_2 Herzberg bands and continua.

Absolute absorption oscillator strength measurements have recently been completed on the O_2 Atmospheric Band system at high resolution.

The "hook" method of interfereometric spectroscopy has been used to measure band oscillator strengths for the NO Gamma system and the NO beta system. They have also recently extended the potential precision of the method by about three orders of magnitude.

Shock tube techniques have been used to measure the absolute band strengths of the CN red and CN Violet systems.

A study has been completed of the intensity distribution in the B-X system of SO.

Wavelength Measurements and Structure Studies on Molecular Spectra

A new study has been made of the vibrational and rotational structure of the visible and near I-R ammonia spectrum. The strongest feature at 6450Å has been assigned to $5\nu_1$, other vibrational assignments have been newly made and the 6450 band has been rotationally analyzed.

The band systems of YO have been shock-excited and a new vibrational analysis of them has been performed.

Identification Atlas of Molecular Spectra

Atlases 8 and 9 on the CN Red and CN Violet respectively have been issued.

Synthetic Spectra

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

Theoretical Studies

Line Strength (Honl-London) Factors

A major study of line strength factors has recently been completed. The prime result of which is a computer programme for evaluation of any Honl-London Factor for any degree of coupling. It has uncovered a number of errors in recently published compilations of the factors which are prime input data for any synthetic spectrum programme.

Franck-Condon Factors and r-centroids

Diatomic

The routine production of diatomic Franck-Condon Factors has continued, and a series of Spectroscopic Reports to distribute them has been instituted.

Polyatomic

A new method has been developed by McCallum for the computation of Polyatomic Franck-Condon factors and recent results have been published for CO_2^+. Other results are being written up.

r-Centroids

The mathematical basis of the r-centroid approximation has been worked out. These ideas have been extended to polyatomic molecular transitions.

Atmospheric Absorption Coefficients

A modification of the SPECTR III computer programme is being used by Cann and Nicholls to study realistic absorption coefficients of atmospheres.

Interpretive Work

The recent discovery of Brewer et al (Brewer, Davis and Kerr, Nature in Press) of an unusual absorption band at 30-60km was identified as NH by Nicholls and spectroscopic and chemical evidence was put forward to explain the occurrence of stratospheric NH.

Field Work

Rocket

No suitable geophysical conditions obtained at Churchill when Nicholls and colleagues were there in March to justify launching the Vacuum UV Rocket.

Solar Eclipse

A party from CRESS made measurements on the solar eclipse from PEI.

Planning for 1973 Solar Eclipse

Planning is well advanced for the Culham, Imperial College, Harvard, Kitt Peak, York rocket expedition to Mauritania for the June 30, 1973 solar eclipse studies. A rocket will be launched to study the spectrum of the solar corona in the vacuum ultraviolet.

Satellite Studies

The atomic oxygen red line (6300Å) photometer has been operating in orbit since April 21, 1971. A first generation software has been written and routine processing is being initiated, but a complete set of data only to August 1971 is in hand now. Work is being done on selected special request passes of interest in December 1971 and January 1972.

The dayside cusp is the most striking feature of the 6300Å emission, and in quiet times it is much stronger than the nightside emission. While it is most intense at magnetic noon, the emission does extend around the entire dayside. The transition to the nightside emission seems remarkably smooth and continuous. In modest disturbances, the nightside emission brightens. Under larger disturbances, the region brightens and expands considerably; for example, on December 17, 1971, it covered 30° extent in latitude. A very common feature is a two-component structure in the nightside emission; consisting of an equatorward band of emission produced by hard electrons, and a band of soft emission about 5° poleward of that.

Emission produced by conjugate point photoelectrons is also evident; the emission appears to vary with the electron density in the field tube,

and a marked intensity step can occur at the plasmapause. Other features that have been seen are a mid-latitude red arc (December 18, 1971) aurora inside the polar cap (December 20, 1971) and equatorial emission. Anyone interested in planning future (or past) simultaneous measurements is encouraged to get in touch, since 1972/73 may be the last full winter of regular observations.

Rocket Studies

Good data were obtained from II-114, which should give an accurate height profile for the N_2^+ rotational temperature. For the coming winter, a repeat flight, as II-127, is scheduled. In November 1973 an ambitious auroral flight (VC-34) is scheduled, with two scanning photometers, Dr. Zipf's mass spectrometer, and Dr. Young's fluorescence probe.

Aircraft Studies

A scanning rocket photometer was flown on an AFCRL aircraft during the polar eclipse in July 1972 and good data were obtained.

Ground Based Studies

The mobile trailer observatory is still not fully functional. Work is being carried out on a scanning photometer, a double-etalon Fabry-Perot spectrometer, a wide angle (single path) Michelson interferometer (WAMI) and a scanning WAMI (or SWAMI). A mini-computer and digital tape transport are being set up to handle the data. The WAMI is being taken to Alaska in January for a joint study with the University of Michigan, on Doppler motions of O^+ and O in aurora.

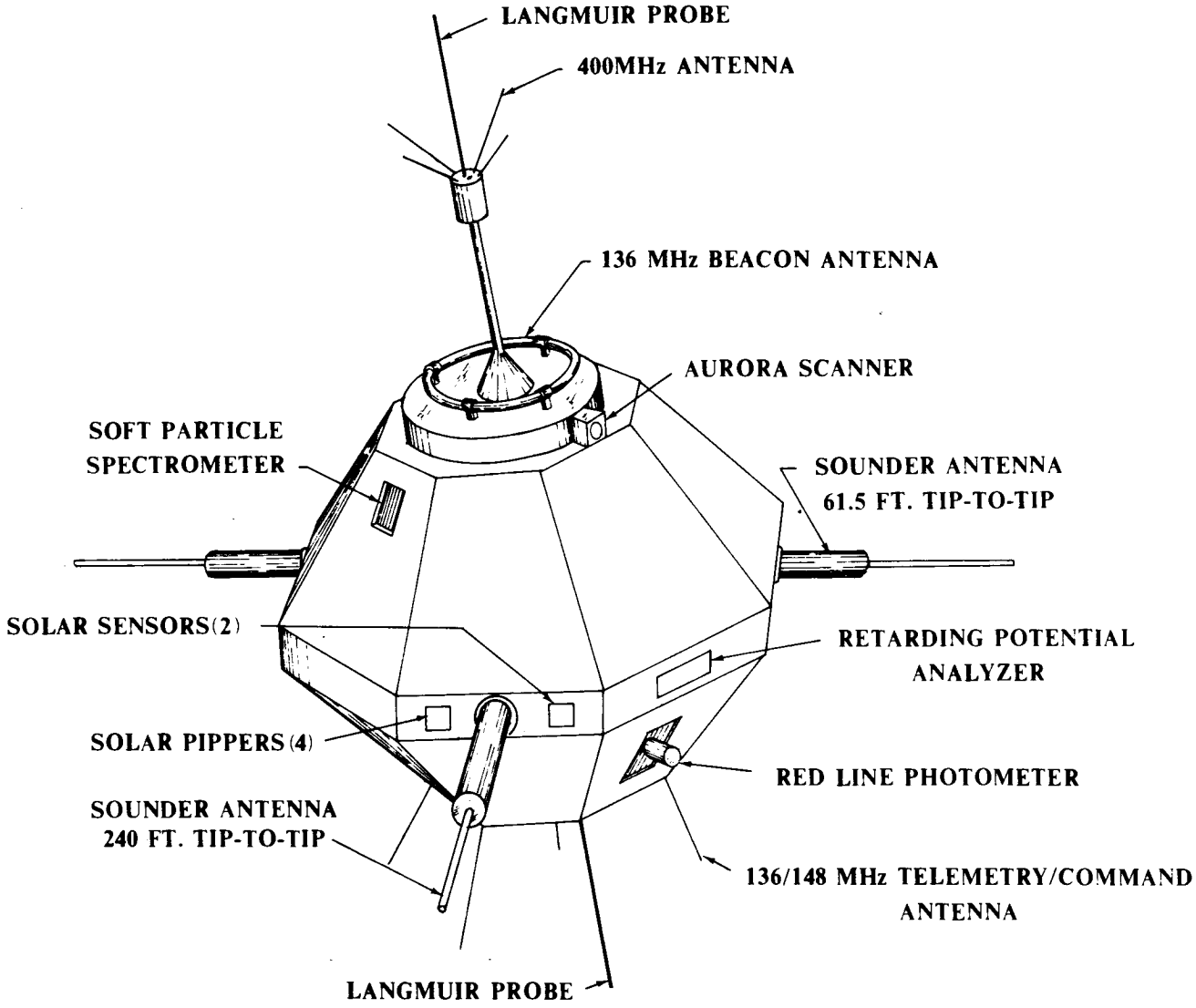
Probe Studies

Theoretical and experimental work is being done to enhance the usefulness of electrostatic probes for ionosphere and plasma measurements. A high power AC probe for ion temperature measurements is being theoretically and experimentally studied. A new multi-electrode probe geometry is being developed which should permit temperature and density measurements using the attracted regions of the probe characteristics, for electrons and also for ions

if the ion speed ratio is small enough. Collisionless theories are being constructed for probes in a magnetic field and for probes in flowing plasmas, the latter using self-consistent symmetric potentials from stationary probe theory as an approximation. An exact continuum theory is being developed for probes in flowing plasmas. A new type of plasma orifice probe is being experimentally and theoretically studied. Sheath distortion caused by intense RF emission from topside sounder antennas is being theoretically studied.

On 21 March 1972 a Black Brant III was flown at Churchill, Manitoba. The payload consisted of six photometers and four thin film oxygen atom probes. The photometers had narrow band-pass filters, centered at the following wavelengths: 557.7 nm from O (^{1}S), to give, O atom profiles, 577.5 nm from NO_2 continuum, also for O atom profiles 252.0 nm from $NO\gamma$ bands, for N atom profiles, 761.9 nm from $O_2(^1\Sigma)$, 1.27 μ from O_2 ($^1\Delta g$).

As a result of a failure of the power supply to these experiments during the greater part of the flight no useful data were obtained. However, results obtained at the end of the flight and post-flight calibration indicated that the atom probes had reacted and that the photometers themselves had not been affected.


LANGMUIR PROBE
400MHz ANTENNA
136 MHz BEACON ANTENNA
AURORA SCANNER
SOFT PARTICLE SPECTROMETER
SOUNDER ANTENNA 61.5 FT. TIP-TO-TIP
SOLAR SENSORS(2)
RETARDING POTENTIAL ANALYZER
SOLAR PIPPERS(4)
RED LINE PHOTOMETER
SOUNDER ANTENNA 240 FT. TIP-TO-TIP
136/148 MHz TELEMETRY/COMMAND ANTENNA
LANGMUIR PROBE

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 a Memorandum 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 U.S.A.'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 4 experiments and is in a circular orbit at a height of 1,000 kilometers. Orbital elements are: inclination 80.5°, perigee 994 km, apogee 1030 km. The experiments are as follows:

Ionospheric Sounder: The ionospheric sounder is used to measure the electron density of the ionosphere as a function of height over the frequency range 1 MHz to 12 MHz with 100 watts transmitted power. The sounder antennae consists of 2 dipoles, 36.6 meters (120 feet) and 22.9 meters (75 feet) tip to tip.

VLF Receiver: The VLF experiment is carried to investigate the generation and propagation of very low frequency waves within the ionosphere.

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.

At time of writing, useful VLF and sounder data are still being obtained from Alouette I for 1/4 hr. daily.

Alouette II

Alouette II was successfully launched on 29 November 1965. Orbital parameters are: inclination 79.8°, perigee 502 kilometers, apogee 2,983 kilometers. 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 which is essentially the same as the one 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 30 kHz.

Cosmic Noise: Same experiment as Alouette I.

Energetic Particle: Same coverage as Alouette I.

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 to 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 capactitive 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 one being obtained during a 2 1/2-hour day operating schedule.

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 anistropy 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.

ISIS I operates between 5 and 7 hours per day, and all experiments, with the exception of the ion mass spectrometer and soft particle spectrometer which are at present producing degraded data, 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 twelve 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 height, 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. The sounder can be operated in a variety of time-sequence modes which can be chosen for compatability with other experiments.

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 occurring VLF signals, the receiver has a dynamic range of about 80 dB, which is

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.

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 on 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.

achieved by the use of an AGC system. The AGC level is telemetered to the ground along with the board-band output of the receiver, which directly modulates the telemetry transmitter. Information is provided on:

a) The relative abundance of H^+, He^+ 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 long 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. At low frequencies the ion composition of the plasma may be an important parameter in determining antenna impedance, especially in the vicinity of the lower hybrid resonance frequency. This probability is being evaluated since the theory of antennas immersed in a plasma is not sufficiently well developed to provide reliable answers.

The observation, from the VLF records, that the topside sounder often generates noise at both the lower hybrid resonant frequency and at the proton gyro-frequency of the medium surrounding the spacecraft is of great interest. The characteristics of these signals are being 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.

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's 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 propagating 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 5577Å and 3914 Å over the portion of the dark earth visible to the spacecraft. A combination of internal electronic scanning and the natural orbital and rotational motions of the spacecraft causes a dual wavelength photometer to scan systematically across the earth. The data is being reproduced directly in the form of separate pictures representing emissions at each wavelength. The pictures will be used to study the ratio of 3914Å to 5577Å emissions (thought to depend upon the energies of exciting particles), and to compare auroral activity with phenomena recorded by other instruments on board the spacecraft and on the ground. All experiments are working well and up to 7 hours of data is acquired daily.

Satellite Support Services

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

Communications Technology Satellite

The Department of Communications, in co-operation with the National Aeronautics and Space Administration, have embarked on an experimental project that will carry Canadian technology into the second generation of communication satellites.

The project to launch a high-powered communications satellite into geostationary orbit in 1975 was the subject of a Memorandum of Understanding signed by officials of the Department of Communications and the NASA.

The Communications Technology Satellite (CTS) will be designed and built in Canada. DOC's Communications Research Centre at Shirley Bay will provide Project Management, R & D support and a spacecraft assembly and test facility; detailed design and fabrication of subsystems will be the responsibility of Canadian industry. NASA will provide the launch vehicle (a Thor-Delta rocket) access to some advanced electronic components and spacecraft environmental test facilities.

The program offers Canada the following advantages:

- -maintaining Canadian aerospace industry abreast of the latest developments in subsystems for communications satellites and the associated ground installations.

