INTERDEPARTMENTAL COMMITTEE ON SPACE

SECOND ANNUAL REPORT

1971

Interdepartmental Committee on Space

SECOND ANNUAL REPORT - 1971

REPORT

Interdepartmental Committee on Space

ANNUAL REPORT - 1971

I. Introduction

1. Since the last report was submitted by the Interdepartmental Committee on Space on 1 February 1970, the ICS has met eight times. The efforts of the committee have been directed mainly towards the question of Canadian participation in the US Post-Apollo Program. Inevitably this study produced a requirement for a Canadian space policy, in general terms, not only to guide thinking on the Post-Apollo problem but also to provide a broad directive for all space activities.

2. Space, like the oceans and the atmosphere, is just another medium which has become available for use by mankind. Using space technology, it is now possible to position hardware semi-permanently in any desired position or orbit above the surface of the earth or to make profile measurements of various phenomena to very high altitudes. This new vista is of great interest to scientists and engineers, but particularly so to those who see in it the possibility of significant advances towards the achievement of earth oriented programs. These applications are mainly related to communications, earth resources and defence. In consequence, interested departments formulate their own policies for the use of space and, hence, a national space program exists only as the sum of the various departmental space programs.

II. Canadian Space Policy

3. There are two possible approaches to a national policy for space: either to state guidelines based on more general policy, or to permit guidelines to build up as the sum of ad hoc decisions. The ICS has attempted to take the first course.

4. Because of the diverse interests of the various departments represented on the ICS, it has not been possible to reach unanimous agreement on a set of guidelines. The draft, which is attached as Annex I, was approved by the majority of the Members at the Ninth Meeting of the ICS on 20 December 1970, but it was not supported by the representatives of DOC and ITandC, and the representative of EA abstained from expressing an opinion. These proposed guidelines will be forwarded to the Cabinet Committee for consideration at such time as a recommendation is made for action with respect to the NASA Post-Apollo invitation.

III. The NASA Post-Apollo Program

5. To investigate and recommend on a response to the NASA invitation for Canadian participation in the Post-Apollo Program, four sub-committees were set up in April 1970 as follows -

i) Scientific Research.

ii) Space Vehicles and Propulsion.

iii) Satellite Applications and Technology, and

iv) International Relations.

Reports were submitted by three of the sub-committees and were considered by the ICS. Although there was keen general interest in the Post-Apollo Program, and particularly in the Space Shuttle, no specific proposal was identified which would justify a submission to the Cabinet Committee. In these circumstances, the secretariat of the ICS was directed to prepare a proposed interim response to NASA's invitation and a draft, attached as Annex II, was considered briefly by the Committee. This was referred to the Department of Industry, Trade and Commerce for consideration, and to determine whether ITandC was prepared to sponsor it or, alternatively, to prepare some other proposal to support industry for consideration by the ICS.

6. During the year, the emphasis which the US has placed on Post-Apollo has changed so that the Space Station is being delayed and the Space Shuttle given priority. A situation report on the Post-Apollo Program has been prepared for Mr. Drury and a copy is attached as Annex III.

IV. Procurement of Communications Satellites

7. The ICS was not consulted in the question of the procurement of communications satellites for TELESAT Canada. In any case, it would have been very difficult, if not indeed inappropriate, for the ICS to offer an opinion, as many of its individual members were acting as confidential consultants to their own ministers on this question at the time.

V. Communications Technology Satellite

8. The ICS reviewed the Department of Communications Memorandum to Cabinet on "Canadian Satellite Communications Policies and Programs," dated 12 October 1970, at its 6th Meeting. Its views were communicated to Mr. Fernand Tanguay, Secretary of the Cabinet Committee, on 16 October 1970. The ICS did not consider the funding adequate to realize the best potential return from a communications technology satellite, but felt that the proposal was consistent with previous Cabinet direction, was within the scope of DOC activities and appeared to be the best compromise available.

.. 3

VI. Remote Sensing of the Surface Environment

9. The ICS has followed the work of the Interdepartmental Committee on Resource Satellites and Remote Airborne Sensing and is prepared to consider any proposals which may be forthcoming on this subject.

VII. Canadian Space Activities - 1970

10. A review of Canadian space activities during 1970 is contained in the National Research Council publication SRFB 048, which is attached as Annex IV.

VIII Statement of Federal Government Expenditures on Space Activities 1970

11. A statement of expenditures on space activities by the various departments involved is included as Annex V.

18 Jan '71

ANNEX I

Interdepartmental Committee on Space

Guidelines for a Canadian Policy for Space Activities

I. Background

1. Space activities in Canada started in 1956 at the Defence Research Board with the solid propellant research and development program which led to the successful Black Brant series of sounding rockets. This was followed in 1957 with the beginnings of an upper atmosphere research program with rockets and in 1959 with the Alouette I satellite project. Since then a reasonably coordinated and very successful program of scientific research in space by sounding rocket and satellite has developed. In December 1967 Cabinet approved a continuing program of research and development in the field of communications satellite technology, and since then has made further decisions in connection with domestic satellite applications for communications, earth resource surveillance and broadcasting.

2. The need for control and coordination of activities related to space has been recognized by:

i) The Royal Commission on Government Organization (January 1963), which made a recommendation concerning the consolidation into a single agency of all government non-military space research.

ii) The Science Secretariat, which commissioned a technical study, Special Study No. 1, Upper Atmosphere and Space Programs in Canada (February 1967).

iii) The Science Council of Canada, which made specific recommendations to the Prime Minister in its Report No. 1, A Space Program for Canada (July 1967).

iv) Cabinet, which approved the formation of the Interdepartmental Committee on Resource Satellites and Remote Airborne Sensing in July 1969 and of the Interdepartmental Committee on Space in December 1969.

3. It is now clear that the space environment is no longer the province of research alone, but that it can be used to further the objectives of departments with no particular interest in space as such. Consequently, and because of the high cost of using space technology, it is now even more important that such activities be coordinated in order to obtain optimum use of resources.

II. Aim

4. The Interdepartmental Committee on Space was instructed "to consider Federal policy for space activity in relation to national interests, needs and opportunities and to formulate and recommend appropriate plans and proposals." It was also directed "to review Canadian space activity.....and to make recommendations concerning the optimum use of resources, the coordination of space activity and the dissemination of information of such space activity." The aim of this paper is to recommend guidelines for a Canadian policy for space activities.

III. National Policy

5. Established national policy seeks to:

i) Foster economic growth.

ii) Safeguard sovereignty and independence.

iii) Work for peace and security.

iv) Promote social justice.

v) Enhance the quality of life.

vi) Ensure a harmonious natural environment.

IV. Space Policy and Objectives

6. Policy for space activities is then simply to use space, whenever necessary or preferable, as a means for the achievement of the aims of National policy. Consequently, the objectives may be stated as:

i) Safeguarding Canadian sovereignty, independence and interests.

ii) Utilizing space systems to achieve national social, economic and political goals.

In order that these objectives may be pursued effectively, continuous effort must be applied to essential subsidiary objectives, namely:

iii) Developing appropriate technological and industrial capability.

iv) Understanding the composition, properties and potentialities of space.

.. 3

V. Guidelines for Future Activities

7. The guidelines which follow are essentially a listing of the basic considerations in developing space activities.

i) Canadian soversignty, independence and interests should be furthered by:

a) Supporting and participating in international activities for the use and regulation of space.

b) Negotiating international agreements for continuing access to technology and facilities required for the pursuit of national objectives.

c) Maintaining knowledge of foreign space activity in order to respond quickly to any developments which might be of potential advantage to Canada or which could pose a threat to Canadian interests.

ii) Utilization of space systems for the achievement of specific goals should be through:

a) Activities proposed by departments already having corresponding terrestrial responsibilities. These activities will be part of departmental programs and will continue to be departmental responsibilities.

b) Interdepartmental coordination of all space activities.

c) Continued maintenance and extension of National expertise to advise on governmental requirements.

iii) Appropriate technological and industrial capability should be attained by:

a) Exploitation of areas in which there is acknowledged Canadian expertise.

b) Development of capabilities which are essential to meet domestic requirements.

c) Encouragement of industrial innovation in which there is promise of international trade and economic gain.

.. 4

iv) The understanding of the properties and potentialities of space requires:

a) Basic research appropriate to Canadian needs, expertise and capabilities.

b) Applied research aimed at solving problems directly associated with approved or proposed programs.

c) Search for potential applications and opportunities to help Canada to maintain a position of advantage in space technology and industry.

15 Dec '70

ANNEX II

Interdepartmental Committee on Space

The United States Post-Apollo Program - Interim Response

I. Introduction

1. In September 1969 a Special Space Task Group recommended to the President of the U.S.A. a program for the Post-Apollo period, which included a space station and a space transportation system consisting of an earth-space shuttle and orbital transfer vehicles. The space station and transportation system is aimed directly at reducing the cost of operations in space. The space station itself will provide a manned facility in earth orbit for research in a zero gravity and vacuum environment.

2. The Space Task Group also recommended internationalization of the U.S. program and, as a consequence, senior NASA officials have solicited participation by technologically advanced nations. In a briefing given to senior Canadian officials by Dr. T.O. Paine and Mr. A.W. Frutkin on 15 December 1969, Canada was invited to participate in the Post-Apollo Program, and the question was referred to the newly formed Interdepartmental Committee on Space.

II. Aim

3. The aim of this paper is to recommend the action to be taken by Canada in response to the U.S. invitation to participate in the Post-Apollo Program.

III. Canadian Objectives and Requirements

4. The objectives of Canadian activities related to space are:

a) Safeguarding Canadian sovereignty, independence and interests.

b) Utilizing space systems to achieve national social, economic and political goals.

c) Developing appropriate technological and industrial capability.

d) Understanding the composition, properties and potentialities of space.

5. The space station/space shuttle system could contribute to all these objectives and will, in fact, become a requirement if the launching of satellites by rocket is phased out. One of the main objectives of the space shuttle is to reduce markedly the cost of placing payloads in orbit by eliminating the cost of all the expendable hardware necessary at present in the rocket system. However, the facility which it will provide to carry out assembly, modification, maintenance and replacement operations in space will also make for considerable reductions in the development costs and for increases in the effectiveness of research and, particularly, of applications systems. There can be little doubt of Canadian interest or of eventual Canadian involvement.

IV. Discussion

6. Four sub-committees were set up by the Interdepartmental Committee on Space to study the NASA invitation and to make recommendations on the action to be taken. A concise summary of their findings follows.

7. The Post-Apollo Program is the blue print for space activities during the remainder of the twentieth century. The impact of a space transportation system serving manned facilities in space will be considerable, and it is probable that the conventional means of launching satellites with large rockets will be phased out in the next fifteen to twenty years. It is clear that the extension of present Canadian applications, technological and scientific programs is bound eventually to become involved with the space shuttle/space station/space tug system.

8. The space transportation and station system is within the established state of the art, although there are still a large number of scientific and technological problems to be solved. Some of these problems could certainly be tackled in Canada and would provide opportunities for the development and profit of Canadian industry.

9. There is still no total US commitment to the Post-Apollo Program and, although it is certain to come, a major development phase is about two years away. Present activity is still in the design study phase, the point at which the course of development is charted and at which the items of interest to Canada should be identified and action to exploit their possibilities initiated.

10. Unfortunately it is not yet possible to establish any relationship between costs and benefits of participating in the program and, consequently, no form or level of involvement in monetary terms can be recommended. However, a contribution to the scientific and technological groundwork of the Post-Apollo Program would probably be a good investment and could be financed through existing departmental channels. Individual cases could be supplemented by additional funds when justifiable.

.. 3

11. The sub-committees recommended that Canada should not seek explicit involvement at this time, but should inform NASA that there is interest, and take steps to identify and support selected areas of interest.

12. It should be noted that Canadian scientific and technological expertise and industrial capacity are very limited. Current Canadian programs are also modest, requiring about fifteen sounding rockets per year and a satellite launch about every two years. Nevertheless, Canada does require a satellite launch capability and access to the space technology and facilities which are economically beyond National capability. Since the United States appears to be intent on and capable of retaining control of the commercial utilization of space for US industry, it is very unlikely that Canadian industry can hope for any serious penetration of the market. However, a careful analysis of the possibilities could well permit the establishment of recognized Canadian expertise and capability in specific areas.

13. As noted above, the US has not yet made a total commitment to the Post-Apollo Program. Also, as far as is known, no other country has made an explicit proposal to participate. In fact, early in November, the European Space Conference failed to agree on the form of a response or on the organizational body through which a response would be submitted. Nevertheless aerospace organizations in several European countries, notably the United Kingdom and Germany, are collaborating with US contractors, apparently with the backing of their governments. There is little doubt that the Post-Apollo Program presents a requirement, an opportunity and a challenge, and should not be ignored.

V. Conclusions and Recommendations

14. Canada will require supporting facilities in space which she is unlikely to be able to provide for herself. In the event that the US succeeds in its space shuttle/space platform/space tug program and phases out its conventional launches, Canada will probably have no economic alternative to using the new facilities. Actual participation with the US in the development of these facilities appears to offer potential economic and political benefits to Canada, though the full extent of these benefits cannot be evaluated without further exploration of the possibilities with the US.

.. 4

15. Therefore, the following recommendations are made:

a) Canada should express her appreciation to the US for offering to internationalize the Post-Apollo Program. She should also indicate her interest in exploring the program further with a view to defining possible areas for participation which could be of mutual advantage to the two countries.

b) To implement (a) above, Canada should establish liaison with NASA:

i) to ensure that adequate information is available to permit any scientific technological or industrial potential to be exploited; and subsequently -

ii) to permit further more detailed recommendations to be made to the government.

c) Canada should continue to consult with other countries about their intentions and arrangements with the US with respect to the Post-Apollo Program and explore any opportunities arising in this regard for advantageous cooperation with them.

23 Dec '70

ANNEX III

ANNEX III

PRIVY COUNCIL OFFICE
SCIENCE SECRETARIAT

CANADA

BUREAU DU CONSEIL PRIVÉ
Our File: ICS/123
SECRÉTARIAT DES SCIENCES
Ottawa 4, Ontario
21 January 1971.

MEMORANDUM TO: Hon. C.M. Drury

FROM: Robert J. Uffen

RE: NASA Post-Apollo Program

1. You will recall that Dr. T.O. Paine briefed you on the NASA proposals for their Post-Apollo Program on 15 December 1969. The main theme of his remarks was that NASA Post-Apollo activities would be concentrated on a manned orbiting Space Station, and a Space Shuttle Transportation System. He also announced that the U.S. proposed to internationalize the program and he invited us to indicate areas where we wished to participate. Dr. Paine repeated his remarks and invitation in Europe, Australia and Japan.

2. Following Dr. Paine's briefing in December 1969, the Interdepartmental Committee on Space (ICS) undertook to recommend appropriate action. The ICS commissioned sub-committee reports on: space research, satellite applications, space vehicles and propulsion, and international aspects. In addition, the ICS followed the evolution of the Post-Apollo Program within NASA, and the activities of other countries, particularly the European countries, in trying to formulate their own response to the NASA invitation.