- -the opportunity to conduct communications experiments with small ground terminals in remote parts of the country.

The significant difference between the CTS project and satellite systems such as Intelsat and ANIK, is in the power of the signal transmitted by the space segment. In the ANIK series 6W TWTs provide a radiated (EIRP)* of approximately 33 dBW power while in the CTS a 200W TWT will provide an EIRP of 55 dBW. Consequently, for the CTS, comparatively inexpensive ground terminals will be required allowing more communities to be served.

EIRP - Effective isotropic radiated power

The heart of the CTS is a super-efficient, high powered Travelling Wave Tube operating in the 12 gigahertz frequency range. This tube is being developed and procured by NASA.

Principal Technological Objectives

Design and Flight Test:

1) a superefficiency TWT of novel design having an efficiency greater than 50% at a saturated power output of 200 watts at a frequency of 12 GHz;

2) a Mercury Bombardment Ion Engine;

3) a 3-axis stabilization system on a spacecraft with flexible appendages;

4) a liquid metal slip ring experiment;

5) a lightweight extendible solar array with an initial power output greater than 1 kW.

Principal Communications Objectives

1) demonstrate colour TV transmission of 12 GHz from a satellite to low-cost ground terminals;

2) demonstrate up-link colour TV transmission at 14 GHz from transportable terminals;

3) demonstrate two-way voice service between small, transportable ground terminals;

4) demonstrate sound broadcasting to small ground terminals;

5) demonstrate wide-band digital data transmission via satellite.

The spacecraft will be assembled at CRC in a new high-bay facility.

Rocket Program

The NRC Space Research Facilities Branch, together with their contractor Bristol Aerospace, Ltd. (Winnipeg), along with scientists from the

NRC, the Communications Research Centre and the Radio and Space Research Station, Slough, U.K. successfully launched four Black Brant III rockets into the ionosphere at the time of the total solar eclipse over East Quoddy, N.S. on 10 July 1972. The sun was very quiet and geomagnetic activity low. The vehicles had a somewhat higher spin rate than desired, which will complicate analysis of the langmuir probe, the Lyman- α and the solar X-ray data, but the CRC propagation experiment was unaffected by the high spin rate. All indications are that good data were obtained. A number of ground-based experiments were successfully conducted in support of the eclipse rocket program; the principal experiments being the partial reflection experiments which were conducted at the launch site, East Quoddy, at Ottawa, Churchill and Resolute.

VLF Program

Studies of the lower ionosphere and of the neutral atmosphere below 120 km continue. Measurements of the differential phase of partial reflections made simultaneously with the differential amplitude measurements have been successfully conducted at Ottawa. The two experiments provide an independent means of measuring the collision frequency at lower D-region heights. The two types of measurements have been found to be in good agreement. Furthermore the two experiments done together provide means of investigating the nature of the irregularities causing reflection. The results of these experiments have been published (September issue of J. Geophys. Res.). Other studies that have been made were concerned with diurnal and seasonal changes in electron densities under quiet conditions over Ottawa, and with effective electron loss rates during the decay phase of solar X-ray events and during abnormal ionization increases associated with small to moderately large energetic particle precipitation events. Instrumentation to measure winds, as well as ionization densities in the mesosphere over Ottawa is under development.

Propagation and Attenuation Activities

The SHF Propagation Program

The objective of the SHF propagation program is to study the effect of the earth's atmosphere on radiowave propagation, at frequencies between about 4 to 30 GHz, particularly as these effects relate to the design of satellite communications systems. Successful utilization of new bands above 10 GHz will require a sound knowledge of atmosphere propagation effects which become increasingly important as one moves to higher frequencies.

Precipitation Attenuation

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

Aircraft Beacon Experiment

During 1967 and 1968, CRC conducted an experiment to measure precipitation attenuation using aircraft-borne beacon transmitters at 4, 8, and 15 GHz. Direct measurements of the transmission loss along the propagation path were compared with path attenuations calculated from measurements of radar reflectivity using a 2.9 GHz weather radar.

ATS-5 Experiments

From September 1969 to July 1971, CRC measured precipitation attenuations using the 15.3 GHz beacons on the NASA ATS-5 satellite. The beacon signal was received with a 9.1 metre antenna. The antenna was also connected to a 15.3 GHz radiometer for simultaneous measurements of the sky noise temperature.

Considerable work has been done in comparing radiometer-calculated attenuations with those directly measured using the ATS-5 satellite. Assuming a fixed medium temperature of 272°K for a wide variety of storms, it has been found that attenuations calculated from the radiometer measurements are in very good agreement with those directly measured up to values of about 8 dB, the expected limit of reliable radiometer predictions.

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.

Precipitation Attenuation Statistics

A radiometer operating at 13 GHz and a data recording system have been developed and several constructed at CRC. To determine the statistics of precipitation attenuation for various geographic regions, these systems will be placed at seven locations across Canada. Each radiometer will be directed at the position of a geostationary satellite at 114°W longitude to obtain attenuation statistics appropriate to a geostationary satellite serving Canada. The equipment will be installed during the winter of 1972-73, and the experiment is expected to run continuously for approximately three years.

Attenuation Statistics Derived From Radar and Raingauges

McGill University, under contract to CRC, has used radar data to develop precipitation attenuation statistics for satellite-earth paths. In addition, methods have been developed which use raingauge and radar-derived storm motion data to obtain attenuation statistics for terrestrial microwave links of various lengths and spacings.

Transhorizon Propagation

Measurements of tropospheric structure and the characteristics of transhorizon propagation are being obtained with a scatter system operating at 15.7 GHz over a 500 km path between Boston and Ottawa. The scatter system employs narrow-beam transmitting and receiving antennas which are synchronously controlled to permit rapid scanning of the scatter volume over a large region of the upper troposphere. In a remote sensing experiment using this system, extimates of average wind speeds obtained from Doppler shift measurements have been shown to agree favourably with radiosonde measurements. In another experiment, statistics of transmission loss over the path are being obtained during 1972 and 1973 as part of an investigation of interference between satellite and terrestrial communications systems.

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, signal fading is observed and can be as high as several decibels in peak-to-peak amplitude. A series of measurements have been undertaken to determine the dependence of this fading on season, climate, elevation angle and frequency. An airborne refractometer was flown along the propagation path and the refractive index structures causing the fading were measured.

Tactical Satellite Communications Project

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

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

ERTS Ground Station at Prince Albert

As part of the Canadian participation in the NASA ERTS Program, the Communications Research Centre has supervised the conversion of the Prince Albert Radar Laboratory into an ERTS ground station. The station has no tracking or command capability, but does recover the broad-band imagery transmitted from the satellite of Canadian terrain. The station became operational in July 1972 with the successful launch of the ERTS A satellite. The imagery obtained by the return beam vidicon cameras, and the multi-spectral scanner system, is recorded on magnetic tape and shipped to the Canadian Centre for Remote Sensing in Ottawa for processing into imagery. The Prince Albert facility does have the capability of producing imagery at the full resolution of the ERTS system, in real time during a satellite PASS. This "Quick-Look" capability is valuable both as a check on the total system performance and for a quick indication of image quality and of any unusual features observable in the imagery.

ERTS - Earth Resources Technology Satellites

LES - Lincoln Experimental Satellite

ERTS GROUND STATION AT PRINCE ALBERT, SASKATCHEWAN

DEFENCE RESEARCH BOARD

Defence Research Establishment, Valcartier (DREV)

Atmospheric Observations

During the past year the analysis of data obtained from high flying aircraft and balloons has continued. Solar absorption spectra obtained with a sunseeker-spectrometer combination mounted on an RB-57 have been used to deduce the methane content of the lower stratosphere. It has been concluded that the methane is uniformly mixed up to 25 km with an average mixing ratio of 0.94 ± 0.16 parts per million; no large latitudinal variation of mixing ratio was observed.

The results of the balloon airglow measurement have been reviewed. The brightness of the 1-0 hydroxyl band at night has been estimated at 300-400 kR, the sudden decrease in OH intensity in morning twilight is ascribed to the photodissociation of ozone. The rotational temperature as indicated by the Q/R branch ratio rose from 170 K at night to 255 K at noon indicating a lower height for the emitting layer during the day.

Solar absorption spectra obtained with a balloon-borne Ebert-Fastie spectrometer launched at DREV have led to the determination of the methane abundance to altitudes up to 28 km. The mixing ratio obtained agrees with the value of 0.9 ppm obtained from the aircraft data up to 18 km, but drops to half that at the greatest altitude reached.

Ground Based Measurements

Analysis of the results obtained during a field trial at Fort Churchill in March 1971 has continued. Hydroxyl night airglow intensities were measured with two infrared photometers and a Michelson interferometer was used to obtain high-resolution interferograms of night airglow radiation in the wavelength region 1.1 to 1.6 microns. Auroral activity was monitored continuously with a 5577 Å photometer.

The photometer results indicate that the OH intensity increased to a maximum approximately 2 hours after local sunset and decreased slowly till midnight. Variation in OH intensity after midnight appeared to be unrelated to time of day. No appreciable enhancement of OH intensity was observed during periods of auroral activity.

Fourier transformation of interferograms of night airglow radiation has continued. Band intensities for the 2-0, 3-1, 4-2, 8-5, 7-4 & 6-3 transitions of OH have been calculated from high resolution spectra. Rotational temperatures for the 3-1, 4-2, 8-5 and 7-4 bands will be computed from OH line intensities. A weighted least-squares computer program will be used in rotational temperature calculations. In addition these interferograms will provide information on the relative intensity of the 1.27 μ band due to $O_2(^1\Delta_g)$. An attempt will be made to determine what correlation, if any, exists between OH rotational temperatures, band intensities and auroral activity.

Laboratory Program

The reaction $NO + O_3 \rightarrow NO_2 + O_2$ has been investigated as a possible source of $O_2(^1\Delta_g)$. The results show that less than 1/300 of the $NO + O_3$ reactive collisions lead to production of $O_2(^1\Delta_g)$.

The efficiency of $O_2(^1\Sigma_g^+)$ formation in the reaction $O(^1D) + O_2(^3\Sigma_g^-) \rightarrow O(^3P) + O_2(^1\Sigma_g^+)$ has been investigated using a flash photolytic technique. It was found that ≥ 0.8 of the $O(^1D) + O_2$ deactivating collisions lead to production of a $O_2(^1\Sigma_g^+)$ molecule.

The following relative rate constants for deactivation of $O(^1D)$ and $O_2(^1\Sigma_g^+)$ by atmospheric gases were obtained from the flow photolysis of ozone at 2537Å:

gas	O_2	CO	CO_2	N_2O	H_2	CH_4	H_2O	O_3
$k(^1D)$	1.0	1.0	2.4	3.6	2.0	5.4	5.0	9.7
$k(^1\Sigma)$	-	-	0.012	0.002	0.065	0.005	0.23	1.0

Rocket Motor Technology

At DREV there exists a well demonstrated capability in the development of new binders for solid propellants, the transferral of laboratory studies to plant scale operations, the evaluation of the combustion characteristics of propellants, the complete design of solid propellant rocket motors, the development of all components except flight-weight casings, and the static testing of rocket motors. This capability is continuously updated by studies in polymer chemistry, analytical techniques, chemical engineering, the internal ballistics of rocket motors and fundamental combustion processes. Recent improvements include digital computer programs covering ballistic design and stress analysis, a digital data acquisition system and a static test spin rig.

DEPARTMENT OF ENERGY, MINES AND RESOURCES

Geological Survey of Canada

Participation in Apollo Lunar Sample Studies

Studies of allotted lunar samples from the Apollo 14 and 15 manned missions have been made, or are in progress, by three teams of investigators. Samples from the Apollo 16 mission are being received, and it is anticipated that all three teams will take part in studies of samples returned from the Apollo 17 mission to the Littrow-Taurus region.

(a) Mineralogy-Petrology (Dr. R.J. Traill, Principal Investigator, Dr. A.G. Plant and Mr. M.R. Dence (Earth Physics Branch,) Co-investigators)

Studies of Apollo 14 samples have been reported and are described in detail in the proceedings of the Third Lunar Science Conference (in press). Glasses and rock fragments in soil samples and fragmental rocks are grouped on the basis of textural evidence and extensive chemical data into four types: alkali-rich (Fra Mauro) basalts; feldspathic (Highland) basalts and anorthosites; mare basalts; and potassic granites. Crystalline rock 14310 is a feldspathic basalt and, by analogy with terrestrial impact craters, is interpreted as an impact melt. From an impact model for the Imbrium Basin based on studies of terrestrial craters the argument is developed that the ejecta at the Fra Mauro site were probably only weakly shocked and heated by the Imbrium event and were derived from the uppermost crust in the Imbrium Basin area. The multiple shock and thermal events recorded in the fragmental rocks and feldspathic basalts are considered to result from intensive meteorite bombardment prior to the Imbrium impact. Some mare basalts also predate this event, but most glass-bearing breccias were probably of later derivation.

Study of Apollo 15 samples still in progress has continued the approach used for the Apollo 14 suite, with emphasis on the testural and chemical characters of the soil fragments and the components of the fragmental rocks. Three major groups are recognized: green glasses; Fra Mauro basalts; mare basalts; together with smaller amounts of highly aluminous (anorthositic gabbro) and potassic granite compositions.

The green glasses are the most distinctive type and their unusual composition (rich in Fe and Mg, and low in Ti) led to re-examination of data from an Apollo 12 soil, 12070 fragment. This relatively coarse-grained fragment consists only of olivine and recrystallized material of aluminous pyroxene composition. Modal analysis and chemical data give an identical average composition for the fragment to that of the average composition for the green glasses for both major and minor elements.

Samples from the Apollo 16 mission to Descartes are currently being received, and examination of them will commence shortly.

(b) Electrical Properties (Mr. L.S. Collett, Principal Investigator, and Dr. T.J. Katsube, Co-investigator)

The Electrical Methods Section, Resource Geophysics and Geochemistry Division, Geological Survey of Canada, has embarked on two agreements with Manned Spacecraft Center, NASA, to measure electrical conductivity, dielectric constant and loss tangent of lunar samples returned from Apollo 14, 15, 16 and 17 flights. The frequency range is from 10^2 to 2×10^8 Hz.

The first agreement is a non-funded contract with NASA to work on Apollo 15, 16 and 17 lunar samples. So far, five of 7 samples from Apollo 16 flight have been received. In the second agreement, Dr. S.H. Ward, University of Utah (Principal Investigator), has a partially funded arrangement with co-investigators, Mr. L.S. Collett and Dr. T.J. Katsube, to make electrical measurements on Apollo 14 and 15 samples. This laboratory has received 3 samples from Apollo 14 flight from Dr. S.H. Ward. The measurements have been completed. The purpose of this arrangement is to have a cross check on measurements performed in the two laboratories and for Dr. Ward to finalize on the 3 frequencies to be employed in Apollo 17 electromagnetic sounding of the lunar surface from the command satellite.

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

Determinations of the major, minor and some trace elements in one rock and one regolith sample from the Apollo 14 mission, and in two rocks and one regolith sample from the Apollo 15 mission, were completed and the data have been submitted for publication. Analytical work has started on the Apollo 16 material which has already been received.

Earth Physics Branch

The magnetic field of the earth extends far into space and is the major parameter controlling the flow of solar plasma in the vicinity of the earth. Interactions of solar wind with the magnetic field can often be observed with ground based magnetometers. The direction of the interplanetary magnetic field can also be obtained from polar cap magnetic observatories such as Resolute. Currents in the ionosphere and some of those in the magnetosphere are readily observed by ground based magnetometers. The rapid temporal and spatial dynamics of these current systems as well as the magnetospheric plasma demands many types of observations for a complete understanding of the complex interactions of the solar wind, magnetosphere, ionosphere and upper atmosphere.

The Division of Geomagnetism operates 10 permanent magnetic observatories in Canada and supplies microfilm copies of the magnetograms to World Data Centres on a monthly basis. Eight of the magnetic observatories are now recording in digital form on magnetic tape at one minute intervals. A new semi-automatic telephone verification system checks the digital magnetometer and recorder of each observatory on a daily basis from Ottawa.

Microfilm of old magnetograms, some of which date back to 1850, is being sent to the World Data Centre. The corresponding mean hourly values of the magnetic field for all observatory data back to 1900 are being recorded in a standard digital form on magnetic tape to be deposited in the World Data Centres.

A meridian 'line' of 6 magnetic recording stations through Churchill is maintained for the support of coordinated auroral zone observations by aircraft, balloons, rockets and satellites. Observatories along the 'line' extend coverage to Resolute in the polar cap and Huancayo on the equator. The synchronous satellite, ATS-5, which is operated by the NASA Goddard Space Flight Center, is on the same magnetic meridian.

Analysis of data from simultaneous electric and magnetic field variations during magnetic substorms indicate the auroral electrojet is turned on by the electric field changing to the southwest direction from the northwest and turned off by a decrease in the ionization rate. The electrojet is linked to the magnetosphere by a complex system of field-aligned currents.

Analysis of data from several coordinated rocket and ground-based magnetic and photometric observations during auroral substorms is in progress. Magnetic variations during the 1972 eclipse are also being studied.

Magnetic field measurements throughout Canada are continually being updated at repeat stations and by a new airborne 3-component magnetometer. The measurements significantly improve the model of the magnetic field configuration over Canada as well as contributing to improved models of the International Geomagnetic Reference Field.

Canadian Centre for Remote Sensing

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

The satellite program includes the readout of the Canadian data from the United States National Aeronautics and Space Administration's experimental earth resources satellites. The first of these - ERTS-1 was launched on July 23, 1972. The sensors on board -- a three camera Return Beam Vidicon System and a four spectral channel Multi-Spectral Scanner -- transmit imagery data covering a swath 185 km wide. Complete coverage of Canada is obtained repetitively every 18 days. An 85-foot parabolic antenna system at the Prince Albert Satellite Station has been converted to receive and record ERTS data. A data handling system has been built at the CCRS headquarters in Ottawa for the processing of ERTS and aircraft remotely sensed data. The National Air Photo Library Reproduction Centre, located in the same building as CCRS, is responsible for the photographic reproduction, indexing and distribution of ERTS aircraft and aerial survey imagery. Individual ERTS satellite images encompass an area of 185 km x 185 km with 10 per cent overlap between adjacent pictures. There are usually 4 orbits and 60-65 scenes per day over Canada.

The airborne remote sensing program was expanded during 1972. The operation of the aircraft and sensors is carried out by the Canadian Forces Airborne Sensing Unit which was established specifically to support the Centre's program. Four aircraft are currently available to perform missions requested by user organizations -- two DC-3's for low altitude work, a CR-100 and a Falcon Fan Jet for high altitude operations. The Data Acquisition Division of CCRS plans airborne missions and sensor packages and modifies sensors and aircraft to meet new requirements.

The applications Division of the CCRS has been formed to conduct research into methods of enhancing and automatically extracting information from remotely sensed data.

An Interagency Advisory Committee on Remote Sensing, with an Assistant Deputy Minister of Energy, Mines and Resources as chairman, was established to govern the National Program on Remote Sensing and to act as the CCRS "board of directors." A Canadian Advisory Committee on Remote Sensing was also established to assist in the co-ordination of remote sensing activities at the working level.

At least 20 ERTS DCS platforms have been deployed by interested agencies for the collection of ground data. NASA decodes these data and transmits them to the CCRS via teletype for distribution to the Canadian users.

Several provincial governments have organized or are organizing, regional remote sensing centres to make optimum use of data collected within their geographical jurisdictions.

Several discipline-oriented agencies have established interpretation laboratories to enhance their capabilities in the interpretation of remotely sensed aircraft and ERTS data.

The Centre has continued to participate in international studies of future requirements for resource satellites and remote airborne sensing.

Test areas for evaluation of ERTS and aircraft remote sensing data have been established where interested agencies are undertaking extensive ground truth studies.

DEPARTMENT OF THE ENVIRONMENT

Atmospheric Environment Service

Weather Satellite Activities

The Satellite Data Laboratory of the Meteorological Services Research Branch is now located at AES Headquarters, Downsview, Ontario. The Laboratory continues to acquire, utilize and distribute weather satellite data transmitted directly via the Automatic Picture Transmission (APT) mode from orbiting U.S. meteorological satellites.

Operational data over the past year has largely been acquired from ESSA 8, the last APT spacecraft of the Tiros Operational Satellite (TOS) series. ESSA 8 has now completed almost four years of constant operational use but continues to provide good quality pictures, largely from one of its two APT Vidicon cameras. Data from the improved TOS series, ITOS 1 and NOAA 1 spacecraft, were also received but the failure of both spacecraft at approximately the same time after very short operating periods, plus the unsuccessful launch of a third replacement spacecraft of this type, resulted in the loss of

infrared data, particularly for night time coverage. The experimental NIMBUS 4 spacecraft's APT system was activated in an attempt to provide this type of data, but low power, plus faulty attitude control, resulted in sporadic operation. The spacecraft has now been shut off until further notice.

The next scheduled weather satellite in the Improved TOS series will be ITOS D (1972). This satellite will not carry APT Vidicon cameras, but both IR and visual data from a scanning radiometer with a resolution of 4 - 7 km will be transmitted via the APT system. This spacecraft will, however, also carry for the first time a Very High Resolution Radiometer (VHRR) system. VHRR data will be transmitted simultaneously with APT type data but via a High Resolution Picture Transmission (HRPT) system. This new real-time transmission service, while it will provide meteorological data with a resolution of .5 km, requires a considerably more sophisticated "S" Band readout station than that required for APT reception. The Satellite Data Laboratory is currently evaluating and making plans related to establishing a VHRR readout capability. It is anticipated that daily real-time reception of high resolution infrared and visual data will provide a valuable tool for meteorological and other environmental applications.

Data from current APT daily receptions and from the accumulated magnetic tape archives continues to be distributed to weather offices, universities, and other governmental and private agencies for applications related to operations or environmental studies. Some 30,000 photos or copy photographs are being distributed to users each year.

Airglow Studies

Measurements of light scattered during twilight to study dust content and its variation in the atmosphere continue.

A Polarimeter to measure sky light polarization is complete, and is being used to study the effects of aerosal layers on the degree of polarization of twilight sky radiation.

Noctilucent Cloud Activities

The visual and photographic observations to study noctilucent clouds are continued, and the processed data published.

Theoretical Studies

Preliminary numerical studies have been carried out to investigate the role of atmospheric transport and radioactive-photochemical processes in determining the basic temperature and ozone structure of the stratosphere and mesosphere. Experiments to date have used a meridional model and plans are underway to supplement this with a full three-dimensional model. Particular experiments have been conducted to consider the atmospheric effects of trace constituents associated with the pollution output of high flying aircraft. Tentative results indicate that such processes will tend to reduce the ozone concentration which might lead to some cooling of the stratosphere.

Upper Atmospheric Temperatures

A scheme for determining the magnitudes and uncertainties of corrections applicable to Arcasonde-1A temperatures was developed by incorporating into the heat transfer equations of a thin-film mounted thermistor, recent theoretical and experimental findings on heat transfer processes in rarefied airflow. The method is now being used to correct rocketsonde temperatures measured at Canadian Stations so as to obtain more reliable temperature profiles required for verifying theoretical models of the atmosphere.

Temperature profiles are being calculated from over 900 density-altitude data obtained from experimenters in the Americas, Australia and the U. S. S. R. The main emphasis in this work has been on estimating, as well as possible, uncertainties in both the measured densities and the derived temperatures. It is hoped that this study will yield a comprehensive set of temperature profiles of known reliability which will be useful in updating standard atmospheres.

Data Acquisition Systems

As part of a project to set up a Data Acquisition System in the Atmospheric Processes Research Branch of the Atmospheric Environment Service, an automatic-control tracking equipment consisting of a Tone Range/Telemetry Interferometer system interfaced to a minicomputer, is being assembled for evaluation. The system is to be used for tracking rocket-and balloon-borne payloads and yields the sort of information normally obtained by means of a good tracking radar, namely, range, elevation angle and azimuth angle. The cost of setting up the system is only about one tenth that of a tracking radar and yet its performance and attainable accuracies are expected to compare favourably with that of a radar. The tracking data are also obtainable from it much sooner than from a standard radar system.

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, the Canadian Aerospace and Engineering Test Establishment (AETE) 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 1972, to the end of November, a total of 82 Lokis were fired. Of these 55 were successful in providing data on temperature and wind to 51 km or better. (Average apogee exceeded 60 km.) A further six provided data on one parameter only and were classified as 'partials'. The highest sounding achieved was 73 km on 22 November. Conjunctive rawinsondes complete the soundings from the ground up to the base of the rocket sounding at 30 km.

This program began at CFB Cold Lake in April 1967, and is continuing. Total launches to date are 548, of which 300 were Arcas rockets; the balance Lokis.

Data is transmitted by teletype the same day for worldwide dissemination. Combined with similar data from other stations and other networks, the program provides a fund of research data, a climatic record of upper atmospheric 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 National Oceanic and Atmospheric Administration, Washington.

Support to the University of Calgary Auroral Research Program

Continued support was provided to the University of Calgary for their auroral research activities. One balloon in the cosmic ray research series was launched in August. In addition, one balloon in the auroral X-ray research series was launched in October.

Ground-based observations of aurora by Image-Intensification TV (IITV) at Primrose Lake Evaluation Range continued in favourable periods (clear moonless nights) throughout the year.

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.

The 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 at first probably over the North Atlantic is being discussed. A system for a complete evaluation would comprise two satellites over a given area 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.

The related experimental program comprises a study of the effects of ionospheric variations on a communications link between satellites and aircraft. The measurements for this study are being carried out at Churchill, Manitoba. In addition evaluations are being carried out of modulation techniques for such a link and of a Canadian design for an economical, high gain, linear phased array, aircraft antenna.

NATIONAL RESEARCH COUNCIL OF CANADA

Division of Physics

The Physics Division is carrying out a continuing series of studies in the fields of magnetospheric particles, auroral physics and cosmic rays.

Magnetosphere Studies

Recent satellite studies have examined dayside solar electron latitude profiles in an attempt to determine more definitely the dayside limit of closed geomagnetic field lines. The measurements suggest that at magnetically quiet times the limit of closed field lines occurs at the position of the electron knee latitude ($\Lambda \sim 78°$) and that as magnetic activity increases, solar electrons scatter or diffuse across closed field lines.

In another study, high latitude outer zone electron profiles were examined near midnight at time of substorms. During the expansive phase of substorms electron pitch angle distributions peaked at 90° to the local magnetic field are observed up to 80° which is roughly 10° higher than normal. Such distributions are characteristic of bouncing particles and imply that the tail magnetic field up to distances of the order of 100 Re is closed and sufficiently regular to allow electrons of 20 keV to bounce between mirror points.

Auroral Particle Studies

A number of auroral ion composition measurements have been carried out in rocket flights from Fort Churchill. In a recent measurement during an auroral breakup fluxes of H^+ and He^{++} were detected whereas no He^+ ions were observed. Energy spectra of H^+ and He^{++} obtained during the flight were found to be peaked at the same energy per unit charge ($\sim$6 keV) and the average ion-flux ratio He^{++}/H^+ was found to be 3%. The results suggest that the auroral ions originated in the solar wind, were injected into the magnetosphere with approximately the same probability per ion incident on the magnetospheric boundary, and fell through an electrostatic potential of about 6 kV before being detected.

In other rocket experiments to study auroral ions it has been shown that convection electric fields can be inferred from the measured anisotropy produced by ion drift motion in the electric and magnetic fields. Further experiments are planned in this area.

Cosmic Ray Studies

Cosmic ray neutron monitor data has been used recently to carry out a study of the streaming of cosmic rays in the vicinity of the earth. It has been possible to estimate the magnitude of the cosmic ray gradient and to demonstrate the existence of the convective and field-aligned components of the streaming.