3. Although the ICS sub-committees expressed general interest in the Post-Apollo Program, no specific Canadian participation in the Post-Apollo Program has been identified which would warrant a formal proposal to the Cabinet for an additional program at this time. However, our current programs such as ISIS B, TELESAT, the Communications Technology Satellite (CTS), and Resource Sensing (ERTS), and studies on other space applications, are proceeding in the normal manner.

.. 2

4. None of the other countries which were approached by NASA have responded formally. In fact, there was a major disagreement at Brussels during the Fourth Conference of Ministers of the European Space Conference on 4 November 1970, when Great Britain declined to approve a proposed response from the European countries on the grounds that the Post-Apollo Program was "undefined." Subsequent to this, Mr. A.W. Frutkin, the NASA Assistant Administrator for International Affairs, visited Europe and proposed more flexible procedures for countries to ascertain, without any actual or implied commitment, how they might participate.

5. In spite of the lack of a formal response from the European countries to NASA, a number of European companies, such as The British Aircraft Corporation, have been able, with government backing, to negotiate arrangements to participate in preliminary design studies related to the Post-Apollo Program. The Department of Industry, Trade and Commerce is actively studying appropriate means of assisting the participation of Canadian industry in a similar fashion.

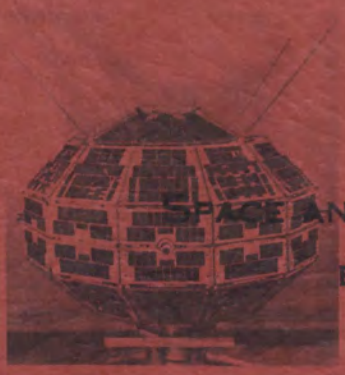
6. In the meantime, NASA has changed its priorities on the main components of its program. The Space Shuttle which requires more new technology and development is being given more emphasis by NASA. On the other hand, the Space Station, which is more within current technology, is being delayed.

7. The various Canadian departments concerned, and the ICS, are continuing to follow the activities of NASA and of the European and other countries with respect to Post-Apollo to seek opportunities for participation to our advantage.

8. I will keep you informed of developments and of progress towards this end.

R.J. U.

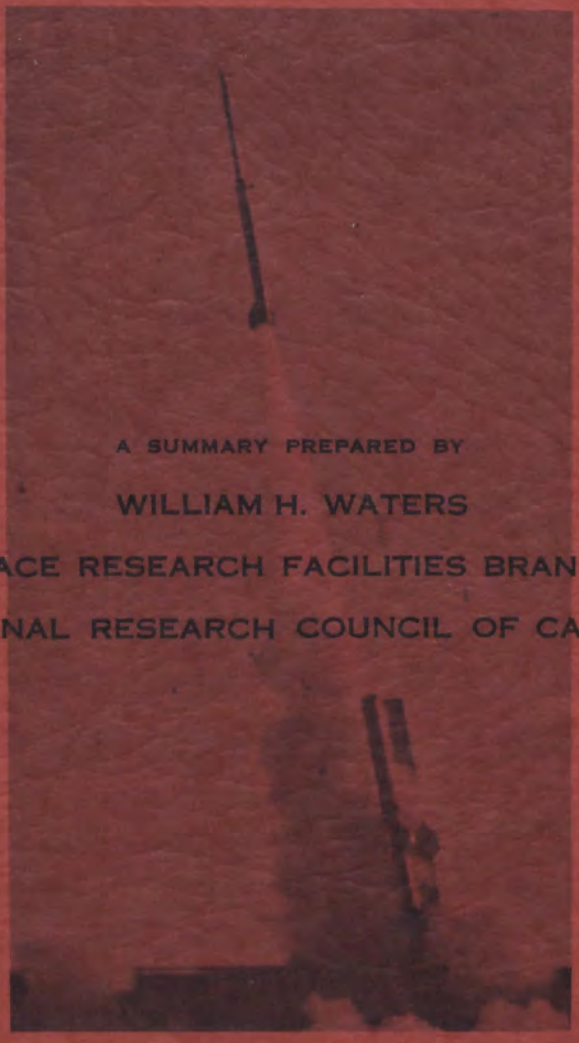
ANNEX IV



SPACE AND UPPER ATMOSPHERE RESEARCH IN CANADA

BALLOONS, ROCKETS AND SATELLITES

1970



A SUMMARY PREPARED BY

WILLIAM H. WATERS

SPACE RESEARCH FACILITIES BRANCH

NATIONAL RESEARCH COUNCIL OF CANADA

OTTAWA

JANUARY 1971

SRFB 048

SPACE AND UPPER ATMOSPHERE RESEARCH IN CANADA
BALLOONS, ROCKETS AND SATELLITES
1970

A SUMMARY PREPARED BY

William H. Waters

SPACE RESEARCH FACILITIES BRANCH

NATIONAL RESEARCH COUNCIL OF CANADA

OTTAWA

JANUARY 1971

FOREWORD

As this publication is used by the Federal Government's Interdepartmental Committee on Space as a resume of "Space and Upper Atmosphere Research in Canada", it is intended to publish the document yearly in order to keep interested scientists, government departments and others informed regarding our space activities. Contributions from participating and associated agencies should be submitted annually in November for inclusion in the January issue.

The first edition of this book (SRFB 024) was published in January 1969. Its introduction on page 1, and pages 2 to 5 inclusive, contained a brief history of space research in Canada, including balloon, rocket and satellite activities. These pages are being continued in subsequent editions in order to make yearly reports as complete as possible. Some changes and amendments will be necessary in order to correct the record.

SRFB 024 in English is now out of print; however, limited numbers of the French version of this first edition are still available. Copies of SRFB 036 in English (printed in January 1970) are available; however, the French version is now out of print. Copies of current and earlier editions still remaining may be obtained by applying to the Space Research Facilities Branch, National Research Council of Canada, Ottawa 7, Ontario, Canada.

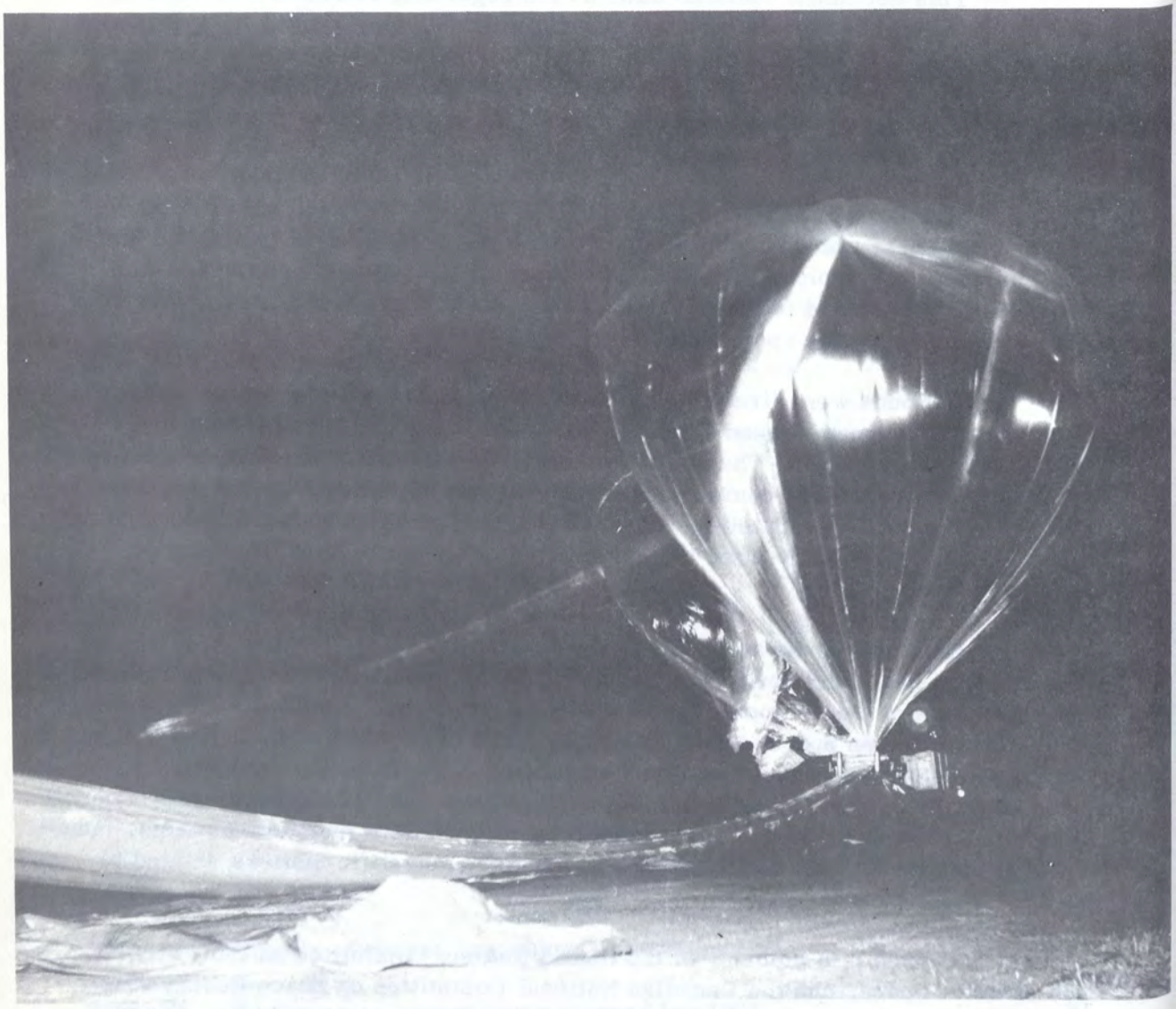
TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

Activities in Universities - Cont'd.

TABLE OF CONTENTS (Contd)

INFLATING A BALLOON PRIOR TO LIFT OFF



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 cooperation 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 cooperation 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 Drs. J. Hampson and C. Cumming.

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 from 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. In October and December 1965, the Institute of Upper Atmospherics, Physics Department of the University of Saskatchewan, made several successful flights from Saskatoon. These carried photometers for detection of airglow emissions. During 1968, these universities launched twelve balloons carrying more than 25 experiments.

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.

TWO STAGE BLACK BRANT IV ON THE AURORAL LAUNCHER

ROCKETS

Beginning with the International Geophysical Year (IGY) in 1957, rockets were first used by the Canadian Armament Research and Development Establishment (CARDE), Quebec, now Defence Research Establishment Valcartier (DREV), and later by the Defence Research Telecommunications Establishment (DRTE), now Communications Research Centre (CRC), 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.

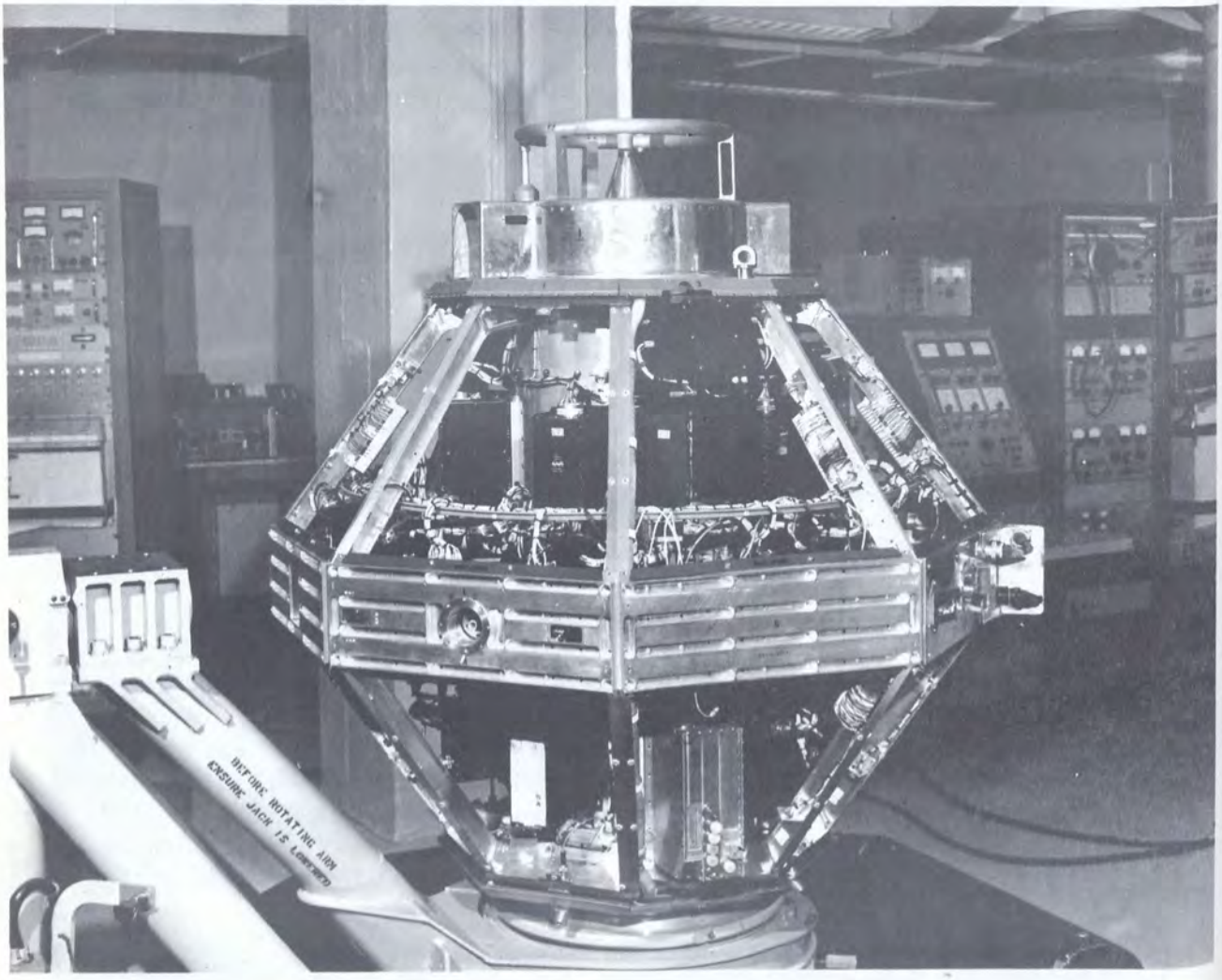
As a result of the rocket research activities at DREV and with the assistance of the government, rocket building technology in Canada became available to civilian industry, and Bristol Aerospace Limited, Winnipeg, Manitoba, became the first Canadian rocket industrial developer. In 1964, with assistance 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, coordination of the program.

Payload planning and construction of the electronic systems and subsystems common to all payloads were included in the group's responsibility. Telemetry equipment, engineering sensors, external and internal switching, and control systems are examples of the systems provided. A launch team for engineering support at the launch site was also part of the assignment. In addition to the direct engineering support, this group carried out a continuing program of investigation into rocket instrumentation and telemetry problems.