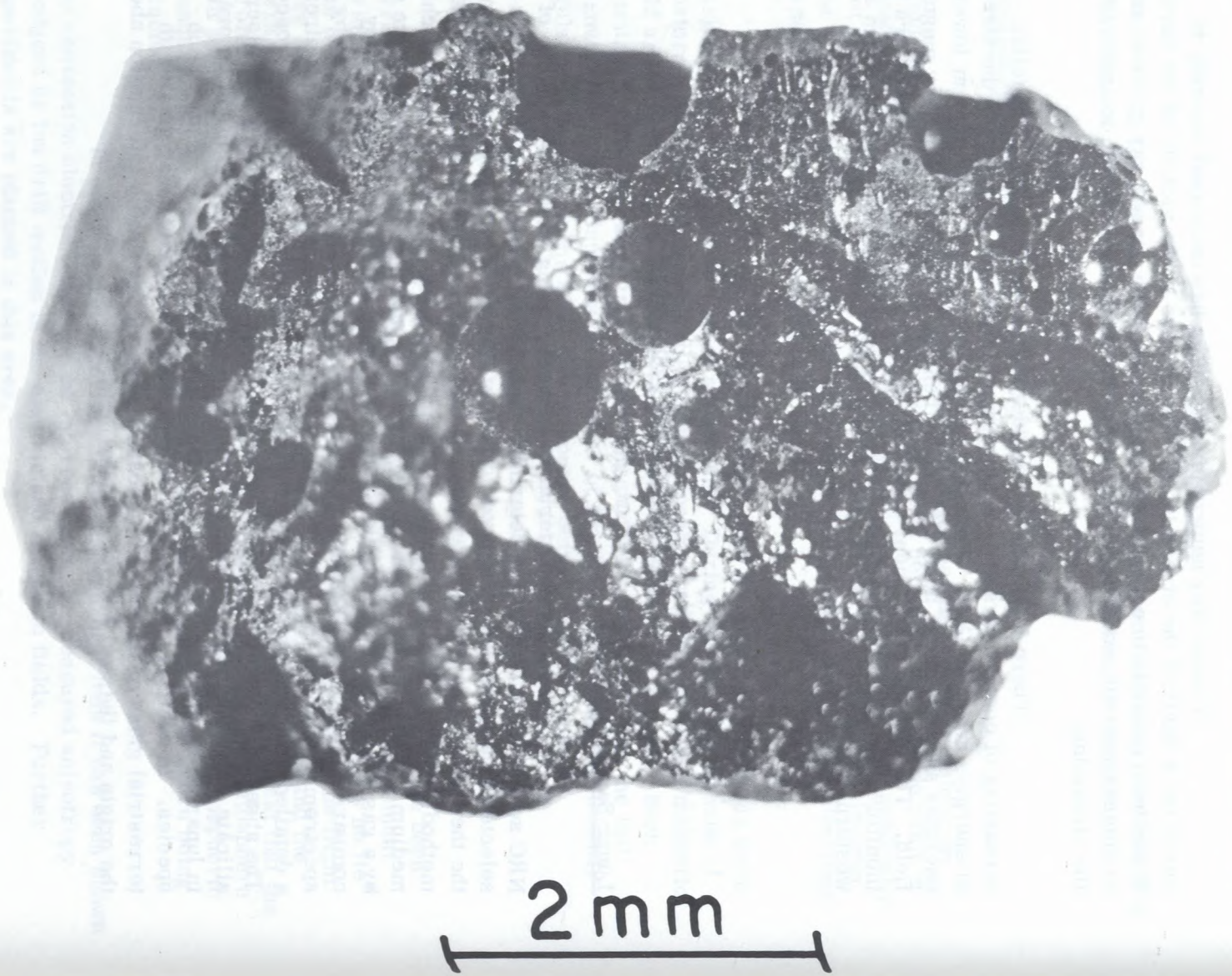
There is currently considerable interest in the interstellar streaming of cosmic rays and an experiment is planned to measure the streaming at energies near 450 GeV. Previous measurements have been done at lower energies and these have been effected by bending in the interplanetary magnetic field. The planned experiment involves a large array of particle detectors to monitor the relative intensities of muons arriving within 10° of the eastern and western horizons.

Atlantic Regional Laboratory

Lunar Sample Studies

Lunar fines material is currently being studied by a group of NRC scientists in Halifax, to determine discrete silicate anions in the fines and selected lunar glasses. The broad object of this work is to gain information on the thermal history of the lunar glass by studying its ionic constitution. The method involved is to dissolve the fines and glass fragments in a suitable chloride medium and then to determine the identity and concentration of the discrete anions by a gas-liquid chromatographic technique. Ionic species are identified by comparing with chromatograms of materials of known structure and also by mass spectrometric analysis. The complex nature of the lunar fines also requires that a detailed examination and modal analysis be carried out by optical microscopy. The absence of chemical weathering on the moon suggests that types of discrete silicate ions, normally subject to leaching in terrestrial soils, might be present in lunar fines and part of the aim of the study is to attempt to identify such species. In addition, comparison of ionic constitutents of lunar glass with terrestrial glass of the same composition may yield valuable information about the origin and thermal history of lunar material.

FRAGMENT OF VESICULAR GLASS FROM APOLLO 11 MISSION



To date samples of fines from Apollo missions 11, 12 and 14 have been studied, including a fragment of vesicular glass from Apollo 11. In several samples careful optical examination has revealed the presence of rare melilite-group minerals; this is the first reported finding of such species from lunar samples. The chromatographic analysis has revealed the presence of a cyclic tetrameric silicate ion ($Si_4O_{12}^{8-}$) in some of the samples. The results suggest this may be due to a yet unidentified mineral in lunar fines. The dominant silicate ion in all samples of lunar fines so far studied is the orthosilicate ion (SiO_4^{4-}) due to the mineral olivine.

The principal investigator of the group conducting these studies is Dr. C. R. Masson of the Atlantic Regional Laboratory of the National Research Council, Halifax, Nova Scotia. Co-investigators on the project are Dr. W. D. Jamieson, responsible for the mass spectrometric analyses; Dr. J. L. McLachlan, who performs photomicrographic studies of the fines and Professor A. Volborth, formerly a guest research worker at the Atlantic Regional Laboratory and currently at the University of Reno, Nevada. Professor Volborth's task is to characterize the specimens and perform the modal analyses by optical microscopy.

Astrophysics Branch

Upper Atmosphere Research Section

Auroral Photometry & Spectroscopy

The eleven-channel auroral photometer and 1/2 metre Ebert spectrometer were operated at Churchill in January 1972. Many auroral spectra in the visible and near infrared region (below 9000Å) were obtained; these are being analyzed to obtain band intensity ratios in various emission systems present in aurora for purposes of determining excitation mechanisms.

In particular, the relative intensification with height of the 1,1 O_2 atmospheric band was analyzed in terms of energy transfer from $O\ ^1D$. Quantative spectrum of aurora from 7000 - 9000 Å with 7.5 Å resolution was prepared and published.

Ground observations were made as part of a substorm rocket experiment with the meridian scanning photometer. The optical spectra showed a low intensity auroral red arc during the rocket flights thus indicating the precipitation of low-energy electrons. Proton precipitation was observed during the substorm.

The relative intensity measurements of IR auroral bands have now provided good values for the intensities of the N_2 IP and N_2^+ M systems.

Construction was begun on a computer - controlled random-access data acquisition system and the first phase is nearing completion. The system will be taken into the field for testing in an expedition to Gillam, Manitoba, in January 1973. Results of the 1972 campaign are awaiting processing. It is planned to correlate the analysis with photometric observations from ISIS-II and ground-based observations from Gillam.

Rocket Measurements of Auroral Plasmas

Several types of thermal electron and ion probes were flown at Churchill and Gillam on six auroral rockets launched during the winter of 1971/72. The Gillam rocket suffered a vehicle malfunction and data were lost, but the experiments on the five Churchill rockets performed satisfactorily. Two of these flew in the same auroral substorm, and the remaining three were launched on other nights into various auroral events.

Rocket Measurements of Type B and Normal Auroras

On January 15, 1972, photometer packages were launched from Churchill Research Range and Gillam, Manitoba, into a single auroral substorm to measure the vertical profiles of N_2^+, atomic oxygen and N_2 emissions. The Gillam rocket AAF-IIIB-53 failed due to a malfunction of the rocket motor. Good data were obtained from the second flight (AAF-VB-33). Three more flights are scheduled for 1973.

Auroral Electrojets

The morphology of auroral electrojets during the growth and expansive phases of auroral substorms near Fort Churchill is under study. Preliminary results of the investigation have recently been written.

Auroral Electrojets and Radio Aurora

The spatial and temporal relationships between auroral electrojets and radio aurora have been studied for a single auroral substorm. A paper has been written for publication in 1973. The study is continuing.

Radio Aurora

The results of the first phase of a study of periodically varying radio aurora have been published. Presently, the relationship between SSC's * and Si's* and the periodically varying radio aurora which sometimes follow these events are being investigated.

During the year a study was made of the magnitude of the aspect sensitivity of radio aurora. It has been concluded that at least two distinctly different aspect sensitivity functions have been observed by various workers, namely 10 dB/degree and 1.5 - 2 dB/degree.

Analysis of the simultaneous data from the four-station auroral radar network is continuing, and new programming techniques for handling these data are being developed. This network operates at Ottawa, Churchill, Thompson, and Great Whale.

Conjugate-Point Auroral Research

A start has been made on the study of auroral photometer data collected at the conjugate pair, Great Whale, Quebec and Byrd, Antarctica, during the four austral winters 1968-1971 inclusive. The records are in the form of paper charts and 1/4-inch magnetic tapes; specialized equipment has been assembled to transfer the data to computer-compatible tapes.

Infrared Aeronomy

Twilight, night airglow, and auroral observations in the 1.2 to 1.6 micron region were made using a photometer and spectrometer at Ottawa and Fort Churchill. N_2^+ Meinel auroral spectra, hydroxyl rotational distributions and diurnal intensity variations, and 1.27 micron oxygen emission and absorption spectra were studied. A significant relation between the intensities of the O_2 1.27μ, OH and (OI) 5577 Å night airglow emission was found.

SSC's - Storm Sudden Commencements

Si's - Sudden impulses

Rocket Measurements during the 10 July, 1972 Total Solar Eclipse

Probe measurements of electron densities in the D and E regions of the ionosphere were made on four rockets at East Quoddy, Nova Scotia, and on four rockets at Churchill. At East Quoddy, two rockets were flown in totality one in a partial phase, and one before first contact. Each rocket carried three Langmuir probes, a 2.66 MHz differential absorption experiment of the Communications Research Centre, and Lyman-α and X-ray detectors of the Radio and Space Research Station at Slough, U.K.

At Churchill, two Langmuir probes were flown on each of the four rockets. These probes measured electron density profiles in support of the airglow experiments of the University of Saskatchewan.

Solar and geomagnetic conditions were quiet during this eclipse, in contrast to the activity during the March 1970 eclipse.

Micrometeoroid Studies

Two collection experiments are currently being pursued. The first is a joint attempt with Dudley Observatory in Albany, N.Y., to collect large (50μ and up) particle, most likely of cometary origin, from a balloon floating at about 80,000 ft. These particles are not numerous; therefore, a long collection area-time product is required. This is achieved by utilizing a funnel 25 feet in diameter and an exposure period of twenty days or so, the time taken for a balloon released from Australia to circle the antarctic and to return over Australia. The collectors have been built; the group is on the verge of flight testing the collectors mated to the deployable funnel. Barring unexpected difficulties, the Australian launch should take place early in January of 1973.

The second experiment involves the collection of micrometeoroids (1μ dia and up) by lifting the collector to about 70 km by rocket and then allowing it to descend by parachute through the atmosphere. The collector is designed to open as soon as the parachute drag becomes moderate and collect for a preset period of time. Collection will be terminated at about 30 km. Since these smaller particles are much more abundant than the larger ones previously mentioned, it appears that a reasonable collection should be possible. The collectors are built and are presently being tested for a target launch date in mid January of 1973.

Meteor Astronomy

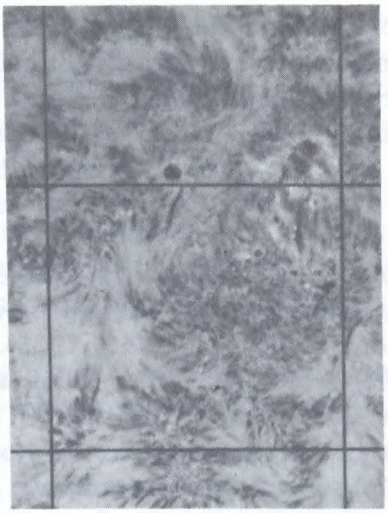
The program of routine observation of meteors using grating spectrographs and two backscatter radars was continued at Springhill Meteor Observatory and at Shiels Meteor Station. During periods in August and December, the NRC observers were joined by groups from Dudley Observatory, Albany, N. Y., and Marshall Space Flight Center, Huntsville, Alabama. These experimenters were using closed-link TV systems: one having an image orthicon in the camera, and the other an image-intersifier-vidicon. Analysis and intercomparison of the observations will be carried out.

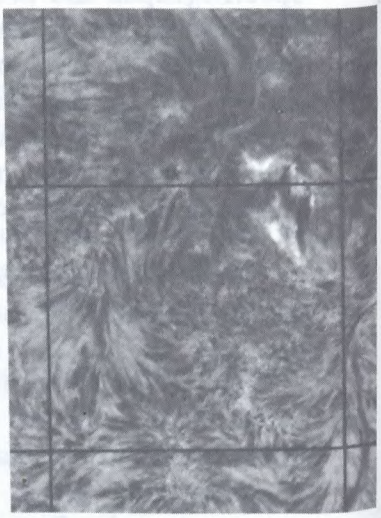
On October 8, 1972, the earth was expected to pass close to the orbit of comet Giacobini-Zinner in circumstances which had in the past produced brief but spectacular meteor showers (1946, 1933). Since the predicted time of maximum was in daylight here, only radar observations were possible at Ottawa. NASA made available to meteor experimenters its aircraft CV-990 for a flight along the Aleutian Island chain, the only part of North America in darkness at the time of the event. Two spectrographs and two scientists from this group were on board. Results were disappointingly negative; no shower occurred.

A detailed study of 21 Giacobinid meteor spectra photographed in 1946 has been completed. Using recently published luminous efficiency factors, chemical abundances of elements Fe, Mg, Na, and Ca have been found to be very similar to carbonaceous chondrites and the olivine-bronzite chondrites. Assistance was provided to NASA Langley Research Center in analysis of 600 meteor spectra secured during 1968-71 on the Langley photographic program in New Mexico. Work previously carried out on spectra from re-entry objects of the U. S. space program is gradually being declassified and some papers are being prepared for publication.