The last vehicles in which REED participated in engineering and coordination were Black Brant rockets AAA-II-101, AAA-II-102 and AAA-II-105. These vehicles were launched in January 1967.

ISIS "B"



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. It still transmits data back to earth on command.

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. This vehicle continues to transmit data back to earth on command.

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 "B"

The fourth Canadian space craft, ISIS "B", is now scheduled for launching in the first quarter of 1971. The space craft will carry twelve experiments and will be launched from the Western Test Range in California, U.S.A.

ANIK I

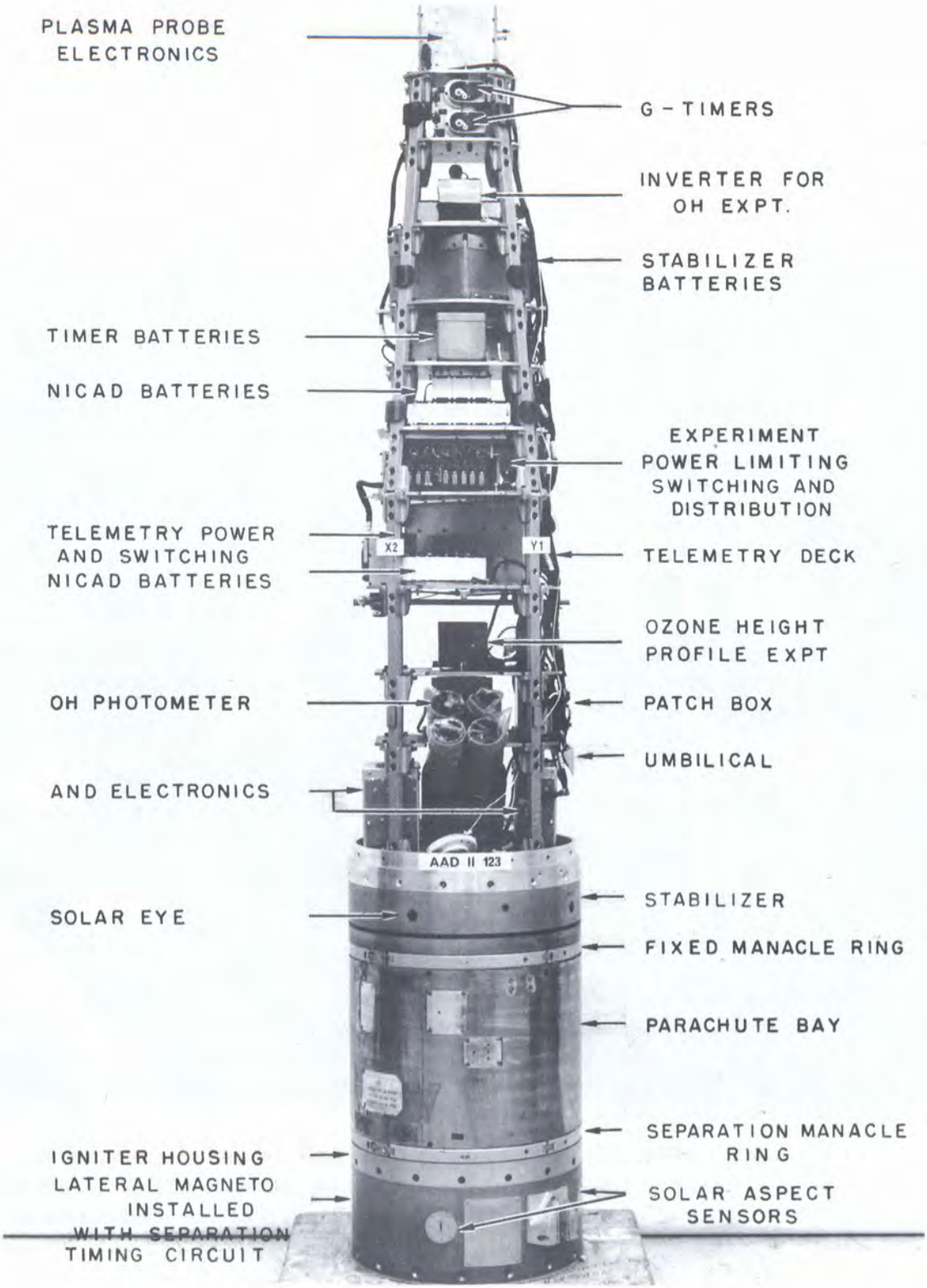
Canada's first domestic communication satellite, ANIK I (an Eskimo name for brother), is scheduled to be launched from Cape Kennedy late in 1972. Details will be found under Activities in Industry - Telesat Canada and The Canadian Domestic Satellite Communication System.

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 continue to be tracked and commanded by Canadian satellite telemetry/tracking stations and the United States STADAN network. The Canadian STADAN station in St. John's, Newfoundland, was closed down on 31 March 1970.

TYPICAL PAYLOAD LAYOUT



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, and the smaller British Skua II rocket. The United States' Boosted ARCAS II has been used on occasions in the past.

The Black Brant vehicles now include a family of nine different types. They are manufactured by Bristol Aerospace (1968) Limited, Winnipeg, Manitoba. At the present time, Black Brant rockets include both single and two-stage solid propellant vehicles, with lifting capabilities of 50 to 145 kilograms (110 to 320 pounds) to heights ranging between 165 to 1150 kilometers (100 to 715 statute miles). 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 (1968) Limited.

The British Skua II rocket is a 12.7 centimeter (5 inch) diameter, solid propellant vehicle, measuring approximately 254 centimeters (100 inches). It is capable of carrying a payload weighing approximately 9 kilograms (20 pounds) to a height of 80 kilometers (50 statute miles).

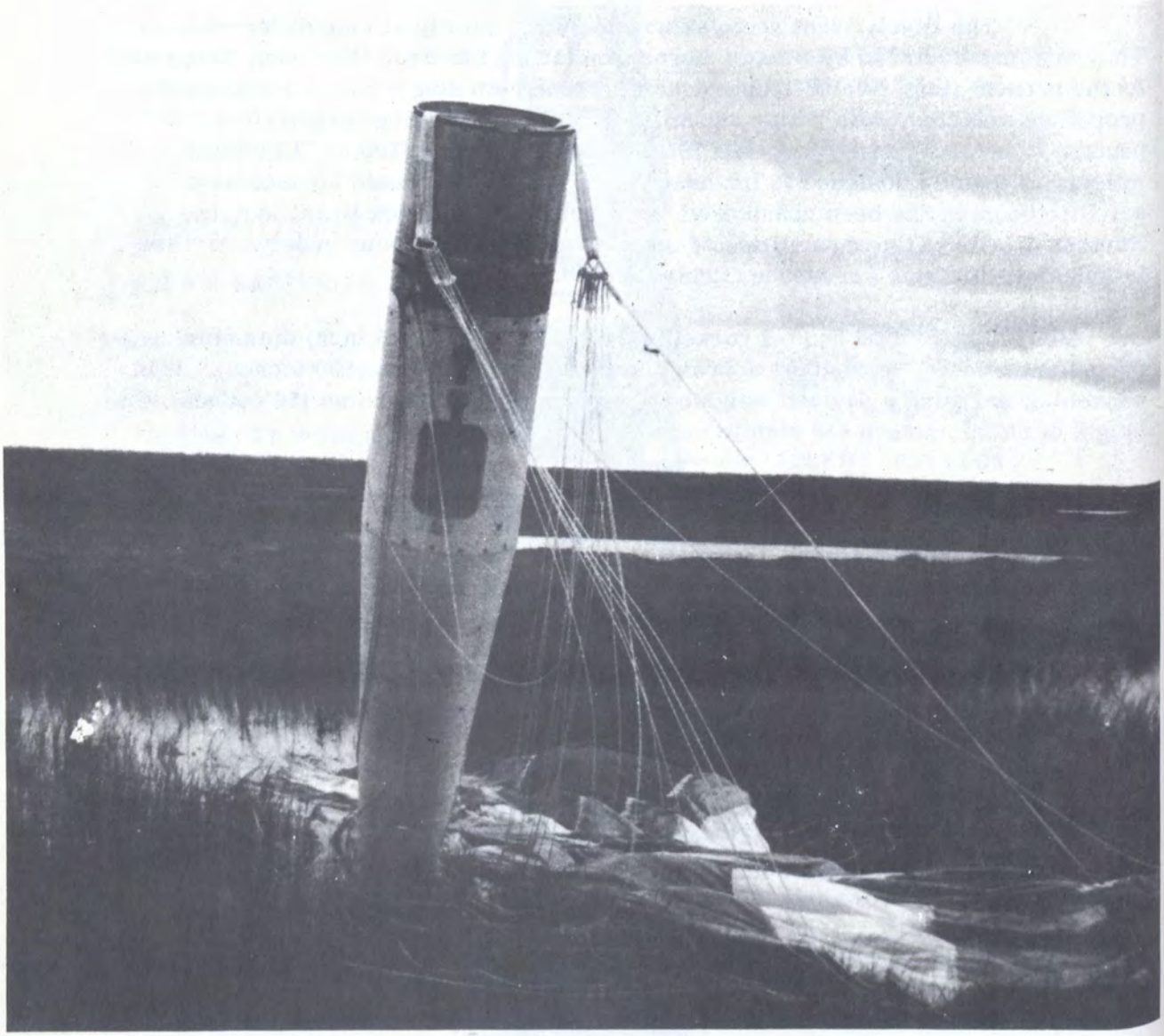
The United States' Boosted ARCAS II rocket is a 11.4 centimeter ($4\frac{1}{2}$ inch) diameter, solid propellant vehicle with a booster stage, measuring about 405 centimeters (160 inches) in length. It is capable of lifting payloads of more than 9 kilograms (20 pounds) to heights of over 105 kilometers (65 statute miles).

Individual experiments are usually provided by the scientists concerned. The Space Research Facilities Branch of the National Research Council of Canada assumes overall coordinating responsibility and provides contract coverage for the integration of the payloads.

The integration of the experiments into vehicle payloads is carried out by Bristol Aerospace (1968) Limited, Winnipeg, the Space Engineering Division of the University of Saskatchewan, Saskatoon, and the Institute for Aerospace Studies of the University of Toronto.

By December 1970, the National Research Council of Canada had participated in 92 rocket launchings which carried aloft 682 different experiments. Seven of these rockets carried experiments from the United States, Sweden, West Germany, Czechoslovakia and the United Kingdom, in addition to the Canadian experiments. By the end of 1970, Canada had launched more than 160 rockets.

AN EXAMPLE OF A RECOVERED PAYLOAD



UPPER ATMOSPHERIC ROCKET AND BALLOON RESEARCH IN 1970

Prior to 1970, the Space Research Facilities Branch arranged for 60 rocket launchings. These vehicles carried a total of 384 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, seven experiments from other countries were included in three of these vehicles.

During 1970, twelve rockets sponsored by the National Research Council of Canada, including one British Skua II rocket, carried 63 experiments to heights ranging from 80 to 800 kilometers (50 to 500 miles) to make measurements under quiet and disturbed conditions in auroral and non-auroral areas. With the exception of four Black Brant IIIA type rockets launched at East Quoddy, Nova Scotia, during the 7 March 1970 solar eclipse, 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 the "SKYHOOK" scientific ballooning program in Canada during 1970. More than thirty balloons were launched from three sites. Six were used in conjunction with Black Brant rocket ADD-VB-31, which carried experiments from six countries, including Canada. Canadian agencies and ground stations participated in this program, which included balloons mostly in the 300,000 cubic meter size (10.6 million cubic feet).

Experiments Carried in Canadian Rockets

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 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.

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 addition, electric field probes, acoustic micrometeoroid detectors, OH dayglow instruments, barium cloud, ozone measuring instruments (above 55 kilometers), solar X-ray and Lyman alpha experiments were carried in six of the above rockets for the United States, Sweden, West Germany, Czechoslovakia and the United Kingdom.

Some of the above experiments were ejected from rockets during flights, while others remained with the parent vehicle.

ACTIVITIES IN UNIVERSITIES

Institute of Earth and Planetary Physics, University of Alberta

The Killam Earth Sciences group has devoted its efforts towards setting up a chain of eight three-component fluxgate magnetometers along the corrected geomagnetic meridian $\sim 302^{\circ}$E. Data are sampled at two-second intervals and are recorded directly on magnetic tape in digital form. The data are being used in the study of magnetic bay and polar magnetic substorm activity. In addition, the dependence on latitude of the characteristic parameters of long period micropulsation activity is under study.

Using magnetic and energetic particle data from the IMP and VELA satellites, studies are under way to investigate variations in the particles and fields in the magnetotail occurring in association with polar magnetic substorms. The study of the VELA energetic particle data is being carried out in cooperation with the University of California, Los Alamos Scientific Laboratory.

In cooperation with the University of Saskatchewan, the Alberta group will participate in a rocket launch into an auroral breakup. Using rocket-released probes carrying stabilized magnetometers, an effort will be made to detect field-aligned currents flowing in the region of the westward travelling surge.

Theoretical studies are under way to determine the distribution of plasma in the magnetosphere from the dispersion characteristics of hydromagnetic whistlers using the normalized dispersion curve method. In addition, the propagation of hydromagnetic waves and the generation of eigenoscillations in the magnetosphere have been investigated in order to evaluate any possible latitude dependence of micropulsation characteristics. Theoretical investigations of magnetic field fluctuations in the magnetotail and interplanetary field have yielded important information on the effect of such magnetodynamic noise on the generation of geomagnetic activity.

Department of Physics, University of British Columbia

The rocket program, to measure cosmic background radiation near 1 millimeter wavelength, is continuing.

Department of Physics, The University of Calgary, Alberta

Ground-based spectrophotometry measurements of airglow hydroxyl and helium emissions are continuing. Digitisation of spectral data obtained in the wavelength range of 0.6 to 2.4μ provides the basis for spectral averaging. Rocket-borne photometers for measuring helium altitude profiles were flown in December 1970.

Balloon study for the measurement of auroral X-rays is continuing. On one of the two flights from Cold Lake, quite large X-ray bursts correlated with bright pulsating aurora were observed. Most of the activity was observed in the > 60 KeV channel, very little in the 40 to 60 KeV channel, and practically none in the 20 to 40 KeV channel. A program to measure the absolute intensity of infrared emissions from the aurora in the one to 2.5μ region using filter photometers and lead sulphide detectors is being developed. The aim would be to look for correlations between auroral X-rays and auroral infrared emissions.

Rocket studies of the space x-radiation from 0.2 to 12 KeV are continuing. A new, hitherto unidentified, intense X-ray emitting object, Cetus-XR2, was observed in 1969 Black Brant IIIB flights from Resolute Bay. Another rocket experiment was flown from Fort Churchill in December 1970.

The balloon flights of scintillation counters were made from Cold Lake, Alberta. From the several hours of data that were obtained, the energy spectra of protons and helium nuclei near the maximum level of solar activity have been obtained.

The image intensifier-TV system has been operated for 6 months at Cold Lake, Alberta, and a detailed analysis made of the video tape records.