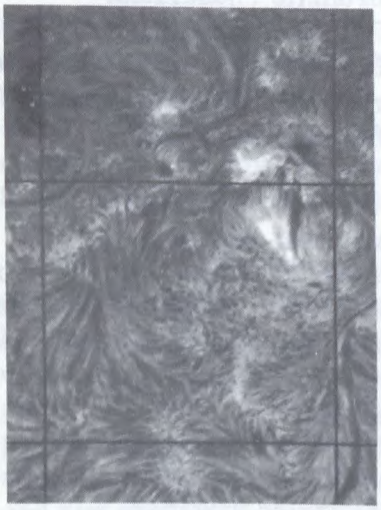
The 12 stations of the Meteorite Observation and Recovery Program (MORP) on the western prairies recorded several bright fireballs over the year, but none that were candidates for a meteorite fall. Several cases were useful for testing and improving the computer programs for trajectory analysis and prediction of meteorite fall area. Detailed lens-distortion corrections for the wide-angled MORP camera lenses are being determined.

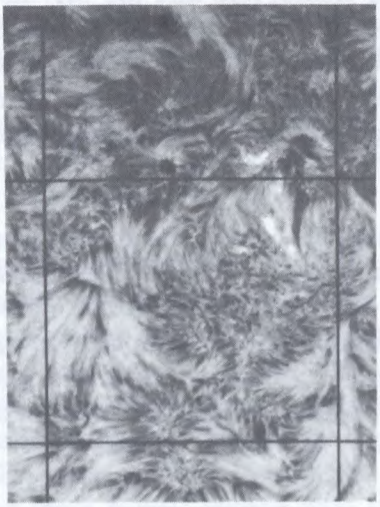
EXAMPLE OF OTTAWA RIVER SOLAR OBSERVATORY DATA

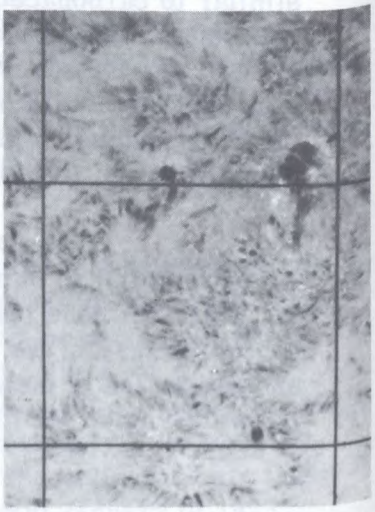




$\Delta\lambda$	+0.90	+0.70	+0.35	Å
Δt	0	2	4	sec







$\Delta\lambda$	−0.20	−0.45	−0.75	Å
Δt	8	10	12	sec

28 JUNE, 1972

Radio Astronomy Section

Daily Observations of Solar Radio Flux

Daily measurements of the intensity of the 10.7 cm radio flux from the sun and any unusual variations in this intensity are measured at the Algonquin Radio Observatory, Lake Traverse, Ontario. This radio emission has been found to accompany the X-rays, ultra-violet light and energetic particles from the sun, which are the major factors in the space environment of planet Earth. In view of this close relationship, solar radio observations have proven useful in describing the solar condition for the operation of spacecraft and for determining that portion of the ionization of the earth's upper atmosphere under the solar influence as part of the international exchange of data. The radio information from the observatory is contributed daily to the Space Disturbance Center in Boulder, Colorado, and the measurement of the radio flux at 17:00 U. T. appears in their daily forecast of solar weather conditions as the Ottawa 10.7 cm flux. The continuous nature of the watch of solar conditions, as well as the complexity of the solar phenomena, requires co-operation 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 3 meter reflectors which produces high resolution fan beam scans of the solar surface. At this time of declining solar activity, the emission from individual sunspot regions can be studied during various stages of their evolution.

Optical Solar Patrol Telescope

The first instrumental package in the multiple solar refractor at the Ottawa River Solar Observatory (ORSO) is nearly completed and operational. With this system, two images will be photographed simultaneously with a single objective lens. One image is formed through a 0.25 Å bandwidth filter tuned to the wavelength of the H-alpha Fraunhofer line, while the other is formed through a much wider (60Å) bandwidth filter centred at the same wavelength. This system will permit a direct comparison of chromospheric and photospheric features.

ORSO participated in the June 1972 Campaign for the Integrated Observation of Solar Flares (CINOF). High resolution photographs were obtained with the narrow bandwidth H-alpha filter of active regions that were specified daily through the information channels of the IUWDS. An example of the ORSO data is shown in the accompanying illustration for June 28, 1972. The grid pattern in the photographs has a spacing of 145 arc seconds and is produced by a fine wire reticle in the primary image plane of the telescope. The centre wavelength of the filter's bandpass was scanned under computer control across the H-alpha absorption line at a two second interval between successive exposures in this sequence. The data are being used to study both line of sight and transverse motions of chromospheric features, their intensity variations and dependence on depth in the solar atmosphere.

Space Research Facilities Branch (SRFB)

General

The function of the Space Research Facilities Branch is to develop and provide facilities to meet many of the requirements of the upper atmosphere and space research programs of Canadian scientists in universities and government agencies. At present, SRFB's work is concentrated primarily on sounding rockets. The major launching site used is the Churchill Research Range (CRR) which SRFB operates for the benefit of Canadian and foreign scientists. The CRR has facilities for the launching of most types of sounding rockets and balloons carrying scientific experiments to investigate the earth's upper atmosphere. Associated ground-based instruments are available to study the Aurora Borealis by photographic and spectro-photometric methods. There is also, for occasional use, a small launching facility at Resolute in the Northwest Territories, and another temporary facility was established at East Quoddy, Nova Scotia. The Branch also operates the Great Whale Geophysical Station at Poste-de-la-Baleine in Quebec, which records auroral and other geophysical phenomena for Canadian and American scientists.

In the implementation of the sounding rocket program, the Branch is responsible for providing the rockets and incorporating the scientific experiments into suitable payloads with associated telemetry and other devices; this work is carried out mainly by means of industrial contracts. The Branch also reduces flight data to provide vehicle trajectory and attitude information to experimenters, and from the telemetered information recorded on magnetic tape provides data required by individual scientists in appropriate forms.

The Canadian Sounding Rocket Planning Group (CSRPG) considers the scope of the rocket program and on the advice of its Scientific Evaluation Panel approves proposals for experiments and allocates priorities. It also recommends the undertaking of engineering developments and the updating of support facilities. The CSRPG after considering the recommendations of its Scientific Evaluation and Engineering Panels sets out a program which the Branch carries out within the limits of available resources.

Range Section

The Range Section is responsible for the administration and supervision of NRC operated sounding rocket ranges. This includes liaison with foreign government agencies regarding their use of range facilities. At present, there are three ranges in use: the Churchill Research Range (CRR) in Manitoba, the expeditionary range facility at Resolute, Northwest Territories, and the temporary range at East Quoddy, Nova Scotia. An additional temporary launch site was prepared at Gillam, Manitoba, for launchings in 1972 and 1973 to investigate auroral substorms.

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

Churchill Research Range (CRR)

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

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

Resolute, Northwest Territories

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

East Quoddy, Nova Scotia

In 1969, a temporary rocket launching site was established at East Quoddy, Nova Scotia, to provide a facility for studying upper atmosphere phenomena associated with solar eclipses. On 7 March 1970, four Black Brant III rockets were launched prior to and during the eclipse. They were instrumented to make measurements of the D region ionization and of the sun's radiation in the X-ray and Lyman alpha segments of the spectrum. During the eclipse of 10 July 1972, these experiments were repeated to obtain comparative data.

Gillam, Manitoba

In December 1970 a proposal was received for the launching of a series of three scientific sounding rockets to study the break-up phase of an auroral substorm. These rockets were launched in January 1972 to make measurements over as wide a latitude spread as possible. Two were launched from the Churchill Research Range while the third was launched from Gillam. In January 1973, the auroral substorm rocket program will be repeated.

Great Whale Geophysical Station

The Great Whale Geophysical Station continues to operate at Poste-de-la-Baleine, Quebec, in close proximity to the seismic and geomagnetic recorders of the Department of Energy, Mines and Resources. At this station various physical quantities are recorded for Canadian and American scientists on a continuous basis.

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. This section also publishes SRFB reports.

At present 20 rocket payloads are in various stages of planning and manufacture. Twelve of these are intended for launching from CRR during the 1972-73 winter auroral season. Among innovations to be considered for the future are recovery of payloads from water and the provision of accurate pointing systems for certain experiments. A total of eight rockets, four at CRR and four at East Quoddy were launched during the total solar eclipse to investigate the effects on the upper atmosphere of the sudden cutting off of the sun's radiation. This was the largest number of Canadian rockets launched in a single day since the program was started.

Development of an improved design for the deployment of clam-shell nosecone fairings has been carried out at Bristol Aerospace Limited. The 25.4 cm diameter version has been successfully flown on two occasions, and the 43.2 cm model will be tested in January 1973. The Space Engineering Division of the University of Saskatchewan (now SED Systems Ltd) has completed a Pulse Code Modulation (PCM) telemetry system to meet increasing PCM requirements. One such system has flown successfully and others will be used in the coming year. Computer compatible PCM data is produced.

An analog-to-digital translation system capable of handling both telemetry and radar data, designed and built by the Data Systems Section of REED, has been transferred to CRR. This provides the experimenters with digital records of their data in forms suitable for computer processing. The digitized radar data is smoothed and tabulated on the NRC IBM-360 computer in Ottawa.

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

To date SRFB has issued 70 publications reporting rocket launchings sponsored by the National Research Council of Canada together with annual editions of Space and Upper Atmosphere Programs in Canada and a Bibliography of resulting scientific papers. The scientific results are published in the appropriate journals by the scientists concerned.

National Aeronautical Establishment (NAE)

NAE is currently involved - together with SPAR Aerospace Products Ltd. and the Department of Industry, Trade and Commerce - in formulating the basis for a Canadian design and development programme in remote manipulators. Although the potential application areas for such devices range all the way from nuclear power stations and industrial processes to various underwater research and exploitation activities, the most immediate application may be envisaged in connection with the space shuttle programme. A Shuttle Attached Manipulator System (SAMS) is an important component of the orbiter, and manipulators for handling special payloads such as the Large Space Telescope (LST), Space Tugs and Sortie Cars will be needed shortly after the shuttle becomes operational. Negotiations are under way regarding a possible Canadian participation in these aspects of the shuttle programme.

In the field of Aerothermodynamics, the cooperative programme with NASA on the dynamic stability of the fully reusable shuttle was continued. Using the dynamic interference data obtained in last year's wind tunnel experiments, a flight mechanics analysis was carried out of the abort separation dynamics. It was shown that situations may be encountered when the two shuttle vehicles oscillate synchronously shortly after separation, and that in such situations the flight of the orbiter may be significantly affected by the dynamic interference from the booster. Similar problems may be envisaged for the currently considered partially reusable shuttle. Another part of the programme covered an investigation of the effect of a simulated jet exhaust plume on the dynamic stability of the launch configuration of the shuttle. It was found that in a few typical situations the resulting reduction in damping was of the order of 10-20 percent.

In the field of Structures and Materials, work continues on the finite element methods of structural analysis which were reported last year. The emphasis is shifting from the development of new methods to their application to concrete problems. Although most applications relate primarily to conventional aircraft or civil structures, studies of stiffened panels are also relevant to problems of acoustic fatigue in space vehicles.

A recent NAE - Flight Research study of an accident in which an airplane crashed into a mountainside in the Northwest Territories, has revealed constraints that may exist on emergency signals, automatically generated, in such cases. In this case a Crash Position Indicator succeeded in providing a long range signal, from near the bottom of a steep walled valley blocked on all four sides. This signal was quickly located in the dark by search aircraft in spite of the lack of any survivors.

The study showed that this case implies a design limit of 35 degrees below which useful long range signals to a fixed receiver should not be counted on, and a limit of 21.5 degrees below which long range signals to a moving receiver are uncertain.

The effects that these constraints should have on the design and tactics used in airborne searches have been studied. An attempt has been made to extend this information to see what constraints it would imply in the design and use of satellite-borne alarm, location and identification system. Since present search and rescue in mountainous regions in Canada constitutes about one-third of the problem, it would not seem reasonable to neglect these constraints in the long run, with either airborne or satellite systems.

DEPARTMENT OF EXTERNAL AFFAIRS

Scientific Relations and Environmental Problems Division
Legal Operations Division

United Nations Committee on the Peaceful Uses of Outer Space

During 1972 Canada participated in the fifteenth session of the Committee on the Peaceful Uses of Outer Space (September 5 to 15), ninth session of the Scientific and Technical Sub-Committee (May 3 to May 11) and the eleventh session of the Legal Sub-Committee (April 10 to May 5).

At the Legal Sub-Committee session Canada tabled a Draft Convention on the Registration of Objects Launched into Outer Space providing for the establishment of an international system for registering all objects launched into outer space. In 1968 France had also tabled a draft convention but the emphasis in their draft had been on national registers rather than on an international register. The Canadian and French delegations were able to combine their separate drafts into a joint draft which was given detailed consideration by a working group of the whole. Although no agreement was reached on some details in the joint draft, most of the important principles were accepted. Work on the joint draft convention will be given priority at the 1973 session of the Legal Sub-Committee.

A Soviet Draft Treaty concerning the Moon was also given priority consideration by the Legal Sub-Committee. Although the text of the Draft Treaty was improved greatly as a result of detailed consideration by the Legal Sub-Committee, a number of difficult points remain to be resolved before a treaty can be approved, e.g. should the treaty apply to just the moon or, as well to "other celestial bodies", and should the treaty stipulate that the moon's natural resources are the "common heritage of all mankind"? These and other outstanding questions will be pursued at the 1973 session of the Legal Sub-Committee.

Work at the ninth session of the Scientific and Technical Sub-Committee was highlighted by consideration of remote sensing of the earth from space, and in particular of the timing for initiating discussion of the organizational requirements of an international remote sensing system and of remote sensing from space. During the same time period as the ninth session, the Sub-Committee's Working Group on Remote Sensing, of which Canada is a member, held its preparatory session to plan its work programme. The Working Group agreed that it should study organizational and legal aspects, as well as scientific and technical matters relating to the activity. Its major accomplishment

was to ask the UN Secretariat to prepare a background paper containing an assessment of all documents submitted to the Working Group, and to establish a task force (comprising the USA, USSR, Sweden, France, India and Canada) to assist the Secretariat in this task. The task force has since met twice to examine drafts of the document and to advise the Secretariat on the preparation of the document, which is to be completed in time for the first substantive meeting of the Working Group in January 1973.