Particularly interesting results have been obtained from simultaneous side-by-side imaging of pulsating auroras in two different wavelengths (5577 Å and 3914 Å). A detailed investigation has been made of the effective lifetime of the metastable 0 ('S) state responsible for the 5577 Å emission. These lifetime measurements have a bearing upon the continuing discussion on the relative importance of possible excitation mechanisms for 0 ('S).

An investigation has also been made of the relative damping of auroral light pulsations in comparison with X-ray pulsations on the pulsation frequency increases, and implications concerning the distance of the source mechanism have been considered.

Other studies completed include an analysis of a class of auroral pulsating forms in which a "triggered" rapid growth in horizontal extent follows the attainment of a critical brightness level in a small-scale core region, and analysis of records of "fast auroral waves" on infrequently observed phenomenon.

The Antenna Laboratory, Department of Electrical Engineering, University of Manitoba

The Antenna Laboratory at the University of Manitoba consists of a microwave anechoic chamber and an outdoor antenna pattern and cross-section range. This laboratory is instrumented from d.c. up to 40 GHz and operates in conjunction with a microwave circuits lab, laser and holography lab, microwave industrial instrumentation lab, microwave power lab and an IBM 360/65 computer.

The main area of interest at present, from a space research point of view, is to study the behaviour of inflated antenna structures (laminate of 0.00035 inch mylar between two layers of 0.0002 inch thick aluminum grid) over a wide range of frequencies. These antennas are extremely light weight and may be preformed to become extremely attractive for point-to-point and ground-to-satellite communications. They may also be combined (e.g., loops and dipoles) and properly packaged aboard deep space sounding satellites for detection of electrostatic, magnetostatic and electromagnetic fields in ionospheric magnetoplasms. These structures are rigid upon inflation when the gas is allowed to escape and may be designed to provide their own hardware (connectors, matching sections, etc.), and are less susceptible to damage from ultraviolet radiation and ambient temperature than most existing structures. It is anticipated that initial space tests of inflated dipoles and parabolic reflectors will be carried out in the future using Black Brant rockets at the Churchill Research Range.

McMaster University, Hamilton, Ontario

Work continues on the studies of lunar samples from the Apollo XI and XII missions. Results from these studies will be available on completion of the Lunar Science Conference, which is to be held in Houston, Texas, in January 1971.

Department of Physics, University of Montreal

Interest in ionospheric sounding is still centered around an experimental program involving rocket-borne probes which are designed to give some details of the low-energy electron distribution function.

At present, three further flights are scheduled; the one experiment flown during the present reporting period was unsuccessful. Earlier results suggested that the modified probes (now being used) should give an accurate independent estimate of electron temperatures and that perhaps it would be possible to identify and measure the flux of electrons with elevated temperatures. These may be either the residue of the electron bombardment process or those thermal electrons which have undergone super-elastic collisions with metastable atoms or molecules. The future program is under review.

Department of Physics and Space Engineering Division,
University of Saskatchewan

Work is continuing in the measurement of electron densities and winds in the D- and E-regions, and the aeronomy of the effects of planetary scale coupling between atmospheric (~30 km) and ionospheric perturbations is being investigated using a wide range of experimental techniques. Extensive investigations of wave propagation through the atmosphere are also being attempted.

The development of a spin-stabilized rocket released probe to measure electric and magnetic fields, electron density and electron temperature has been completed and provided very good experimental data during a recent flight into a major auroral breakup. The soft electron spectrometer and vacuum u-v photometer investigations are also continuing, and it is intended to complement these with a vacuum u-v spectrometer, which is presently being designed. Other auroral investigations are concerned with the relationship between particle precipitation and brightness fluctuations; ground-based observations have been made at Thompson, Manitoba, in an attempt to correlate with the data recorded by the ATS-E satellite.

New investigations of the characteristics of the polarization of FM waves scattered from plasma irregularities are also being undertaken.

Work is continuing in the study of the infrared atmospheric system of O_2 and ground-based measurements of the emission at 1.27μ are presently being conducted on a synoptic basis. This work is closely related to the analysis of the OH emission, which has been observed from balloons and rockets, and an attempt to relate the rotational intensity distribution and the excitation mechanism is being made.

Engineering studies related to electrical systems in Black Brant rocket payloads resulted in the design and development of a DC/DC converter, the first of which was flown successfully in vehicle ADD-VB-31. Subsequent SED-manufactured payloads will have DC/DC converters as standard equipment. Work continued on the development of a standard split nose cone for Black Brant rockets, and some progress has been made in the development of a different type of mechanical recovery system and a more efficient recovery beacon for rocket payloads. Three special payloads were launched successfully during the year, one of which was recovered and will be re-manufactured. The reorganization of the Churchill Research Range has resulted in increased responsibility for the supervision of SED-manufactured payloads at the range. Reduction and analysis of telemetered data continued to be carried out, but on a reduced scale. Improvement of research and manufacturing facilities continued. Special emphasis was placed on studies of quality control, and all SED engineers attended a concentrated quality control course sponsored by the Extension Division of the University of Saskatchewan.

u-v ultraviolet
SED Space Engineering Division

University of Toronto

Institute for Aerospace Studies

Summary

The rocket program at the Institute is centred around the development of two separate, complementary in altitude range, instruments for the measurement of upper atmospheric temperature and composition. The first one of these, called the optical analyzer, is based on the fact that an electron beam projected from the rocket will produce a measurable luminescence in the ambient atmosphere. It is practicable to view only the light coming from a region sufficiently far from the rocket to observe essentially an undisturbed atmospheric sample. The luminescence so produced will yield information about composition and temperature by suitable spectroscopic analysis. The instrument is capable of giving sufficient signal over an altitude range from about 60 km to 140 km.

The second instrument, the aerodynamic spectrometer, measures the same properties but depends on its operation on collision-free conditions and will, therefore, be useful at altitudes exceeding 110 km and is capable of giving data up to 200 km. Its principle is to measure the details of the density distribution of the flow behind a slit facing the direction of motion. Different species will spread at different rates, and the density profile which is determined by the sweep due to rocket roll will need the kinetic temperature as well as composition.

Status

a) The optical analyzer instrument was flown first in January 1969. The initial experiment measured the relative intensity of two spectral regions within the rotational structure of molecular nitrogen to measure the rotational temperature. This experiment was wholly successful. Subsequently, a repeat of this experiment was prepared for launch in April 1970. In addition, a three-channel miniaturized version of the instrument was prepared to be flown at the same time. These three channels were set up to measure the partial density of molecular nitrogen, molecular oxygen and atomic oxygen. Unfortunately, the rocket broke up early in its flight and no data were obtained, although the check-out showed the reliability of the instruments and their calibration stability over long periods of storage. Passenger space was found to allow a further launch in January 1971.

At present the instrument package for that flight is complete. It consists of a single five-channel instrument, which is compact, light and relatively cheap. It will measure partial density of molecular oxygen, molecular nitrogen and atomic oxygen in addition to rotational temperature and transmit the information on a single telemetry channel.

The interpretation of the composition data require the value of the optical excitation cross-section of atomic oxygen. These will be determined in a laboratory experiment, in which atomic oxygen of known concentration is produced in a bath of

molecular nitrogen. This laboratory apparatus is now nearing the completion of the construction phase.

Further instrument packages for a flight in late 1971 are now under construction. These will be five-channel instruments capable of measuring vibrational temperatures in nitrogen in addition to the measurements in the earlier flight in January 1971.

b) The aerodynamic spectrometer is ready for flight in January 1971. The instrument is kept in a high vacuum environment; it will be extended on a moveable boom and opened up for measurement after the appropriate altitude is reached. Since the instrument has to face the flow, it will be turned over near apogee to allow measurements to be made on the down-leg as well. Again, the present version has been designed to be used as an additional experiment on other rocket flights.

Its results for atomic oxygen concentration will serve as a second calibration for the optical analyzer in the altitude range where the two instruments are simultaneously in operation.

Department of Physics,
Geophysics Laboratory

The Geophysics Laboratory has become deeply involved in space exploration in the past year or so. Prof. Strangway has been given a leave of absence to act as Chief of the Geophysics Branch at NASA's Manned Spacecraft Center in Houston, Texas. Here he is concerned with research on lunar and planetary geophysics and is involved with planning of the remaining Apollo missions.

Three graduate students from the University of Toronto have been appointed as student scientists at the Lunar Science Institute in Houston and will continue their studies toward a Ph. D. in the following areas:

i) Magnetic properties of returned lunar samples;

ii) Electrical conductivity and dielectric studies of returned lunar samples;

iii) Scientific support for an electromagnetic sounding experiment now planned for Apollo 16 or 17.

Prof. Strangway is a principal investigator for the magnetic and electrical property experiments and a co-investigator for the sounding experiment.

Prof. Derek York has also been appointed a principal investigator for lunar samples from future Apollo missions. His work will involve the use of K-A_r geochronology to study the age and thermal history of returned lunar materials. He will be applying the A_r^{39} technique in particular using neutron bombardment to create the artificial isotope.

Department of Physics, University of Victoria

A birefringent filter photometer has been in continuous operation since February 1967 to monitor optical emissions from alkali metals in the upper atmosphere during twilight.

Studies of twilight sodium emission show the usual seasonal variation in the emission rate, about 1 kilorayleigh during the summer and 4 to 5 kilorayleighs during the winter. In addition, the height of maximum density of atomic sodium appears to show regular variations throughout the year, being higher during the equinoxes than during the solstices by 4 to 6 km. The evening layer appears to be situated at a higher level than the morning layer by about 5 km near the equinoxes and appears to be at about the same height as the morning layer near the solstices, when both layers appear to be at a height of about 90 km. Whether this phenomenon is an effect peculiar to location has not been determined.

Correlation studies between the plateau brightness variation and stratospheric temperature variations have been carried out in cooperation with the Institute of Space and Atmospheric Studies at the University of Saskatchewan using a time-series analysis technique. A strong correlation between atmospheric sodium brightness at Saskatoon and stratospheric temperatures at several Arctic stations confirm the relationship with Arctic stratospheric warming events. The correlations found have been interpreted in terms of a frontal motion. Weaker correlations with Victoria sodium suggest that Victoria is outside the Arctic regime as far as stratospheric warmings are concerned.

Measurements of twilight emission at a wavelength of 6708 Å have been made regularly since September 1968. The emission rate appears to increase during the winter and becomes very low during the summer. From time to time sudden enhancements occur, lasting from 3 to 5 days. If these can be attributed to atomic lithium, the emission rate reaches values of 150 rayleighs during these times. It has not been determined whether the emissions observed are of artificial origin or due to natural lithium. The absence of known artificial releases prior to many of the observed enhancements suggests a natural origin for this emission.

Centre for Radio Science, Department of Physics, University of Western Ontario, London, Ontario

The common theme running through all space activities work at Western is the use of radio waves as diagnostic tools to study the structure of upper atmospheric space and solar plasmas. One line of investigation is based on techniques of accurate measurement of direction of arrival of radio waves. This technique has been applied using satellite-borne transmitters to investigate the detailed structure of ionospheric inhomogeneities in the F-region, using rocket-borne transmitters to investigate the structure and motion of ionization associated with major solar disturbances. The satellites currently being used for these investigations and those outlined in the following paragraph include ISIS-1, the Transit series and ATS-3.

The second line of investigation makes use of the modification in electrical path length imposed on radio waves by ionospheric structure in a somewhat different way. Satellite studies and rocket studies have used both Faraday rotation measurements and differential doppler methods to determine structure. Ionospheric absorption associated with the disturbed ionosphere has also been studied using satellite-borne, rocket-borne, and ground-level transmitters and natural extraterrestrial emissions. A system for the measurement of ionospheric absorption using meteor signals has been completed recently.

Ground-based techniques include the use of VHF transmitters and receivers to study the scattering of radio waves from ionospheric structures. Particular attention is now being paid to studies of the gross motions of ionization, motions of the neutral atmosphere and motions of waves generated in the ionospheric plasma. Results have been obtained recently from a near bistatic meteor winds system.

Centre for Research in Experimental Space Science, York University, Toronto, Ontario

Auroral and Airglow Photometry in the Visible Region

A multiplex photometer was successfully launched into daytime airglow on 23 April 1970 in vehicle AMD-VB-25. A multiplex coding disc, stepping eight times per second, gave seven spectral elements in each of two channels. The first contained a Fabry-Perot etalon to measure the width of the 5577Å OI emission, and the second an interference filter to measure OI 6300Å emission intensity. The same experiment will be flown in January 1971 as AMD-VB-26, in which the 6300Å channel will be converted to NI 5200 .

Rotational temperature data from N_2^+ obtained in the series AKD-II-110 to 113 have been analyzed and reported in a M.Sc. thesis by F. E. Bunn. Dr. V. V. Agashe analyzed data from AHF-IV-15 and ADD-VB-11, which will shortly be published. These data concerned OI 6300Å emission intensities in the daytime and nighttime respectively.

A two-channel multiplex photometer is now being planned for auroral rocket ADD-II-114.

Atmosphere Composition by a Fluorescence Technique

An experiment is now under construction for AED-VB-28, in which a source of 1304Å radiation (the resonance line of OI) will be used to measure atomic oxygen concentrations. The resonance scattering and absorption produced by this source on the local atomic oxygen density will be detected by a scanning photometer.

Auroral and Airglow Satellite Photometer

The flight unit of the 6300Å photometer for ISIS-B has been tested and is now in the spacecraft at the Goddard Space Flight Center undergoing pre-launch tests. The photometer's 2.5° field is perpendicular to the spin axis so a scanning pattern of 140 km resolution on the ground is obtained. The device will detect 50 rayleighs to 10^6 rayleighs of emission and is protected against dark current enhancement to light levels of about 10^9 rayleighs. Launch is planned for March 1971.

Excited Molecular Oxygen Emissions

A Black Brant III rocket was used to measure simultaneous emissions from O_2 ($^1\Delta_g$), O_2 ($^1\Sigma$), OH and O (^{1}S). Although quiet launch conditions were called for, the behaviour of the $^1\Delta_g$ emission was quite unexpected. Auroral all-sky camera records showed a weak diffuse aurora developing simultaneously with the launch. Comparison with the O (^{1}S) emissions showed that a surprising amount of the energy was deposited and appeared as O_2 ($^1\Delta_g$) excitation. The OH and O_2 ($^1\Sigma$) did not show this unusual enhancement. Their height profiles are now being analyzed.

Oxygen Atom Probes

The simple O-atom probe, consisting of a thin film of silver deposited on a small pyrex rod, was found to respond with considerable sensitivity and reproducibility under laboratory conditions but not in the earlier rocket configurations. Contamination of these probes by the rocket exhausts, etc., was suspected. A new version, in which the probes are capsulated and deployed only on reaching altitude, was developed and tried first on a Nike Cajun rocket fired at Wallops by NASA. All four probes worked well, and excellent O-atom height profiles were obtained. A similar package was launched at Churchill on a SKUA. Although telemetry failed during a critical part of the flight, positive evidence was obtained to show that all four probes responded in the manner expected. The method now appears to be proven.

Laboratory Aeronomy and Astrophysics

Measurements were continued of band strengths of aeronomically and astrophysically important molecular transitions using the methods of emission (including shock tube) and absorption spectroscopy and of the interfereometrically based "hook" method. Recent work has provided data on O_2 Herzberg, NO β and γ, CO Cameron systems, as well as the astrophysically important molecules TiO, VO.

Production of identification atlases of molecular spectra was continued. Recent issues include O_2, Herzberg, VO Yellow Green, CO Fourth Positive, CN Red and Violet.

Excitation mechanisms and energy transfer processes have been considered. Recent work includes a study of CN fluorescence (which has applications to cometary astrophysics), the energy resonances in CO_2 lasers and the many processes taking place in active N_2.

Theoretical work on magnetospheric precipitation has proceeded.

Theoretical work on the use of the methods of synthetic spectra to assess auroral and airglow emissions has continued.

Theoretical work on the expected performance of rocket-borne vacuum ultraviolet spectrographs in a variety of aurorae and rocket trajectories has continued.

Routine calculation of realistic Franck-Condon factors for diatomic and polyatomic molecules has continued. A compilation of 127 diatomic band systems has recently been produced (including all the aeronomically important ones). In addition, a similar study has been made of CO_2^+ and NO_2^+ band systems.

Auroral and Airglow Observations

Continued payload preparation is in progress for the next vacuum ultraviolet spectrograph flight early next year. CRESS has nearly completed the construction of a mobile auroral and airglow observatory.

Solar Eclipse Rocket Spectroscopy

As part of the Culham-Imperial College-Harvard-York consortium, vacuum ultraviolet spectrographs were flown through the 7 March 1970 solar eclipse in an Aerobee Rocket at Wallops Island and recorded for the first time a sequence of 50 slitless spectra of the eclipse between 900 and 2000Å. The chromospheric solar flash was observed as was the vacuum ultraviolet spectrum of the corona. Data analysis proceeds. Further details of the 1970 and 1972 Solar Eclipses and Canadian studies on solar astrophysics using rocket spectroscopy will be found under that title elsewhere in this publication.

1970 AND 1972 SOLAR ECLIPSES AND CANADIAN STUDIES ON SOLAR ASTROPHYSICS USING ROCKET SPECTROSCOPY

During these solar eclipses, eleven scientists from universities in the United States, the United Kingdom and Canada are participating in experiments in rockets flown from Wallops Island missile range in the United States in March 1970 and to be flown from Eskimo Point, Northwest Territories, Canada, in July 1972.

A solar eclipse presents an ideal opportunity to study the corona-chromosphere interface using spectroscopic techniques, either from ground based or from rocket or satellite observatories. During an eclipse, the much brighter light from the disc of the sun is obscured. The low wavelength (or ultraviolet and vacuum ultraviolet) region of the spectrum is of great interest in solar studies, and as this light is strongly absorbed by the earth's atmosphere, spectrographs have to be carried in stabilized rockets or satellites for such work. About three solar eclipses occur each year; however, few fall on useful regions of the earth.

In 1966, Dr. Robert Speer of Imperial College, London, England, pointed out that in March 1970 a total solar eclipse would traverse the eastern United States seaboard and would cross the Wallops Island range. A rocket spectroscopy experiment to exploit this eclipse was proposed, and a consortium of four laboratories in Canada, the U.S. and Great Britain was formed. The laboratories (Imperial College, The Science Research Council Astrophysical Research Unit of Culham Laboratory and Harvard College of the United States, and the Centre for Research in Experimental Space Science, York University, Canada) have been collaborating for years in general research in laboratory astrophysics, so that the extension to flight experiments was a very natural development.

The March 1970 experiment involved the flying of two spectrographs covering the wavelength range 900 - 3000Å through the shadow zone on a rocket whose trajectory allows relatively slow scan of the disc of the sun by the apparent motion of the moon. Pointing accuracy of 0.4 arc/second was achieved. About 50 sequenced photographic spectra were obtained during the flight. They recorded the solar spectrum in sequence prior to second contact into totality. The experiment worked very well, and data analysis is proceeding. Many new spectra features have been discovered.

The great success of the March 1970 eclipse enterprise has encouraged the same consortium to make firm plans to repeat the experiment in Canada during the July 1972 eclipse, which will run west to east across mid-Hudson Bay. Whereas the 1970 rocket trajectory was roughly perpendicular to the eclipse path, the July 1972 trajectory will be down the eclipse path. The launch will be from temporary facilities to be installed at Eskimo Point, Northwest Territories. Flying the instrumentation down the eclipse path will enable a much greater time (and spatial) resolution to be attained. Site surveys and decisions on launcher locations, etc., were carried out during the summer of 1970. Construction will take place during the summer of 1971, and the experimental group will be at Eskimo Point during the summer of 1972.

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. 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 consist 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) Alpha 5 MeV to 2.8 BeV.

At time of writing, useful data are still being obtained from Alouette I for periods of 1 to $1\frac{1}{2}$ hours daily.

Alouette II

Alouette II was successfully launched on 29 November 1965. Orbital parameters are: inclination 79.8^{o}, 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^{o} to 5000^{o} K.

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

All experiments and facilities worked as planned. Results indicate that the capacitive antenna coupling combined with the ion guards have been successful in reducing considerably the effect of the plasma sheath. The bandwidth extension of the VLF experiment has yielded new information, while the re-designed sounder system suffers less interference than did Alouette I. After 40 months in orbit, the 300-watt sounder transmitter became defective. The back-up 100-watt transmitter was then switched on, and much useful data are being obtained during a $4\frac{1}{2}$-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 parameters are: apogee 3,522.54 kilometers, perigee 573.72 kilometers, inclination 88.43 degrees, period 128.3 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 anistrophy 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 approximately $9\frac{1}{2}$ hours per day, and all experiments, with the exception of the ion mass spectrometer which is at present producing degraded

data, are performing as planned. As well, by using the onboard clock and programmer and tape recorder, much useful data are being obtained on the ionosphere over previously unexplored regions of the globe.

ISIS B

The launch of this third in the series of ISIS satellites is scheduled for early 1971. ISIS B will contain the twelve experiments shown below:

Swept-Frequency Sounder
Fixed-Frequency Sounder
VLF Receiver
Cosmic Noise
Energetic Particle Detector
Langmuir Probes (2)
Soft Particle Spectrometer
137.950 MHz Beacon
Ion Mass Spectrometer
Ion Probe
Oxygen Red Line Photometer
Auroral Scanner

The first ten experiments are similar to those in ISIS I. Indeed, it is expected that the first eight will be practically identical, while the two ion measuring experiments, although different from those in ISIS I, will have the same purpose.

Two new experiments will be carried, both to observe optical phenomena. The oxygen red line photometer will study the atomic oxygen emission at 6300Å, while the scanning photometer will observe an atomic oxygen emission at 5577Å and one due to ionized molecular nitrogen at 3914Å and the ratio between them.

Satellite Support Services

As well as the design of the spacecraft, the ISIS program includes support services in the form of two telemetry stations and a data processing center. The telemetry stations are situated at Resolute Bay on Cornwallis Island and at Ottawa. The Ottawa station, as well as receiving data, also serves as the control station for all Canadian satellites. The Data Processing Centre, when Alouette I was the only Canadian satellite, processed all telemetry tapes from some 14 telemetry stations located around the globe. In this time, 15,000 reels of magnetic tape were processed (731.52 meters/2,400 feet per reel) with some 10^6 ionograms being produced. With the advent of Alouette II an arrangement was reached with Goddard Space Flight Center, Environmental Science Service Administration/Research Laboratories, and with the Radio and Space Research Station for a division of the work on Alouette II among the four agencies. This arrangement was continued for the work on ISIS I when that vehicle was launched. DRTE, now the Communications Research Centre, is still responsible for processing the majority of Alouette II and ISIS I ionograms, and for the quality control of all telemetry tapes, for copying all VLF, solar noise, housekeeping, energetic particle data and Langmuir probe data. All Alouette I results

are still processed at CRC.

Conclusions

It is now almost a decade since Alouette I was conceived. In that interval four satellites containing topside sounders have been launched: Alouette I, Explorer XX, Alouette II and ISIS I. Another, ISIS B, has been designed and is under construction. This interval of time has seen progress in the development of topside sounding satellites from Alouette I with its rather simple supporting experiments, to ISIS B with a total of 12 experiments designed to meet fairly fully the objectives of the program.

Rocket Program

On 24 February 1970, a Black Brant IV rocket was launched from Churchill Research Range. Included in the payload was a very low frequency receiver using a loop antenna, in conjunction with particle flux experiments flown for the Physics Division of the National Research Council of Canada.

Early in 1971, another Black Brant IV vehicle will be flown to measure the impedance of 50-foot dipole antennas, on a small throw-out package, over the frequency range 300 Hz to 3 MHz. An electron source on the package will be activated periodically to study antenna impedance changes with changes in the ion sheath about the antenna.

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 and 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 atmospheric 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. A direct measure of the transmission loss along the propagation path was obtained. In

addition, a weather radar at 2.9 GHz was used to obtain radar backscatter measurements from precipitation along the propagation path. From the radar data, it is possible to estimate attenuation using empirical relations between radar reflectivity and attenuation coefficient per unit distance. CRC has a contract with McGill University to use radar data for developing the statistics of occurrence of rainfall attenuation. Measurements obtained from the aircraft experiment provide a means for investigating the accuracy of radar predicted attenuation values.

ATS-5 Experiments

Since September 1969, CRC has been carrying out precipitation attenuation measurements using the 15.3 GHz beacon on the NASA ATS-5 satellite. The beacon signal is received on a 30-foot antenna, and the transmission loss data obtained provide a direct measure of precipitation attenuation. The 30-foot antenna is also fitted with a 15.3 GHz radiometer for simultaneous measurement of atmospheric emission temperature. An estimate of attenuation can be obtained from the sky noise temperature measurement.

A 2.9 GHz weather radar is used to obtain backscatter data along the propagation path in the direction of the satellite. The radar is also used in a scanning mode to provide information on predicted attenuation in other directions and a measure of storm cell size.

Considerable work has been done in comparing radar-predicted and radiometer-predicted attenuations with those measured directly using the ATS-5 beacon. Generally good agreement has been obtained with the data analyzed to date.

Simultaneous measurements of ionospheric fading at frequencies near 136 MHz, 250 MHz and 1550 MHz have been in progress at CRC since January 1970. Satellites employed in this program include the ATS-5 and the TACSATCOM-1 satellites. The major objectives of this program are to accumulate statistical data on fading amplitudes and their frequency dependence to permit satellite communications systems margins to be specified accurately in the VHF/UHF range.

Low-Angle Tropospheric Scintillations

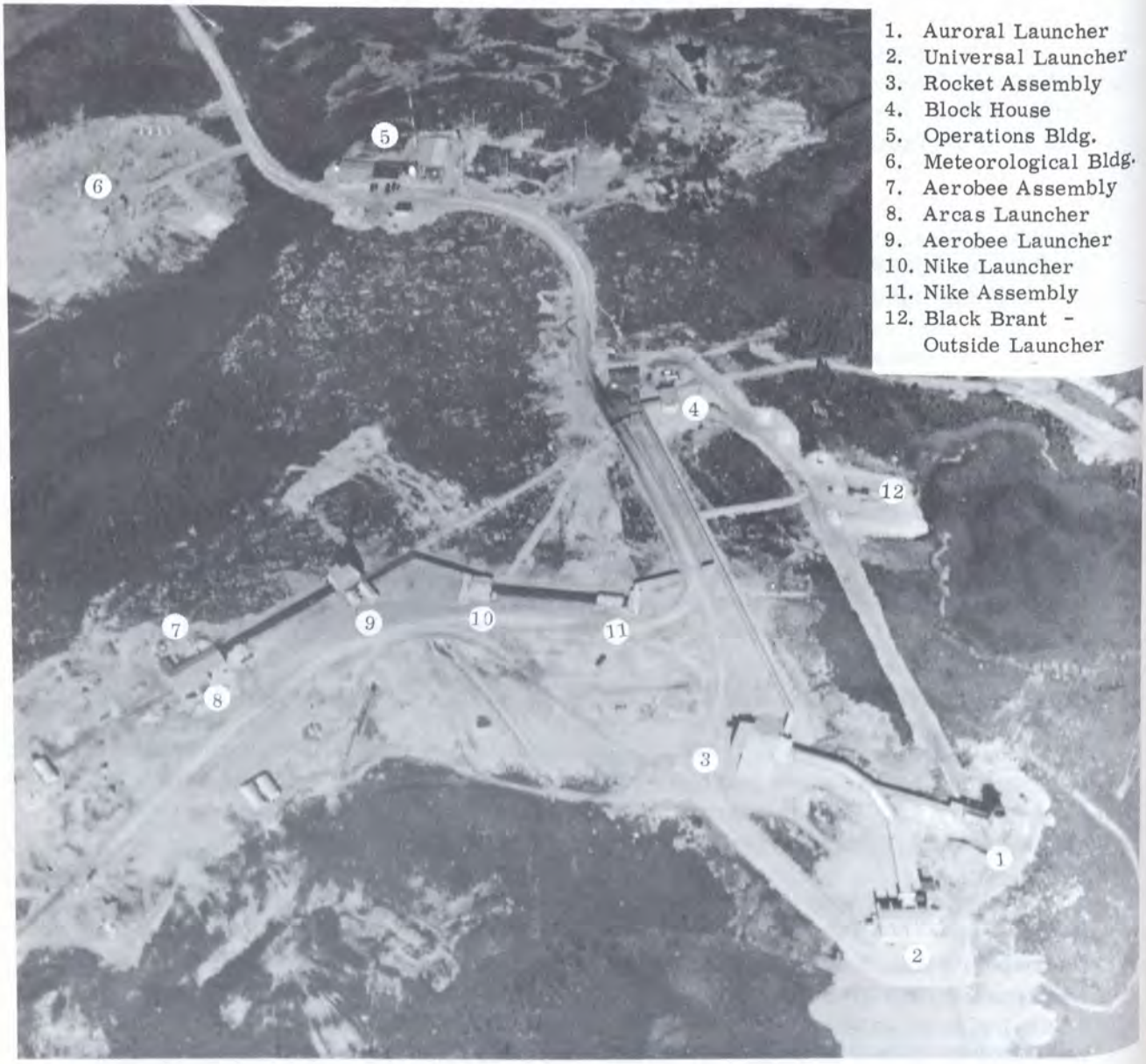
It is common practice to limit operation of satellite communication systems to elevation angles, at the earth's surface, greater than five degrees. However, in Canada it may well be necessary to consider operation at very low angles to achieve coverage of the Canadian North from the geo-stationary orbit.

Signal amplitude fading results when SHF signals are propagated through the troposphere. The depth of fading is dependent on the length of the path in the troposphere and, hence, on the elevation angle of a satellite communications circuit. Amplitude fading statistics are important for system designers who must make allowances for propagation margins. A continuing series of measurements of low angle tropospheric fading is being carried out by CRC employing a fixed 30-foot ground terminal and a transportable 6-foot ground terminal.