On the recommendation of the Committee on the Peaceful Uses of Outer Space, the U.N. General Assembly agreed at its 1972 session to a Canada/Sweden proposal that the Working Group on Direct Broadcast Satellites (DBS) should be reconvened in 1973 (it will meet from June 11 to 22 in New York) to review, inter alia, the following new developments:

(i) The decisions and recommendations adopted by the International Telecommunications Union (ITU) at the World Administrative Radio Conference for Space Telecommunications, Geneva, 1971. These decisions, which upon ratification will enter into force on 1 January 1973, deal with the allocation of frequencies for all kinds of space communications including satellite broadcasting, as well as with the technical and administrative regulations concerning the establishment and operation of satellite communication systems.

(ii) The UNESCO draft declaration of guiding principles on the use of satellite broadcasting for the free flow of information, the spread of education and greater cultural exchange, which was approved by the UNESCO General Conference at its October-November, 1972 session.

(iii) The on-going work performed by UNESCO and the World Intellectual Property Organization (WIPO) with regard to the protection of television signals transmitted via satellites.

(iv) In August, 1972 the USSR requested the inclusion on the agenda of the 1972 session of the General Assembly of the question of the elaboration of an international convention on the principles of the use of artificial satellites by States for direct television broadcasting. The USSR has tabled a draft convention on this subject.

THE INTERDEPARTMENTAL COMMITTEE ON SPACE (ICS)

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

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

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

Observer status is accorded to representatives of:

Ministry of State for Science and Technology
Treasury Board Secretariat.

CANADIAN OVERSEAS TELECOMMUNICATIONS CORPORATION

Activities in Space Radio Communications

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

The recently up-dated station on the East Coast of Canada, the Mill Village earth station complex, is presently operating with Intelsat IV over the Altantic and is in communication with 11 countries.

Due to rapidly growing internation traffic requirements over the Altantic, plans are now in progress to up-date and expand Mill Village I which was originally constructed by D. O. T. in 1965. Full commercial operation of the station is planned to be restored in early 1974 via Intelsat IV over the Atlantic. Early traffic congestion may necessitate Mill Village I to be partially operational mid way through the up-grading period.

West Coast Station

Construction of the new 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 COTC Lake Cowichan station is presently capable of transmitting 3 F. M. multi-destination carriers in the 6 GHz band and receiving 10 F. M. carriers within the 4 GHz band. The station also has the capability for the transmission and reception of one television and associated sound channel.

East Coast Station

COTC is currently investigating the feasibility of modifying and expanding the east coast complex located at Mill Village, Nova Scotia. The complex now consists of two antennas, the first MV I originally completed by D. O. T. in 1965 as an experimental station and the second completed in 1969 for continuous operation.

The modification program is intended to transform MV I into a standard earth station as specified by Intelsat. The modification will consist of changing various sub-systems to up-date the system performance and to arrange these sub-systems to allow for ease of maintenance during continuous operation.

Mill Village I

Although Mill Village I was originally an experimental station, it was used for commercial operation up to August 1972, at which time operations were suspended due to traffic rearrangements and station operational limitations. The station was previously capable of transmitting one F. M. carrier in the 6 GHz band and receiving two F. M. carriers in the 4 GHz band. The reception and transmission of television and sound was capable only with the suspension of the message carrier.

Mill Village II

The Mill Village II antenna and associated communication equipment has a total of 3 transmit chains with the capability of transmitting five F. M. carriers simultaneously. Nineteen receiver chains are available for reception at 4 GHz, three of these chains are used as standby and one will be used for the SPADE terminal.

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, the University of Toronto, the Department of Energy, Mines and Resources, (the Geological Survey of Canada), and the National Research Council of Canada (Atlantic Research Laboratory) in Halifax, N. S. 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 co-ordinating authority for Canadian agencies studying moon material.

TELESAT CANADA

The world's first geostationary domestic communications satellite, Anik I (an Eskimo word for brother), was launched from Cape Kennedy at 2014 EST, 9 November 1972, and arrived at its final orbital station on Friday, 24 November 1972, paving the way for the beginning of Telesat Canada's commercial operations early in 1973.

Under contract with the U. S. National Aeronautics and Space Administration (NASA), the spacecraft was launched by a 116-foot, thrust-augmented, three-stage, Thor-Delta rocket. NASA's responsibility ended when the spacecraft had been placed in a transfer orbit, approximately 26 minutes after launch, and the control of Anik reverted to Telesat Canada.

In this highly elliptical transfer orbit the satellite was tracked and commanded from stations at Allan Park, Ontario, Lake Cowichan, B. C. and Guam in the Pacific. After several reorientation maneuvers during nine transfer orbits the satellite was placed into an almost geostationary orbit by the firing, on November 13, of the apogee motor on board the spacecraft.

Several reorientation and orbit correction maneuvers were carried out following the apogee motor firing and the satellite was finally placed at its permanent orbit position of 114° west longitude on November 24, 1972, whereupon the normal station-keeping routine, required to maintain the satellite in that position for its seven-year life, began. During this period, the satellite will be controlled from Telesat's main earth station at Allan Park, Ontario with auxiliary services provided by Telesat's Lake Cowichan station.

The 37 earth stations which make up the terrestrial segment of Telesat's initial communications satellite system, are nearing completion and will be ready for customer service early in 1973. The initial baseline system consists of six different types of stations and will be continually expanded to provide additional services throughout Canada. A contract was being negotiated at the end of 1972 to provide telephone message service and data to 15 additional locations in Canada's North.

Following the successful placing of the first satellite on station, the satellite communications antenna was despun and controlled to provide coverage over all of Canada. A comprehensive test program is underway with this satellite to verify satisfactory operation of both the space and earth segments of the system, and demonstrate to Telesat's customers that the system meets the specifications set out in their contracts with Telesat Canada.

ANIK (and NAYAQ)

The implementation of the second and third flight units of Telesat's spacecraft is proceeding on schedule and it is anticipated that F2 will be launched on April 18, 1973, and then placed five degrees away from F1 at 109° west longitude. F3 will be maintained as an on-ground spare for replacement in case of failure of either F1 or F2 or for system expansion in 1973 or 1974.

During 1972, Telesat Canada leased seven of the 10 commercial channels on Anik 1. An eighth channel will be leased to the Canadian Overseas Telecommunications Corporation on completion of the Cantat II cable in 1974.

In mid-1972, the Canadian Broadcasting Corporation signed a contract for three radio frequency channels, each capable of carrying one colour television signal, two audio channels and a cue and control channel.

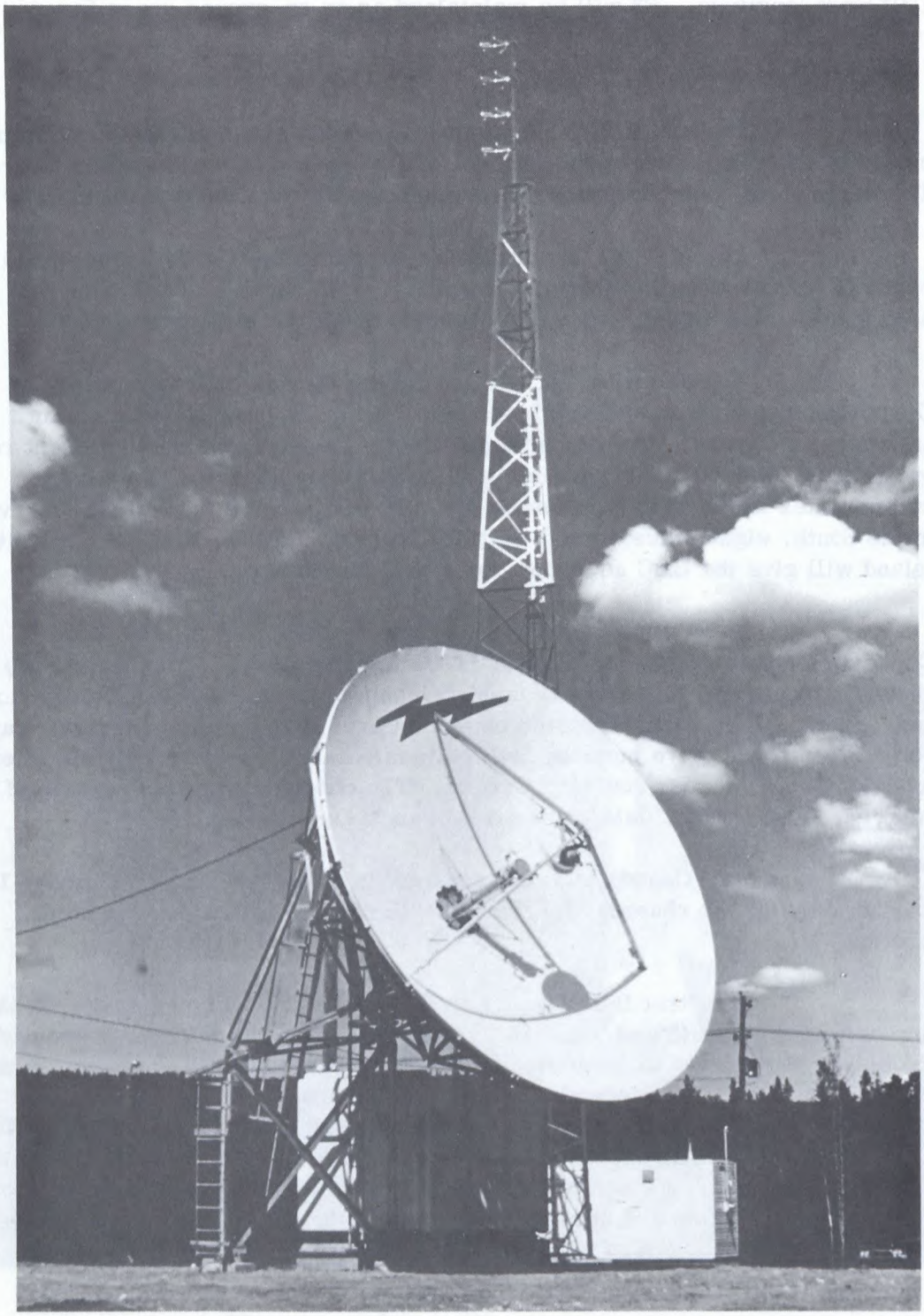
The satellite link will enable the Canadian Broadcasting Corporation to distribute live French and English language programming anywhere in Canada. Isolated communities in the North which at present rely on airlifted videotape packages for limited television service, and other communities which have no television at all, will receive the full CBC service. In the South, eight Telesat earth stations from St. John's, Nfld. to Vancouver Island will give the CBC additional access to its network.

In September, the Trans-Canada Telephone System and Canadian National/Canadian Pacific Telecommunications jointly leased two channels to provide high-density trunk telephone service between Vancouver and Toronto. The channels which can carry up to 960 simultaneous two-way voice circuits will give member telecommunication carriers a reliable alternate telephony route across southern Canada. The channels are also capable of relaying Telex, TWX, data transmission and facsimile service.

Bell Canada signed a contract in Frobisher Bay on October 13 for the lease of two channels for use with its service in Canada's eastern Arctic.

The first Bell channel, to be used as a medium-density trunk line between the South and the High Arctic, will initially provide 36 circuits to Frobisher Bay and 12 to Resolute and has additional capacity to accommodate traffic expansion. The second channel, with a capacity of 60 circuits will provide "thin-route service" of two circuits to each of 17 locations in the North. The first two locations are Pangnirtung, on Baffin Island, and Igloolik, on the Melville Peninsula. Fifteen other locations have been selected for "thin-route" service and contracts are under negotiation for the award of construction of these stations by the end of 1972.

TYPICAL TELESAT RTV EARTH STATION



ACTIVITIES IN INDUSTRY

BRISTOL AEROSPACE LIMITED, WINNIPEG, MANITOBA

Bristol Aerospace manufactures the family of solid propellant high altitude research rockets called Black Brants. These rockets have been developed over a period of 10 years and seven different models are now flight proven and available for scientific usage.

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

During 1972 a new vehicle, designated the BB VC, was successfully flight tested. This vehicle is a four fin variant of the well proven BB VB and was developed in order to make it compatible with the Aerobee 150/350 towers at Wallops Island, Virginia and White Sands Missile Range, New Mexico. The vehicle is equipped with rubbing strips for tower operation or, if desired, the rubbing strips may be replaced by launch lugs in an underslung position for a rail launcher. Ten flights have been carried out to date, five being tower launched and the balance rail launched from Churchill Research Range and Natal, Brazil.

Several attitude control systems are available for use on all models of the Black Brants. These provide two or three axis stabilization as well as solar and stellar capabilities. A new ancillary ogive recovery system assembly (ORSA), developed for NASA use in the SKYLAB calibration program, features a nose-mounted para-recovery unit permitting aft-mounting of scientific viewing devices which can then use the full 17" vehicle diameter.

Further Black Brant developments taking place are as follows:

1) Engineering evaluation is being carried out on Nike boosted versions of the Black Brant IIIB and VC. Performance of these vehicles is calculated to be 75 kg. to 460 km. and 204 kg. to 400 km. respectively. First flight of the Nike IIIB is scheduled for late 1973.

2) In the design concept are two new members of the Black Brant IV series, designated the Black Brant IVC and IVD. These vehicles will use the flight proven Black Brant IIIB motor as a second stage; the former is intended

to be rail launched and will have the BB VB motor, with modified grain geometry to achieve high launch acceleration, as a booster. The latter will utilize the standard BB VB motor, and is to be tower launched.

Twenty-eight Black Brant rockets have been launched to date in 1972, including four near-simultaneous launches from both Churchill Research Range and East Quoddy during the eclipse of July 10. The first flight of a Black Brant (a BB VA) from the Poker Flats (Alaska) range was also carried out.

A total of 231 Black Brants have been launched, comprised of the following:

Black Brant I	-	17
Black Brant II	-	52
Black Brant IIIA	-	54
Black Brant IIIB	-	9
Black Brant IVA	-	28
Black Brant IVB	-	4
Black Brant VA	-	25
Black Brant VB	-	32
Black Brant VC	-	10

Black Brants have proven themselves for their simplicity of launching and reliability. They are ideal for use from remote sites or ranges which possess only a minimum of support facilities. They have gained international recognition and have been used by scientific agencies in North America and Europe.