Tactical Satellite Communications Program

A cooperative program with the Department of National Defence to investigate the properties of UHF satellite systems at frequencies near 300 MHz has been in progress since July 1967. One of the main objectives of the program has been the investigation of the propagation environment as it affects UHF satellite communications system performance. An extensive series of measurements of signals received from the LES-5, LES-6 and TACSAT-1 satellites has been performed at various Canadian locations, including Ottawa, Churchill and Resolute Bay.

CHURCHILL RESEARCH RANGE LAUNCH SITE



DEFENCE RESEARCH BOARD

Defence Research Establishment Valcartier (DREV)

There are two groups engaged in space-oriented activities at DREV. One group is involved in solar-terrestrial relationships and is concentrated on the photochemistry of the ozonosphere. A second group is concerned with the development of improved solid propellants and high-performance rocket motor systems.

Atmospheric Radiative Processes

The DREV program is focussed on the photochemistry of the ozonosphere, the region wherein the bulk of the solar energy driving the atmosphere is deposited. Much of the work forms part of CRAM (Centre de recherches sur les atomes et les molecules), which groups together a considerable number of DREV scientists with staff members of the Departments of Physics, Chemistry and Electrical Engineering, Universite' Laval. Research is underway in the following areas:

(i) Aircraft-borne experiments are used for those studies of infrared airglow and stratospheric composition where obstacles to viewing, such as clouds, haze and absorbers, must be avoided and where wide geographical coverage is desirable. A joint ARPA*, USAF, DRB (DREV) program which has measured stratospheric abundance of minor gases, emission intensity of $O_2(^1\Delta_g)$ and OH, and OH rotational temperatures over a wide range of latitudes is scheduled for completion by late 1970. A program to measure airglow in the visible and near infrared from Arctic latitudes is planned for 1971. Emissions from excited oxygen, OH, and aurorae will be examined to determine ambient illumination levels near the surface and to deduce upper stratospheric and mesospheric photochemistry.

(ii) Laboratory investigations underway or scheduled for 1971 include:

a) Singlet molecular oxygen formation by photolysis of ozone;

b) Atmospheric OH rotational temperatures as a true measure of mesopause temperature;

c) Atmospheric composition derived from solar and lunar absorption spectra of high spectral resolution obtained by a ground-based interferometer coupled to an optical tracker.

(iii) The best available kinetic reaction rates, atmospheric composition, temperatures, and circulation are used to derive models of atmospheric radiation processes. Photochemistry of the stratospheric and mesospheric regions, 10-100 km, is stressed. Model predictions of constituent distribution are compared to observed data to verify the modelling technique and highlight critical unknowns.

---

*ARPA - Advanced Research Projects Agency

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.

The development of the Black Brant series of rocket motors was based largely on DREV technology and was conducted jointly by DREV and the industrial firm now known as Bristol Aerospace (1968) Ltd. More recently, a second joint program with BAL has been concerned with the development of two small rocket motors to be used for meteorological soundings. These high performance motors must withstand extremely severe environmental conditions with exceptional reliability, all at an unusually low production cost. Having completed the major portion of its contribution to this program, DREV continues to provide engineering support to BAL, where the two vehicles are now in an advanced stage of development.

DEPARTMENT OF TRANSPORT

Canadian Meteorological Service

Weather Satellite Activities

The Canadian Meteorological Services Automatic Picture Transmission (APT), Research and Development Project, continues to evaluate and apply data received directly from U. S. Weather Satellites for meteorological study and for distribution to other agencies. Present distribution is approximately 30, 000 copies per annum.

The Satellite Data Laboratory acquires APT mode data from the TOS series of operational meteorological satellites and from the experimental NIMBUS and I-TOS spacecraft. APT re-transmissions from ATS-1 and ATS-3 have also been acquired and evaluated in cooperation with the U. S. Environmental Science Service Administration. Daily coverage obtained at the station covers North America, with the exception of the Alaska Peninsula but includes the Arctic Archipelago.

Data are used for meteorological research, forecasting, ice reconnaissance and hydrological applications and are provided to other agencies and universities for operational assistance or research relating to the earth and environmental sciences and other uses.

Infrared night-time data from NIMBUS III and I-TOS 1 have been studied with densitometer techniques to obtain quantitative surface temperatures and cloud height data. Surface temperatures of large water bodies have been obtained and cloud height has been derived from the densitometer measurements. These correlate well with surface observations.

Information relating to large-scale air pollution areas in day-time visual Automatic Picture Transmission pictures have been used to re-examine earlier qualitative studies to derive quantitative data, but this study has not yet been finalized.

Noctilucent Cloud Activities

About 70 stations in Canada make visual observations of noctilucent cloud and report in a manner consistent with that recommended in the World Meteorological Organization International Noctilucent Cloud Observations Manual. Observations from Canada, Alaska, Iceland and Greenland are compiled, processed and published.

The cross-Canada string of uniformly mounted 35 mm Konica cameras, developed to obtain quantitative information for studies of noctilucent cloud height, morphology and gravity waves, has been completed by increasing the numbers of participating stations to nine. The parallactic photography system developed on a test basis by 448 Test Squadron, Canadian Forces, at Cold Lake, Alberta, in 1969 was not effective, and no attempt was made to operate it during 1970.

Airglow Studies

Intensity fluctuations of night sky emission in oxygen green line (5577Å) and background radiation recorded simultaneously at two stations 15-20 km apart, during the dark period of clear nights, were obtained for a few test cases. Results are currently being studied to evaluate the usefulness of the system for estimating drifts at the emission level.

Plans are being developed to investigate the interactions of photochemistry and dynamics by numerical modelling and to orient the measurement activities to parameters required in specifying or verifying the model used.

Theoretical Studies

Theoretical studies have been carried out on transport of non-conservative trace constituents near mesopause level in relation, for example, to the nature and cause of anomalous absorption in the D-region.

Density variation in stratosphere, mesosphere and lower thermosphere were studied in relation to temperature and height.

Meteorological Rocket Program

Modifications in scientific and operational requirements are monitored as they relate to the strategic plans for the meteorological rocketsonde network. Action has been deferred pending easing of current government restrictions on spending and new programs.

DEPARTMENT OF ENERGY, MINES AND RESOURCES

Geological Survey of Canada

Participation in the Apollo Lunar Sample Studies

1. Apollo XI - Approximately 110 grams of lunar rock chips and unconsolidated surficial material, and several petrographic thin sections, were received by the five investigative teams in October 1969. Work began immediately on the five areas of study which had been approved by the National Aeronautics and Space Administration in 1967, as part of its Principal Investigator program for studying the samples to be returned from the Apollo XI, XII and XIII manned lunar landings. These investigations included the mineralogy and petrology (with the collaboration of the Earth Physics Branch of the Department), chemical composition, isotopic composition and geological age, electrical conductivity and magnetic properties of the samples, which comprised specimens of the igneous crystalline rocks, breccias and the lunar regolith. The methods and equipment employed in the work were those used by the Geological Survey in its continuing investigation of Canadian rocks and minerals, and no special preparations were made for the lunar studies.

In addition to delineating the major mineralogy of the lunar material, a hitherto terrestrially-unidentified new mineral was found, as well as several new mineral phases; on the basis of the samples studied, it has been postulated that the moon had a simple magmatic history. The presence of a small, but measurable, remanent magnetism suggests that the moon had a magnetic field in the geologic past, but the origin of the field has not yet been deduced. The isotopic abundance measurements of Li, K, Rb, Sr, U and Th showed no major deviations from accepted terrestrial values; of the two sets of ages determined, that of 4.6 billion years is in essential agreement with the accepted age of the earth and those of 2.2 - 3.4 billion years suggest that they were stages in the thermal evolutionary history of the moon. The electrical conductivity of the lunar crystalline rocks was found comparable with that of terrestrial basalt, but that of the breccias and the unconsolidated surficial material was much greater, probably because of the presence of a metallic phase in the latter samples. The chemical analyses showed an unusually high concentration of titanium, very low concentrations of sodium and potassium and a conspicuous lack of volatile constituents, such as water, fluorine, chlorine and carbon dioxide. Detailed descriptions of the work done, and the results obtained, in these five areas of investigation have been published in Science (Vol. 167, January 30, 1970) and in the Proceedings of the Apollo II Lunar Science Conference Vols. 1-3, Pergamon Press, 1970.

2. Apollo XII - Similar studies are being completed on rock chips and unconsolidated surficial material returned from the Apollo XII manned lunar landing, with the exception of the isotope and geochronological work which was confined to the Apollo XI material only. The results will be communicated to the Apollo XII Lunar Science Conference in Houston in January 1971 and will probably be published shortly afterwards in the Journal of Geophysical Research. The first occurrence of garnet in lunar samples has been reported by the mineralogy-petrology investigative team.

Earth Physics Branch

The Division of Geomagnetism operates 10 permanent magnetic observatories in Canada and supplies microfilm copies of the magnetograms to World Data Centers on a monthly basis. Three of these observatories are now recording in digital form on magnetic tape. Four observatories record micropulsations in the period-range 10 to 150 seconds.

In a cooperative program with the Goddard Space Flight Center of NASA involving the synchronous satellite ATS-5, the Division has operated, since October 1969, four unattended magnetic recording stations in Manitoba, at Lynn Lake, Thompson, The Pas and Winnipeg. The magnetic field-line passing through the satellite reaches the earth's surface near Thompson in the auroral zone. There is a strong correlation between changes in the magnetic field observed at the satellite and the substorms and pulsations recorded at the ground stations.

Program Planning Office for Resource Satellites and Remote Airborne Sensing

Pending approval of an international agreement with the United States, Canada will read out the data from NASA's earth resources technology satellites ERTS (A) and (B) from the Prince Albert Radar Laboratory (PARL) in Saskatchewan, which will be modified for this purpose. This station can receive data for the whole of Canada. ERTS (A) is to be launched in near polar orbit in March 1972 and ERTS (B) in December 1972. These satellites will be transmitting high resolution television pictures and multi-spectral line scan data of the underlying terrain covering a swath 100 nautical miles wide on each pass.

The data taped at PARL will be air-expressed to Ottawa, where it will be transformed to geometrically corrected hard copy at a data handling centre, reproduced and distributed to users across Canada.

Specialized working groups on Data Handling, Sensors, Geology, Agriculture and Geography, Water Resources, Cartography and Photogrammetry, Ice Reconnaissance and Glaciology, and Air Pollution, with representatives from federal and provincial governments, universities and industry, have been meeting periodically since April 1970 to map out a schedule for the implementation of the program, for the utilization of the data and for the long-term considerations for a national program of remote sensing.

The final reports of these working groups are due on 1 March 1971, at which time the Interdepartmental Committee on Resource Satellites and Remote Airborne Sensing will make recommendations to the Government of Canada.

Satellite and Rocket Studies

Data from the Alouette II satellite have been used to carry out further studies of the entry of solar particles into the inner part of the earth's magnetosphere. Latitude profiles of solar protons and electrons have been studied and compared with recent cut-off rigidity calculations and with the location of the high latitude boundary of 35 keV outer zone electrons. It has been found that the latitude knee for solar electrons lies 5^{o} to 8^{o} above the knee for low energy ($\sim$1 Mev) solar protons and that the location of the electron knee agrees approximately with the 35 keV outer zone boundary. The measurements indicate that a field model could be chosen to give agreement between trajectory calculations and measured knee latitudes for 100 Mev solar protons and 35 keV solar electrons but that lower energy protons penetrate more deeply into the magnetic field than can be accounted for on the basis of these calculations. In some cases intensity changes, not associated with the knee latitude, occur in the lower energy proton distributions at latitudes which coincide approximately with calculated cut-offs.

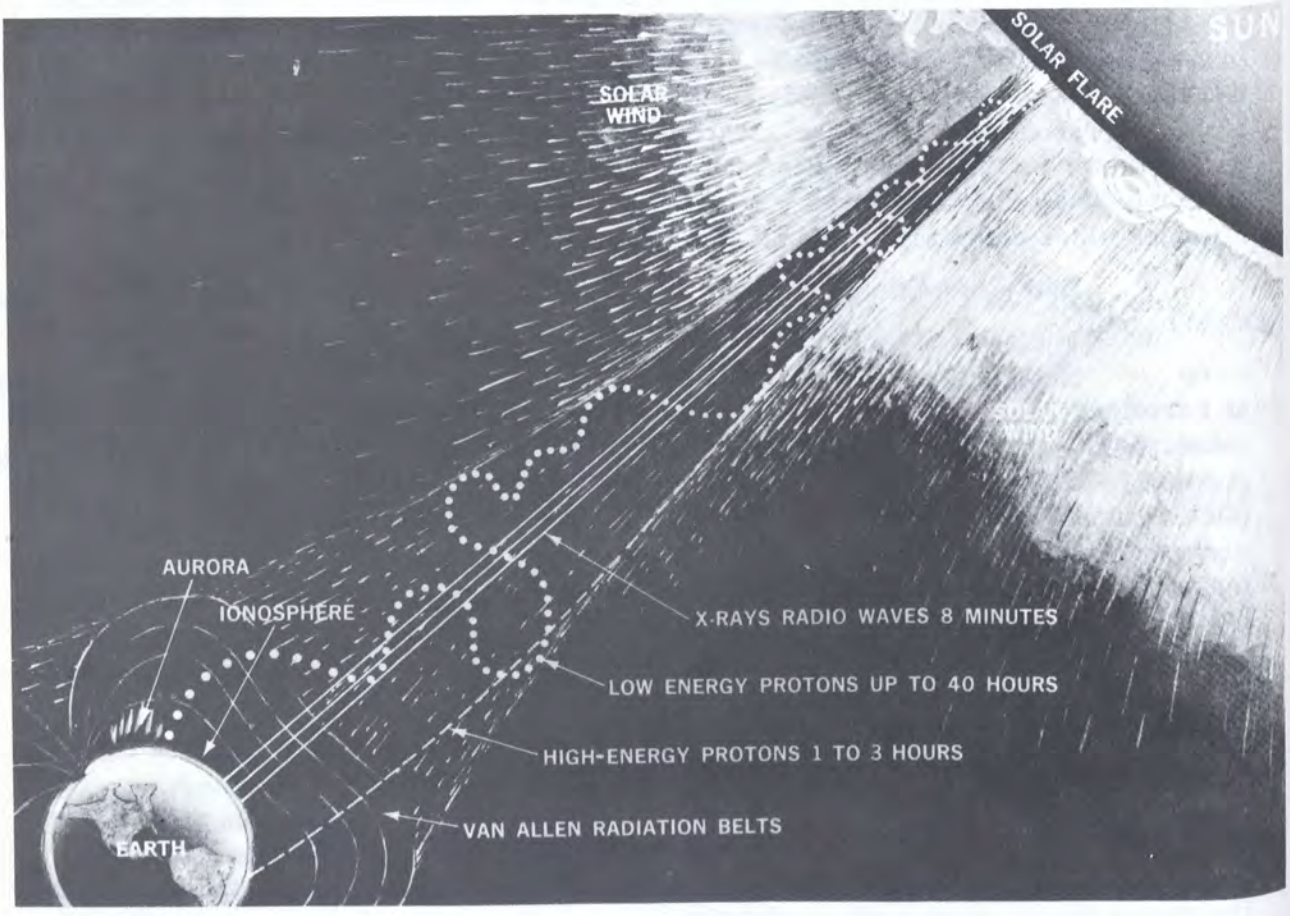
Data processing for the ISIS-A satellite has started, and a few initial studies have begun.

Several studies have been completed using data obtained during rocket flights at Fort Churchill. Temporal characteristics of particle precipitation during an auroral substorm have been determined from two rocket flights into the breakup and post-breakup phases of a substorm. Unusual characteristics were observed in energy spectra and pitch-angle distributions of energetic electrons and protons simultaneously with the arrival of the northern edge of a series of northward propagating auroral arcs. When the northern edge passed the rocket, electron intensities increased and the spectrum hardened appreciably, both changes occurring with time constants less than about 2 seconds. Dispersion in arrival times of electrons was observed with low energy particles arriving first.

Particle measurements have also been carried out during an early morning pulsating aurora. Pulsations found in the 25 to 80 keV electron precipitation were in phase with ground-based photometric observations of the 3914Å emission. The lower energy electrons were found to have anisotropic pitch-angle distributions peaked at 90^{o} going isotropic during a pulsation and were found responsible for a significant fraction of the 3914Å intensity modulation.

A rocket-borne ion spectrometer capable of separating and detecting H^{+}, He^{+} and He^{++} with energies between 2 and 24 keV has been flown into an early-evening proton aurora. No statistically significant flux of He^{+} was observed, but the He^{++} intensity at 15 keV was measured to be $7 \pm 3.5 \times 10^{3}$ $(cm^{2} sec\ sr\ keV)^{-1}$, a value which is consistent with He^{++}/H^{+} ratio in the solar wind. The observation of auroral He^{++} and H^{+} ions of approximately the same ratio as in the solar wind, and the apparent lack of He^{+} ions, is strong evidence for a direct solar wind origin of auroral primaries.

MANIFESTATIONS OF A SOLAR FLARE



Astrophysics Branch

Reorganization of Government Astronomy in Canada

In April of this year the government consolidated within the National Research Council all of its activities in astronomical research. The move, which was first recommended by the Glassco Commission and endorsed late last year by the Science Council, involved the transfer of astronomical research programs in the former Observatories Branch of the Department of Energy, Mines and Resources. The decision was not solely based on administrative convenience. It was felt that the research effort, particularly in radio astronomy, would benefit from the substantial engineering support which exists in the Council's laboratories.

The activities which have been transferred include two major observatories, the Dominion Astrophysical Observatory and the Dominion Radio Astrophysical Observatory. Also included were the Time Service of Canada and the groups working in solar physics and meteor astronomy, formerly based at the Dominion Observatory in Ottawa.

NRC's Division of Physics has for a long time been responsible for Canadian frequency standards. Since modern timekeeping is based on atomic frequency standards, the Time Service has been combined with the group involved in frequency standards in a new Time and Frequency Section within the Division of Physics. All other astronomical activities formerly in the Observatories Branch have been placed in the Radio and Electrical Engineering Division, which for many years has administered the Council's activities in radio astronomy, meteor research and upper atmosphere research. To coordinate the combined astrophysical research programs, a new branch has been formed within the Division known as the Astrophysics Branch.

The Dominion Astrophysical Observatory, near Victoria, B. C., has for more than fifty years been making significant contributions to optical astronomy. Its 72-inch telescope was, for a short time after the opening of the observatory in 1918, the largest in the world and with it the devoted staff quickly gained for Canada a prominent position in world-wide astronomy. It was not until 1962 that a second, but smaller, telescope was added. Skilful optical design by the staff of the DAO has, however, made this telescope as powerful for spectrographic work as the largest telescopes now in existence. The observatory also operates a station on Mt. Kobau. Chosen as the location for the cancelled Queen Elizabeth II telescope, Mt. Kobau is at present the site of a 16-inch telescope used for photometry and direct photography. As a legacy of the QE II project, the DAO possesses the nucleus of a team skilled in large telescope design and in the design and manufacture of astronomical optics.

The Dominion Radio Astrophysical Observatory, established in 1960, near Penticton, B. C., has three major radio telescopes - a parabolic dish 26 meters (84 feet) in diameter for high frequency studies and two T-shaped arrays for low frequency observations. A fourth telescope is under construction. This new telescope, which employs the aperture-synthesis principle, will be used for spectroscopic studies of the 21 centimeter radiation of the neutral hydrogen atom. The equipment and programs of the DRAO complement those at the Council's Algonquin Radio Observatory, Lake Traverse, Ontario.

METEORITE OBSERVATION AND RECOVERY PROJECT (MORP) STATIONS

The transfer has brought the groups working in solar and meteor physics in the former Observatories Branch of the Department together with their counterparts in the National Research Council Laboratories. At the time of the move, the Branch had under construction a new solar observatory at Shirley Bay on the Ottawa River, west of Ottawa. The telescope which will be installed later this year is specially designed for studies of the small-scale structure of the solar atmosphere. For this type of work image definition is important. The Shirley Bay location was chosen since extensive tests showed that for much of the day "seeing" at this site was excellent. The studies which this new observatory will make possible will complement the studies of the solar radio radiation which have been carried out in NRC's Radio and Electrical Engineering Division since 1946.

At the time of the transfer, the Observatories Branch was also engaged in providing a new facility for meteor research. The project known as the Meteorite Observation and Recovery Project (MORP) will, when completed, consist of a network of twelve photographic stations scattered over the prairie provinces with headquarters in Saskatoon. The network is designed for the recording of bright meteors or fireballs to aid in the rapid recovery of the fallen objects for laboratory analysis with minimum delay. This project, together with the continuing studies of meteor spectra, are now part of the research program of the Upper Atmosphere Research Section of the Astrophysics Branch. This section, formed in 1955, operates the Springhill meteor Observatory, south of Ottawa, for the observation of meteors by visual, spectrographic and radar methods. The meteor data yield certain information about the upper atmosphere, but the section is also engaged in more direct studies, rocket-borne experiments and radar and optical studies of the aurora and airglow.

Radio Astronomy Section

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. 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 basic data are also available in daily URSIgrams. The continuous nature of the watch of solar conditions, as well as the complexity of the solar phenomena, requires cooperation among various observatories on earth. The lack of 10.7 cm solar noise observations between stations on the eastern coast of North America and in Japan was met by the installation of equipment by the National Research Council at the Dominion Radio Astrophysical Observatory near Penticton, B. C. The observational material is collected in monthly reports and published in divisional reports at six-month intervals. These are entitled "Observations of Solar Flux at the Algonquin Radio Observatory on 2800 MHz and at the Dominion

OTTAWA RIVER SOLAR OBSERVATORY-TELESCOPE BUILDING

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 optical solar patrol telescope project begun by the Dominion Observatory was transferred to the newly-formed Astrophysics Branch of NRC in April 1970. A building for this telescope has been erected on a point of land extending eastwards into a broad bay of the Ottawa River at Shirley's Bay, Ontario. This site, now called the Ottawa River Solar Observatory, was selected to take advantage of the extended periods of good solar seeing that occur at sites surrounded by water. Installed on its pier in August 1970, the telescope is a multiple refractor designed for direct high-resolution photography of solar active regions in several wavelength bands. Initial observing programs are aimed towards an improved understanding of the earliest phases of sunspot growth and flare production. Simultaneous photographs will be obtained at high time lapse rates of selected active regions in two wavelength bands corresponding respectively to photospheric and H-alpha chromospheric levels. Radial mass motions of chromospheric material will be detected by sweeping the band pass of a narrow band (0.25Å) filter across the H-alpha absorption line.

Upper Atmosphere Research Section

Meteor Astronomy

Instrumentation of the 12 camera stations of the Meteorite Observation and Recovery Project (MORP) proceeded during 1970 and became operational late in the year. Several bright fireballs have been recorded by the network in its first months of partial operation. In connection with the transfer of all astronomical research from the Dominion Observatory to the National Research Council, the meteor observatories at Meanook and Newbrook, Alberta, were closed in March 1970 and the instruments moved to the Ottawa area.

Combined meteor observations were continued at the Springhill Meteor Observatory (latitude 45° 11.8' N, longitude 75° 28.3' W) during the periods of the major annual meteor showers in 1970. This program involved the use of two meteor radars (32.8 MHz, omnidirectional antennas), batteries of meteor spectrographs, image orthicon equipment (operated by the Dudley Observatory, Albany, New York) and a team of visual observers.

Conjugate Point Aurora Studies

Photoelectric auroral photometers were operated at the near-conjugate pair, Great Whale-Byrd, during the period of common darkness, April-mid-August 1970. Failure of the equipment at Byrd curtailed the observations prematurely at this time. Construction, assembly and testing of the automatic auroral photometers was progressing well by late 1970, and it is proposed to deploy the network during the late summer of 1971.

Aurora and Airglow

Fortran programs have been written to generate and plot synthetic spectra of aeronomic interest. The band systems which have been included are the oxygen infrared atmospheric, nitrogen first positive, ionized nitrogen meinel and first negative, ionized oxygen first negative and hydroxyl meinel bands.

The theoretical calculations dealing with the modeling of an oxygen-hydrogen atmosphere have been extended to include new information on reaction rates and photodissociation coefficients. The role of water vapour has been considered in greater detail.

A multi-channel infrared airglow and auroral photometer employing a Ge detector is being built to investigate the behaviour of the O_2 1.27μ band, the Q branch of the OH 3-1 band and the N_2 IPG 0-1 band.

An expedition was made to Churchill in March 1970, and the 11-channel high-speed photometer was used with a meridian scanning attachment to record data over a 10-day period of strong auroral activity. These data, together with those from the 1969 NASA Airborne Auroral Expedition, are being analyzed by computer methods from the digital magnetic tapes. Preliminary results include interesting results on type-A red auroral arcs from Churchill and O_2 1.27μ nightglow from the NASA expedition. The averaged IR spectra from the flight show an acceptable signal to noise ratio and are providing values of O_2 1.27μ band intensity and OH intensities.

A 0.5 m Ebert scanning spectrometer is under construction for use with the 11-channel photometer for auroral observations. This system should enable comprehensive spectroscopic observations to be made on an expeditionary basis.

Auroral Photometry

Permanent photometric observations from Churchill were terminated in May 1970, but it is hoped to continue measurements on an expedition basis in the future. The meridian scanner is being modified to provide computer compatible output. The system is designed to accept simultaneous information from 5 other photometers as well.

The scanner data for 1969/70 are being analyzed for type-A events, but the indications are that this season was not as profitable as the 1968/69 season. A number of substorms will be selected for detailed investigation.

Type-B Aurora

Visible emissions of type-B auroras have been under investigation since 1968, and a continuation of the program is planned until at least 1972. Both photometer and spectrometer techniques have been used. Future studies will be strictly photometric.

Until 1970 efforts were directed towards detecting an enhancement of the O_2^+ ING emission relative to that of the N_2 IPG in type-B auroras. An enhancement was not observed. A report of this study is given elsewhere (CJP, 48, 2283).

Future experimentation is being directed towards determination of the mechanism responsible for the red coloration. Particular emphasis is being placed on volume emission rates of selected emissions.

Auroral Electrojet Currents

Auroral electrojets have been under study since early 1969. The instrumentation consisted of a line of 5 magnetic observatories extending northward from Gillam, Manitoba, through Churchill to Eskimo Point, N. W. T. These observatories were removed in April 1970.

In a large number of cases it has been possible to chart the northward movement of the apparent position of an electrojet during the expansive phase of an auroral substorm. Positions and current intensities have been calculated, and propagation velocities have been estimated using two techniques. These results will be submitted shortly for publication.

Radar Aurora

448 MHz range-azimuth data from radar aurora have been analyzed. These were recorded at Prince Albert, Saskatchewan, during the summer of 1966. It was found that echoes were detected from lower latitudes when local magnetic activity was high than when conditions were quiet. An empirical relationship between the minimum latitude of detectable echoes at Prince Albert and magnetic disturbance magnitude approximately below the radar aurora has been published (CJP, 48, 1411).

Radio Aurora Studies

Auroral radars were operated continuously at Ottawa, Thompson, Churchill and Great Whale. It is planned to start a program of improvements to the system in the coming year.

Eclipse Rockets

Four Black Brant III rockets were fired successfully during the total eclipse on 7 March from Nova Scotia. The rockets and experiments behaved well, and analysis of the data is proceeding. (Interest is heightened by the high solar activity at the time.)

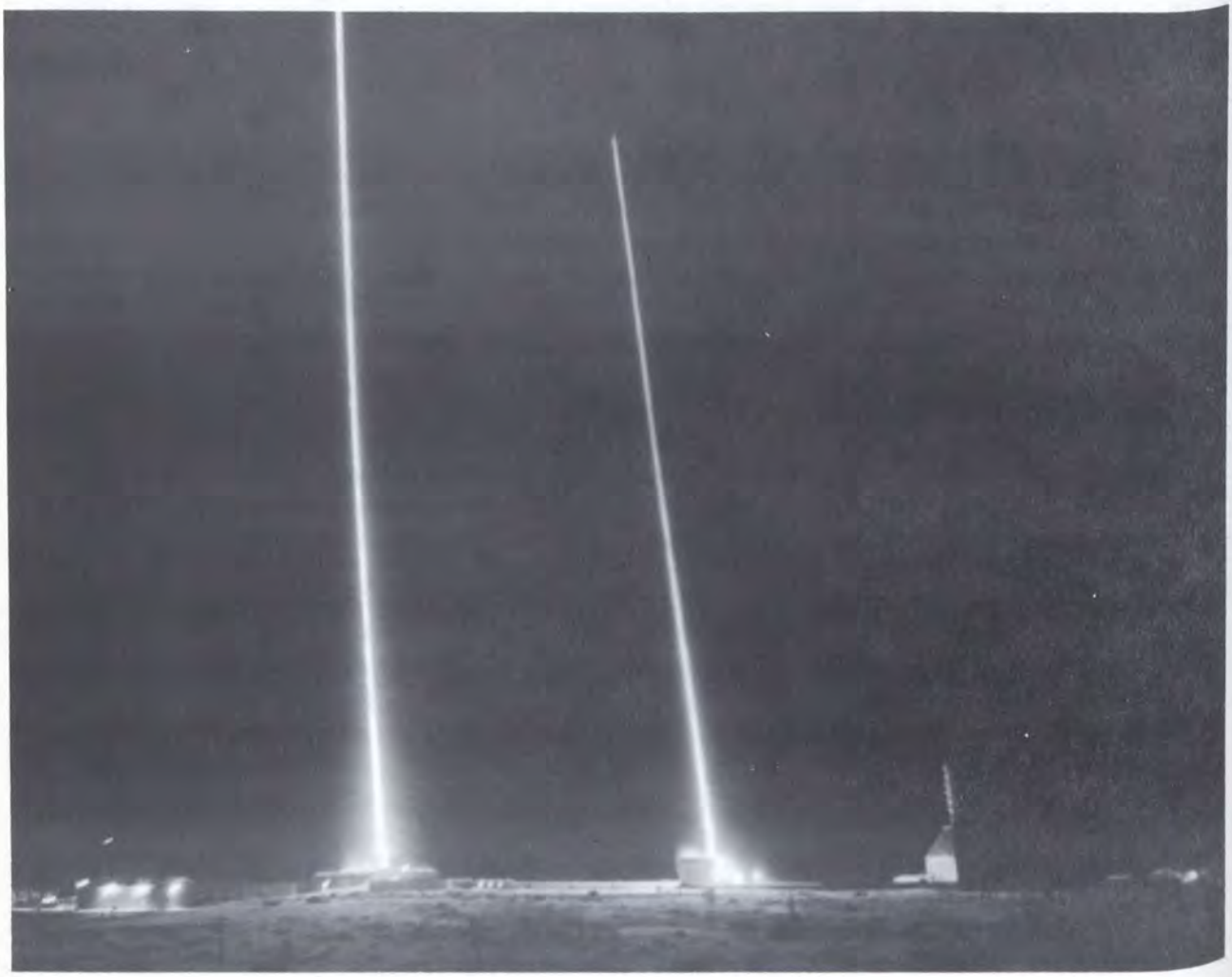
Other Rocket Studies

Plasma probe experiments were flown on four other rockets from Churchill, including a repeat low-angle flight, AAF-VB-29. The on-board experiments worked, but the clamshells failed to release so that no data was received from the ejected probes.