NORTHERN ELECTRIC COMPANY LIMITED

General

The Company has established a modern well-equipped satellite manufacturing facility at its Lucerne, Quebec site near Ottawa. These facilities are suitable for production and testing of "flight" hardware and include space-simulation equipment to ensure that satellite designs can meet the vibration, temperature and vacuum encountered during launch and while in orbit.

ANIK

Manufacture of the electronics "payload" for three "ANIK" type satellites was completed at the Lucerne Centre during 1972. The first flight model was launched at Cape Kennedy on November 9 and was successfully placed into its final orbital station on November 24. This electronics "payload" is a despun platform on which is mounted the microwave transmitters and receivers, the telemetry and command system, the power control electronics and the battery system. The ground control equipment which interfaces with the satellite-borne telemetry system was completed, tested and delivered to the ground control station at Allan Park early in 1972.

U.S. Domestic Satellite System

The "ANIK" type satellite has been offered to several U.S. Satellite operating companies for use in U.S. Domestic systems. The first of these systems will be established by Western Union and work has commenced on a set of three satellites for completion in 1973. These satellites will resemble ANIK very closely but will have antenna coverage directed to the U.S.A.

INTELSAT IV

The F-4 (fourth) flight model of INTELSAT IV was placed into orbit over the Pacific Ocean in January of this year. The microwave transmitting-receiving equipment on board was manufactured by Northern Electric in Canada as one member of a large team of Hughes-led INTELSAT suppliers. The satellite link over the Pacific was set up in time to carry high quality television coverage of the visit to China by President Nixon.


HS-333
F-1
SPACECRAFT

BELL-NORTHERN RESEARCH

General

As the research centre of the Bell Canada-Northern Electric group of companies, Bell-Northern Research is engaged primarily in the creation and development of communications systems. Formerly the Northern Electric Laboratories, the company achieved corporate status on January 1, 1971. Its equity is retained by the parent companies in the proportion of 51 percent Bell and 49 percent Northern. The company's headquarters and central laboratories are in Ottawa and regional laboratories are located at Montreal and Lachine in Quebec, and at London, Bramalea, Belleville and Kanata in Ontario.

Space and satellite activities in Bell-Northern Research are focused on the planning, evaluation and design of communications systems used in satellite and space projects, both earth and space segments.

Systems Engineering

In its role as long range planners for Bell Canada, the Systems Engineering group of Bell-Northern Research continued the investigation of the application and potential of satellite facilities in the domestic networks in Canada. Work carried out was related to studies on digital techniques, single-channel-per-carrier communications to the North, and demand assignment.

During the year a contract study was undertaken for the Department of Communications related to a multi-beam 12-14 GHz satellite system for Canada for the time frame 1977-1985. The potentials of frequency re-use, on-board time division switching and single-channel-per-carrier techniques with speech compression, were examined. The Report of this study was submitted to the Department of Communications in November 1972.

One of the systems engineering staff participated in the preparation of 'A Review of Satellite Systems Technology' drawn up by the Satellite Systems Committee of the Aerospace and Electronic Systems Group of the Institute of Electrical and Electronics Engineers, as manager of the group's Systems Applications Committees. The review outlines the current state of the art and future trends in this field, as applied to communications, broadcasting, tracking, navigation and data relay satellite systems.

Terrestrial Microwave Radio

The design of the RA-3TU6 high-frequency microwave system was completed, and the system has now become a Northern Electric product. The system was developed to distribute the signals received from Canadian satellite ground stations to main centres of population. Using the latest semi-conductor technology, it employs a different frequency spectrum from those presently assigned for satellite and earth station transmission in order to avoid interference. It operates in the upper six band, employing frequencies from 6.425 to 6.590 GHz and 6.770 to 6.930 GHz. The first installation has been made between the city of Toronto and the ground station at Allan Park, to relay voice signals to and from the Canadian domestic communications satellite, ANIK. Design of the RA-3T4, a similar system which operates at a lower frequency, has been finalized and commercial production by Northern Electric has begun. This operates in the frequency range 3540 to 4200 MHz.

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

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

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

Earth Stations

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

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

RCA Limited's work for the Intelsat global satellite network in 1972 comprised the completion of three stations - 30-meter stations in Karachi, West Pakistan and at Lake Cowichan, B.C. for C.O.T.C. for Canada's Trans-Pacific satellite traffic, and a 10-meter station in Shanghai; and the start of work on three new 30-meter stations - two for the People's Republic of China at Peking and Shanghai and a second station for the Government of India near New Delhi.

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

For the tracking subsystem, the company perfected during 1972 an on-off, signal maximizing type of tracking system using an adaptive controller as a cost-effective alternative to the conventional 3-channel monopulse tracking system. The new system, termed "step-track", operates from the maximum beacon or communications' signal as detected at the output of a conventional receiver chain, and dispenses with the difference mode circuitry of the feed system, the tracking downconverter and the 3-channel tracking receiver of the conventional monopulse tracking system. The step-track system was installed on two 30-meter stations and is being supplied on two new RCA 30-meter stations.

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

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

In ground communications equipment RCA developed a system of carrying 3 sound channels and the TV video signal on a 6.8 MHz subcarrier to achieve reduction of transmit and receive equipment in a domestic satellite terminal. Equipment with microintegrated circuitry is under development to achieve an 8-fold reduction equipment volume of the ground communications equipment subsystem.

Satellites

RCA's Canadian industry leadership in the field of satellite technology continued during the period of 1971-1972.

In 1971 RCA participated with Communications Research Centre of the Department of Communications in Systems planning and program definition of the new Communication Technology Satellite - a joint Canada/US, NASA project with satellite launch scheduled for 1975. RCA has responsibility for most of the electronics design in the spacecraft including SHF antennas and transponder, telemetry command antennas, transmitters and receivers, power conditioning, and attitude control. The preliminary design (Phase C) was mainly completed as of the last quarter of 1972.

In 1971 RCA Limited was designated the skill centre within the RCA Corporation for all satellite transponder activity including research and development. In this capacity RCA has carried out significant research and development in the application of Graphite Fibre and Epoxy Composites (GFEC) to the production of light weight temperature stable filters and multiplexers, and in the corresponding development of a light weight 24 channel transponder for U.S. Domestic Satellite applications.

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

Research

RCA's research activities on aeronomy and space physics continued over the period between January 1971 - October 1972.

The studies on the electromagnetic wave interaction with plasmas continued with emphasis on strong field effects and transfer of information through anisotropic plasmas. Research on radar backscatter involved theory experiment comparison of direct and cross-polarized backscatter from turbulent plasma and electromagnetic field modification in turbulent plasma. The work on antennas in plasma was completed with detailed theoretical and experimental investigation of the problem. Theoretical studies were performed on the accuracy of 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. Other activities involve development of a high intensity light source (150 kw) for airborne illumination, CO_2 laser side-looking radar imaging system, laser reflectivity measurements on various rocks, liquids and plants for possible application of satellite or airborne remote sensing of resources. The research laboratories were involved in various satellite programs. A number of research personnel were assigned to CRC as consultants on the Communication Technology Satellite (CTS) program. A study was undertaken on UHF satellite communication systems based on thin route traffic model. A system study was carried out to outline the various possible ways of interconnecting the transponder subsystem and the antenna subsystem of a satellite to serve U.S. Domestic Communication requirements. A trade-off study comparing transistor amplifiers and the driver TWT for use in the transponder for the U.S. Domestic Communication Satellite was also carried out. Another important activity concerned continuing development of sealed off CO_2 lasers with glass and ceramic tube for satellite communication system. Several tubes were supplied to NASA Goddard for evaluation and

they performed better than previous lasers supplied by other sources. A study was also undertaken on possible use of millimeter wave radiometry at 180 GHz on either satellite or aircraft to determine the vertical distribution of water vapor in the atmosphere. A feasibility study was performed on the use of microwave spectroscopy for air pollution monitoring. A number of projects were also undertaken on space electronics and systems. A study on intermodulation study on transistor amplifiers was carried out comprising experimental measurements and computer calculations using a program which included phase nonlinearities as well as amplitude nonlinearities.

S.E.D. SYSTEMS LIMITED

(Previously the Space Engineering Division of the University of Saskatchewan)

The Space Engineering Division was incorporated on July 18, 1972 into SED Systems Ltd., a company wholly owned by the University of Saskatchewan.

The newly formed company is engaged in space activities through contracts with the Canadian Government, Universities and companies in this or other countries.

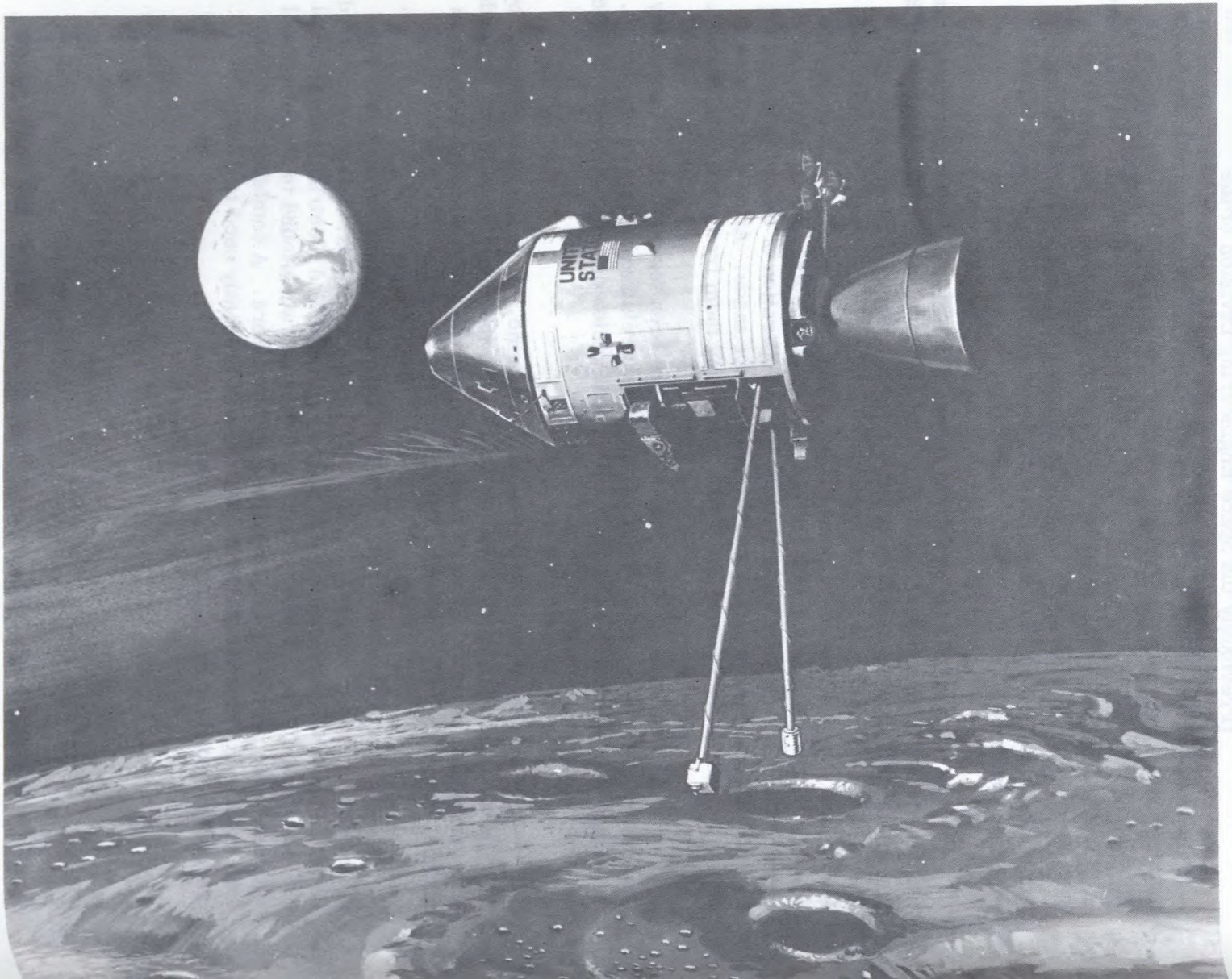
In the satellite field, SED is involved in attitude acquisition simulation studies and instrumentation. Several rocket payloads were built by SED in 1972. These carried experiments provided by government and university scientists. Two of the payloads were specially instrumented for recovery. For these payloads, new devices were developed which could protect experiments during the re-entry of the payload. Special shutters for photometers and extension and retract mechanisms were built to allow for the operation of experiments during the part of the trajectory that measurements were made. At re-entry these devices shielded the experiments, thus protecting them from excessive heating.

A "ram sensor" developed by SED has been tested in flight repeatedly. The sensor determines the attitude of the vehicle relative to its velocity vector. When this information is combined with magnetometer data the complete attitude history can be determined.

High power capacity in very small volume, which has been designed by SED, is a new power supply system which will be incorporated in future payloads. The completion of work on the PCM encoders provides a substantial increase in channel capability in the telemetry system.

Rocket released probes carrying their own telemetry were used for the measurements of currents, electric and magnetic fields. Results processed so far indicate the presence of field aligned currents and electric fields parallel to the magnetic lines. Electric fields and currents were found to correlate well with energetic particle precipitation and visual aurora. A combination of ion drift velocities, electric fields and currents is presently used to deduce ionospheric conductivity along the magnetic lines.

STEM BOOMS AS USED IN APOLLO 15 AND 16



SPAR AEROSPACE PRODUCTS LTD.

An increase of approximately 50% in Spar's aerospace business is recorded for 1972. This is attributed to the accelerating pace of Canada's Communications Technology Satellite (CTS) program as well as increased activity in spacecraft subsystems work.

Two new subsidiaries, Astro Research Corp. of California and Astro Spar S.A. of Brussels, Belgium were formed. Spar's aerospace activities in the respective markets are expected to increase accordingly.

Domestic Communications Satellites

As a result of the key role played by Spar in Canada's Domestic Satellite named Anik construction of three satellite structures for United States' Domestic Communications System has already begun. The Hughes' satellites due for launch in 1974, will be identical to Anik except for the antenna/reflector profile. Hughes predicts the sale of a further twelve Anik type satellites with Spar under agreement to provide the structural components.

Communications Technology Satellite (CTS)

Since May 1970, Spar has been conducting a number of services in connection with the CTS program including program definition, mission analysis, satellite configuration studies, design and development, and hardware fabrication.

During initial studies, Spar engineers were involved in the development of the overall spacecraft system. Responsibilities included optimum configurations of subsystems and components and the choice of a baseline design. Detailed design studies of the major subsystems and their integration into the complete satellite system were carried out.

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

The remainder of the CTS program aimed at a 1975 launch consists of the build of engineering, qualification and flight hardware and in support of the Communications Research Center in Ottawa during integration, launch preparation and post-launch evaluation of experimental results.

Lockheed Communications Satellite

Spar Aerospace is a key member of an international team which Lockheed has assembled to finalize a design and fabricate a full scale mock-up for an advanced communications satellite which Lockheed is proposing for the Intelsat V program. Spar's responsibility includes the complete extendible solar panel mechanical design, including the sophisticated rotary power transfer device, sun tracking system, and caging and release mechanism.

Solar array development hardware has been shipped to Lockheed and are undergoing vacuum life test.

Apollo Missions

The last two Apollo flights featured equipment designed, developed and built by Spar. Apollo 16 was equipped with two 25 foot (7.6 m) extendible STEM (Storable Tubular Extendible Member) booms used to extend Mass and Gamma-ray Spectrometer experiments away from the interfering effects of the Command and Service modules. These instruments measured the elements which make up the thin lunar atmosphere and analysed how this composition changes with altitude, solar illumination and position. Mapping of the radio-active sources was also carried out by these instruments.

Spar also provided the Apollo 17 Lunar Sounder antenna system which consists of a solid yagi array, an 80 foot (24.4 m) tip-to-tip BI-STEM dipole and the associated electronics. The Lunar Sounder experiment, considered as the most important of the mission, conducted a wide spread survey of sub-surface layering, depth of lunar rubble, pockets of moisture and ghost craters down to a depth of 1 km.

Spacecraft Machanisms

During the past 12 years, Spar has designed, developed, manufactured and flown over 450 extendible antennas, booms and structures for a wide variety of spacecraft programs. The acquisition of Astro Research Corp. has added another capability in Spar's field of extendible structures. Termed Astromast, this collapsible lattice structure is expected to find many applications in future satellite programs.

TABLE I

DETAILS OF ROCKET LAUNCHING AND EXPERIMENTS - 1972

VEHICLE	NOSE CONE Kgs	PLACE TIME DATE	Effective Launch Elevation	Apogee Kms	Apogee Time in Sec	Roll Rate rps	ROCKET PERFORM-ANCE	REQUIRED LAUNCH CONDITIONS	EXPERIMENTS	EXPERIMENTERS	EXPERIMENT RESULTS
AHF-IIIB-53	69.9	Gillam 2337 CST 14/1/72	-	-	-	-	Normal until T + 11.5 secs	night no moon single aurora substorm	Energetic Particle Detector Plasma Probes (3)	B. A. Whalen A. G. McNamara	Vehicle failure. Approx T + 11.5 secs Nil results SRFB 063
AAF-VB-33	201.9	CRR 0000.32 CST 15/1/72	84.0	(300)	(280)	4.0/ 0.5	Normal	Night, no moon single aurora substorm	Energetic Particle Detector Plasma Probes (3) Photometers (3) Electric Field Probes (2) Propagation Measurements Photometer (1)	B. A. Whalen A. G. McNamara F. R. Harris A. Knowles J. S. Belrose A. Monfils Belgium	Good data all experiments SRFB 063
AAF-IVB-25	67.13	CRR 0003:42 CST 15/1/72	85	(770)	(460)	3.22/ 0.28	Normal	Night, no moon single aurora substorm	Energetic Particle Detector Plasma Probes (3)	B. A. Whalen A. G. McNamara	Good data all experiments SRFB 063
ADD-IIIA-54	65.8 approx.	CRR 0345 CST 8/2/72	87.0	121.3	163.9	8.3	Normal	Night, with no magnetic or visual activity.	Two Channel Photometer (1) Single Channel Photometer (1) Plasma Probes (2)	E. J. Llewellyn/A. Vallance Jones E. J. Llewellyn A. G. McNamara	Good data SRFB 064
ADD-II-114	225.7	CRR 2148 CST 14/2/72	88.2	132.8	176	0.69	Normal	Night, recovery	Spectrometers (2) Photometers (2) Auroral Scanner (1) Photometers (2) Plasma Probes (2) Photometers (2)	D. J. McEwen D. J. McEwen C. D. Anger E. J. Llewellyn A. G. McNamara G. G. Shepherd	Good data and payload recovery in good condition. SRFB 065

TABLE 1

DETAILS OF ROCKET LAUNCHING AND EXPERIMENTS - 1972 (Cont'd)

VEHICLE	NOSE CONE Kgs.	PLACE TIME DATE	Effective Launch Elevation	Apogee Kms	Apogee Time in Sec	Roll Rate	ROCKET PERFORM-ANCE	REQUIRED LAUNCH CONDITIONS	EXPERIMENTS	EXPERIMENTERS	EXPERIMENT RESULTS
AMF-IIIA-52	78.1	CRR 0237 CST 21/3/72	86	119.3	162	7.9	Normal	Undisturbed No visual Aurora Recovery	Photometers (6) Atomic Oxygen Sensors (4)	H.I. Schiff L. R. McGill	Recovery Good data and payload recovery in good condition. SRFB 066
AED-VB-28	230	CRR 0344 CST 24/3/72	75	192.5	235	4.3	Normal	Clear sky No auroral forms Sun not visible below 200 km.	Electron Beam Flourescence Probe Atomic oxygen and nightglow emission measurements Plasma Probe Aerodynamic Spectrometer Micrometeoroid Detector Ion Impact Detector	J. H. DeLeeuw G. G. Shepherd A. G. McNamara J. Visentin R. Wlochowicz W. E. R. Davies	Low Angle Good Data SRFB 067
APF-IVB-26	90.7	CRR 0100 CDT 17/5/72	85	(660)	(420)	3.16/ 0.22/ 0.14	Normal	Night launcher with quiet geomagnetic and solar conditions for 1 week prior to launching	Galactic and Cosmic Soft X-ray Detector X-ray Detector	B. G. Wilson) R. J. Francey) D. Venkatesen	Good Data (Telemetry dropouts) SRFB 068
ADD-IIIA-55	81	CRR 0600 CDT	80.0	106.2	150	8.3	Normal	During the 10 July Solar Eclipse.	Infra Red Measurements Plasma Probes (2)	E. J. Llewellyn W. E. J. Evans A. G. McNamara	Useful Data SRFB 069
ADD-IIIA-56	81	1419	80.0	97.2	127	8.8	"				
ADD-IIIA-57	82.5	1526	80.0	103.3	155	8.3	"				
ADD-IIIA-58	82.5	1450 10/7/72	80.0	103.2	155	8.3	"				
AAF-IIIA-59	53.57	East Quoddy 1629:00.0 ADT	85.0	143.1	174.7	9.5/2.0	Normal	During the 10 July Solar Eclipse.	Plasma Probes (3) Radio Frequency partial reflection X-ray Lyman Alpha	A. G. McNamara J. S. Belrose J. F. Hall	Good Data SRFB 070
AAF-IIIA-60	53.98	1732:20.0 "	85.0	148.3	182.8	9.7/4.6	"				
AAF-IIIA-61	54.07	1739:00.0 "	85.0	144.3	181.5	8.7/2.5	"				
AAF-IIIA-62	53.80	1740:45.0 " 10/7/72	85.0	151.9	181.2	9.6/4.6	"				
AND-IIIB-63	64 approx.	CRR 1923 CST 30/11/72	-	-	-	-	Normal	Lunar darkness sun below horizon at apogee.	Cosmic Background radiation Measurements.	H. Gush	Good Data SRFB 073

TABLE II

ROCKETS AND EXPERIMENTS PLANNED FOR 1973

Vehicle No.	Pr. Scientist	Engineering	Launch Period	Conditions	Experimenters	Experiments	Remarks
AMF-II-126	Nicholls	BAL	CRR Early 1973	Distinct and sustained aurora	Nicholls McEwen McNamara	Spectrum photography and photometer Vacuum ultraviolet Ionization density	Recovery Reflown payload AMF-II-115
AAF-IVB-27/28	Whalen	BAL	January CRR	An auroral substorm event.	Whalen Anger/Cogger Kavadas/Koehler McNamara	Energetic Particle Detector Dual Wave length Mark IV auroral scanner Ejected Electric Field spin probes. Plasma Probes	One rocket into development stage of substorm one-half hour before second IV and VB-36 and IIIB-67 from Gillam and two Arcas rockets
AAF-IIIB-67	Whalen	BAL	January Gillam	An auroral substorm event.	Whalen McNamara Harris	Energetic Particle Detector Plasma Probes (Tip and 2 Swing-out 3-Channel Photometer	Repeat of AAF-IIIB-53 To be launched with AAF-IVB-27/28 and AAF-VB-36 and two Arcas rockets.
AAF-VB-36	Whalen	BAL	January CRR	An auroral substorm event.	Whalen McNamara Harris Monfils	Energetic Particle Detector Plasma Probes (Tip, 2 Swing-out and an Ejected) Three-channel Photometer Twin Photometer	Repeat of AAF-VB-33 To be launched with AAF-IVB-27/28 and AAF-IIIB-67 and two Arcas rockets
ADD-IIIB-64/65	McNamara	SED	February CRR	An appropriate radio aurora plus clear sky, no moon or sun at apogee	McNamara	Electromagnetic Probe to measure the aspect sensitivity function of electromagnetic scattering from radio aurora. Electrostatic Probe to measure the dimensional spatial spectrum of the ionization microstructure causing radio aurora.	Will use Churchill Auroral Radar One to two days between rockets.
ADD-II-127	McEwen	SED	February CRR	Visual aurora intensity Intensity II or greater	McEwen Anger Llewellyn McNamara Shepherd	VUV Spectrometer, Electron Spectrometer, Up and Down Looking Photometer and a Forward Looking VUV Photometer Optical measurements of various wavelengths Forward and side looking photometers to measure emissions at various wavelengths Swing-out side and ejected plasma probes To measure intensities of H4861, OI 5577Å emissions looking upward	Recovery Reflight ADD-II-114

TABLE II

ROCKETS AND EXPERIMENTS PLANNED FOR 1973 (Cont'd)

Vehicle No.	Pr. Scientist	Engineering	Launch Period	Conditions	Experimenters	Experiments	Remarks
AAF-VI-01/02	Wlochowicz	BAL	March CRR	A few days after the Quadrantid Meteor shower of Jan. 4/73 or other unexpected dust events	Wlochowicz	Dust collection in the 80 km to 30 km region.	Recovery Will need co-operation with Spring Hill Meteor Observatory One to two days between rockets A Dart to be launched before each VI.
AAF-VB-37	Roberts	BAL	March CRR	Sky clear to 2000 feet for photography	Roberts Fia Llewellyn McNamara McEwen Wlochowicz DeLeeuw Evans	Aerobee Tower modification 17" Vertical Hinge clamshells Tone Ranging Photometer Electromagnetic probes Vacuum Ultraviolet Photometers Micrometeoroid Detection Retractable Probe Photometer	Engineering rocket to test new and modified equipment
APF-IVB-30	Wilson	BAL	June or Oct. Hawaii	Geomagnetic and solar quiet for approx. a week prior to launch	Wilson Venkatesan	Cosmic X-ray probe Cosmic X-rays	As high an apogee as possible 700+ km. Repeat of APF-IVB-26
AMD-VB-34	Shepherd	SED	Late 1973 CRR	Electron aurora of IBC-II or more, no moon. Good visibility	Shepherd Young Zipf Harris Kavadas McNamara McEwen	Photometer Stimulated Fluroescence Mass Spectrometer Photometer Spin Probes Plasma Probe VUV Spectrometer	Recovery in conjunction with VA-35
AMD-VA-35	Young	SED	Late 1973 CRR	Quiet	Young Shepherd Zipf Kavadas McNamara McEwen	Stimulated Fluorescence Photometer Mass Spectrometer Spin Probes Plasma Probes VUV Spectrometer	Recovery in conjunction with VB-34

ABBREVIATIONS

AECL	Atomic Energy of Canada Ltd.
AFCRL	Air Force Cambridge Research Laboratories (U.S.)
ANIK	Eskimo name for brother
ARCOM	Arctic Communications Station
AU	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
CAE	Canadian Aviation Electronics
CANTAT	Canadian Atlantic Telephone Cable
CARDE	Canadian Armament Research and Development Establishment
CF	Canadian Forces
CHU	A radio station
COMSAT	Communications Satellite
COSPAR	Committee on Space Research
COTC	Canadian Overseas Telecommunications Corporation
CRAM	Centre for Research on Atoms and Molecules
CRC	Communications Research Centre of the Department of Communications
CRESS	Centre for Research in Experimental Space Science
CRR	Churchill Research Range
DCBRE	Defence Chemical & Biological Research Establishment
DND	Department of National Defence
DOC	Department of Communications
DOT	Department of Transport (now MOT - Ministry of Transport)
DRB	Defence Research Board
DREV	Defence Research Establishment Valcartier (ex CARDE)
DRIR	Direct Reading Infrared Readout
DRTE	Defence Research Telecommunications Establishment (now CRC)

Abbreviations (Continued)

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

Abbreviations (Continued)

PCM	Pulse Code Modulated
PSK	Phase Shift Keying
RADINT	Radio Doppler Interferometer
RCA	Radio Corporation of America
REED	Radio and Electrical Engineering Division
SED	Space Engineering Division
SN	Super Nova
SPADE	Single PCM Multiple Access Demand Equipment
SRFB	Space Research Facilities Branch
SSCC	Spin-Scan Cloud Camera
SST	Super Sonic Transport
STADAN	Space Tracking and Data Acquisition Network
STEM	Storable Tubular Extendable Member
TACSATCOM	Tactical Satellite Communication
TELESAT	Telecommunications Satellite
TIROS	Television Infrared Observational Satellite
TOS	TIROS Operations System
TT&C	Telemetry Tracking and Command
TWT	Travelling Wave Tube
URSI	International Union of Radio Science
USA	United States of America
UT	Universal Time
VELA	Nuclear Detection Satellite
WEFAX	Weather Facsimile
WMO	World Meteorological Organization
NOAA	National Oceanographic and Atmospheric Administration (previously ESSA)

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
$L \approx 4$	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
$O_2{}^1\Delta g$	term used in spectroscopy

Symbols (Continued)

$(OI)_{32}$	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