Micrometeoroid Detection

During the past year, acoustic and ionization impact detectors were flown as piggy-back experiments on a few rockets. The major effort, however, was directed towards the planning and construction of a micrometeoroid detecting payload, rocket AAD-VB-30, scheduled for launching during the geminid meteor shower, 12-14 December 1970. The payload carries 13 experiments from 4 countries, 12 for detecting micrometeoroids and one pair of plasma probes to measure the contribution of the meteor shower to E-layer ionization. The 12 experiments have 70 sensors and represent 9 different measurement techniques. In addition to the usual determination of number and distribution of the particles, the comparison of responses from the various detectors exposed to the same environment is considered of prime importance. A Black Brant VB vehicle was chosen to provide a high velocity in the 80 to 100 km region so that particles which may be quasi-stationary individually or accumulated in slowly sinking layers can be detected.

A DUAL NIGHT LAUNCH OF BLACK BRANT ROCKETS



Space Research Facilities Branch (SRFB)

General

The Space Research Facilities Branch supplies the means by which upper atmosphere and space research programs of Canadian scientists are carried out. The scientists involved are, in general, from universities and government agencies.

In the summer of 1969, it became apparent that the Canadian Upper Atmosphere Research Program would be curtailed for budgetary reasons. At about the same time, it was decided by the National Aeronautics and Space Administration (NASA), the United States agency with whom Canada had been cooperating in operating the Churchill Research Range (CRR), that from 1 July 1970 NASA would discontinue the joint funding arrangement. It was also agreed between NRC and NASA that the Space Tracking and Data Acquisition Network Station (STADAN) near St. John's, Newfoundland, was becoming less important in tracking and acquiring data from United States and Canadian satellites. It was, therefore, decided to cease operations at that station on 31 March 1970.

SRFB continues as the service agency in making arrangements for an upper atmosphere research program in Canada. The most noticeable changes attributable to financial policy will be that the sounding rocket program will be smaller in the immediate future and services provided to user scientists at the CRR will not be as extensive as they have been.

SRFB is responsible for an expeditionary base for rocket launching at Resolute, Northwest Territories. A somewhat similar site at East Quoddy, Nova Scotia, which was established for rocket launches during the eclipse of the sun of 7 March 1970, has been retained for use on the occasion of the eclipse of the sun of 10 July 1972. A temporary launch site is also being prepared at Eskimo Point, Northwest Territories, for the 1972 solar eclipse. The operation of the Great Whale Geophysical Station at Poste-de-la-Baleine, P.Q., continues to be the responsibility of this branch.

Range Section

This section administers and supervises all sounding rocket ranges operated by the NRC. This includes liaison with foreign government agencies regarding their use of range facilities. At present there are three ranges in use and a fourth is in the process of being set up: Churchill Research Range in Manitoba, the expeditionary facility at Resolute Bay in the Northwest Territories, and the temporary ranges at East Quoddy, Nova Scotia, and at Eskimo Point, Northwest Territories.

Churchill Research Range

In Canada, we have a large land mass from which the many and varied phenomena associated with the auroral zone can be conveniently studied. The fact that Canada's area is nearly bisected by the auroral zone brings with it many special problems (mostly associated with disturbances in radio and telegraphic communications), but it also provides a suitable location for a facility at Churchill that is unique among the nations of the world for the investigation of many of the current problems relating to the upper atmosphere and near space. It seems likely that a significant fraction of the new knowledge concerning these reaches of our atmosphere and its interaction with the atmosphere of the sun will be gained by observations made in and near the auroral zone. We have not only the opportunity, but in a very real sense the duty in the space age to undertake to provide this knowledge.

The research range is operated for NRC by a contractor who provides more than 90% of the staff at Fort Churchill. The range provides all the test support aids essential to launching and also arranges for land recovery of payloads. Range instrumentation includes surveillance, acquisition and tracking radars; telemetry, sound ranging and radial doppler interferometer (RADINT). Meteorological support, impact prediction, communications and timing are provided. In addition, an Auroral Observatory is equipped to undertake spectroscopy, photometry, the measuring of magnetic fields and ionospheric absorption and all-sky photography. The CRR operates and maintains an all-sky camera, a riometer and a magnetometer in support of rocket programs. The other instrumentation at the Auroral Observatory is maintained in a serviceable condition by the CRR for the use of visiting scientists. The calibration and operation of spectrometers and photometers is a user responsibility. In conjunction with the Auroral Observatory, and on behalf of other agencies, the CRR maintains and operates an auroral radar, a realtime satellite tracking station (RTT), a neutron monitor and a magnetic observatory.

The Range Section was engaged during the first half of the year in planning the reorganization of the CRR facilities and services made necessary by the termination on 30 June 1970 of the Canada/USA agreement for the joint funding and operations of that range. With this termination, the Joint Range Policy Committee (JRPC) ceased to exist, and the full control of the range was vested in SRFB. For the future operation of the CRR, the staff at the range was reduced to about 70 persons, and the launch rate capability was reduced to support approximately 35 major rocket launchings per year; however, the range retains the capability of handling, launching and retrieving data from the same types of rockets and payloads as in the past. In its new configuration, CRR has successfully supported 5 major rocket projects, which carried experiments for scientists from Canada, United States of America, Federal Republic of Germany, Czechoslovakia, Sweden and United Kingdom.

A detailed description of the present range facilities at the CRR is contained in the revised (July 1970) version of the Handbook for Range Users. Scientists proposing to use the CRR are encouraged to become familiar with the Handbook, which has been widely distributed.

Resolute Bay Rocket Launching Facility

During 1966, a requirement to launch scientific payloads in a region not influenced by the Van Allen Belt led to the establishment by the Research Support Section of the Space Research Facilities Branch of a temporary launching facility at Resolute Bay, Northwest Territories. With the exception of 1970, Canadian launchings of Black Brant III rockets have taken place at this site yearly since its activation. NASA, under an agreement with NRC, conducted launchings of Boosted Arcas rockets at Resolute during 1967, 1968 and 1969.

In October of 1968, the Range Section of SRFB assumed responsibility for the provision of field launching facilities, as well as the coordination, control and safety aspects of the Resolute Bay launching operations.

Although NRC has no plans for a rocket program for Resolute in 1971-72, NASA has a proposal for the launching of Black Brant IIIB rockets during October/November 1971 or, alternatively, in May/June 1972. These launchings are proposed in support of the sub-satellite to Apollo 16 and will provide a supporting study with sounding rockets during the time when the sub-satellite is operating. The scientific objectives are concerned with the entry of charged particles into the magnetosphere and, hence, with the fundamental problem of magnetosphere convection. An additional measurement is of the solar flare spectrum at low energies. The expected payload weight to be flown is about 50 Kg with an estimated apogee of 235 km. NRC support would be limited to the provision of existing facilities, coordination of services and support from agencies at Resolute and arrangements for range safety clearance, RF authorization and approval for operation in the NWT. An NRC representative would also act as mission coordinator and range safety officer during operational periods.

1970 Solar Eclipse

The National Research Council of Canada launched four Black Brant III rockets from the temporary rocket launching site established at Smith's Point, near East Quoddy, Nova Scotia, during the 7 March 1970 solar eclipse. The four vehicles launched before, during and after totality of the eclipse carried Langmuir probes, receivers for radio frequency propagation experiments, X-ray and Lyman alpha detectors to measure ionization changes in the D- and E-regions. Vehicles performed satisfactorily, and good data were obtained from all experiments.

Further details can be found in Space Research Facilities Branch Engineering Report on these launchings, "Black Brant Rockets AAF-IIIA-42, -43, -44 and -45 Launched at East Quoddy, Nova Scotia, during the 7 March 1970 Solar Eclipse" (SRFB 043), July 1970, which publication can be obtained through SRFB, NRC.

EAST QUODDY LAUNCH SITE-ROCKETS READY TO LAUNCH 7 MARCH 1970

10 July 1972 Solar Eclipse

Preliminary details for this eclipse have been discussed, and proposals have been made for launching from Eskimo Point on the Hudson Bay and at East Quoddy, Nova Scotia. The proposal for the launching of 4 Black Brant III rockets from East Quoddy made by Drs. E. J. Llewellyn and A. G. McNamara has been accepted.

In July 1970, a team of NRC and NASA representatives visited Eskimo Point to assess the feasibility of supporting an expeditionary rocket launching operation at this location during the 1972 solar eclipse. For this operation, an Aerobee 150 rocket will be used to carry a payload identical to one flown from Wallops Island during the 1970 solar eclipse. The main object of the experiment will be to study the solar ultraviolet flash spectrum, which is visible for only a few seconds during a total eclipse of the sun. It was concluded that the operation was feasible, although difficult, and a suitable location for the launch was selected. Preliminary work in the form of moving the required materials and the laying of a foundation base for the Aerobee launcher has been completed.

Rocket Systems Section

This section is responsible for implementing the Canadian upper atmosphere sounding rocket program.

In general, the section is a service organization which arranges for experiments to be incorporated into rocket payloads, along with appropriate housekeeping equipment, rocket-borne telemetry, power supplies and mechanical devices. It also supplies the rockets, documentation and vehicle support at the launch site. This work is done almost entirely by contract, and the personnel of the section are involved in contract administration, program control and provision of coordination during launch operations. However, the section also has the responsibility for ensuring that the engineering involved is adequate and acceptable. This involves general direction and detailed monitoring throughout every project. Section engineers also provide the link between scientist and contractor. Engineering inadequacies and their solution, together with the selection and development of equipment to meet new requirements, are continually under review.

In November 1970, the responsibilities of the former Data and Reports Section were added to those outlined above. These include the preliminary processing and distribution of rocket data and the preparation of engineering reports, together with the supervision of the Great Whale Geophysical Station.

Recent innovations in the Canadian program include the use of parachutes specifically for the recovery of valuable payloads; two cases involved the recovery of expensive stabilization systems. One complete payload and the two stabilization systems will be reflown in 1971 after they have been refurbished at a fraction of their original cost.

Payload contractors have been responsible for producing many special electronic devices, including timers, DC to DC converters and for combining PCM and FM systems in a single transmitter. A PCM encoder is now under development. STEM antennas have been used in two payloads, and in one case a pair of antennas measuring 80 feet from tip to tip was used to despin a Black Brant IVA vehicle. Despinning has now become a standard operation with the Black Brant series of rockets with suitable devices developed for both the 10 and 17 inch vehicles.

The section has been responsible for the preparation and launch of 72 rocket vehicles carrying a total of 462 experiments. For a small, low budget, short lead-time program, and on a comparative basis internationally, the Canadian success record is excellent.

The information from the experiments carried in research rockets is usually telemetered to the ground during the flight and recorded on magnetic tape. The data from many experiments must be separated and translated into forms more readily usable by the scientists concerned.

This data reduction was, until mid-1970, carried out by the Space Engineering Division of the University of Saskatchewan under contract to SRFB. With the reorganization of Churchill Research Range, much of this work will be carried out at Churchill. The Radio and Electrical Engineering Division of the National Research Council of Canada is developing special-purpose equipment to provide digitizing of analogue data and transformation of radar data for computer application. The trajectory information is obtained from the data recorded by the radar or from doppler ranging records. Attitude determination requires the interpretation of magnetometer and signal strength records.

In order that all scientists in universities, government agencies and industry may be kept aware of the research rocket program and its preliminary results, brief reports on all rockets fired under the auspices of SRFB are written as soon as the material can be assembled.

By December 1970, 46 publications had been written, which reported the launchings of 69 rockets sponsored by the National Research Council of Canada since the Space Research Facilities Branch was formed in April 1965. Included in these reports was the second edition of Space and Upper Atmosphere Research in Canada (SRFB 036) and a second bibliography of scientific papers resulting from the Canadian Upper Atmosphere Research Program (SRFB 037). At time of writing, more than 400 scientific papers have been written as a result of this program.

In addition, SRFB publishes yearly reports on space activities for the United Nations and the International Committee on Space Research (COSPAR).

STADAN Station

Until 31 March 1970, SRFB operated a Satellite Tracking and Data Acquisition Network (STADAN) Station about twelve miles north of St. John's, Newfoundland. This station formed part of the NASA/Goddard Space Flight Center's

STADAN and was operated by contractors for the National Research Council of Canada as a Canadian contribution to cooperative space research with the United States.

The work of the station included interferometer measurements on satellites passing near the station to obtain precise position data, the recording of telemetry signals from satellites and the transmission of commands to satellites. In addition, when weather conditions permitted, photographs were taken of flashing or reflecting satellites against the star background.

Due to a change in the NASA requirements, it was mutually agreed that the station should be closed, and network operation ceased on 31 March 1970. Canadian satellites continue to receive support from Canadian stations in Ottawa, Ontario, and Resolute in the Northwest Territories, and from other NASA stations.

Great Whale Geophysical Station

At Poste-de-la-Baleine, P. Q., at the southeast corner of Hudson Bay, the Great Whale Geophysical Station, originally built and staffed by NRC's Division of Pure Physics for the International Geophysical Year, is used by many different Canadian and American experimenters. Many of the experiments started during the IGY still continue to provide valuable data. This station, with its staff of three, is now the administrative responsibility of SRFB.

Experiments include auroral photography with all-sky cameras, photometry on five different wavelengths and the operation of an auroral radar for the Radio and Electrical Engineering Division. For the Defence Research Board, an 80 kHz transmission from Ottawa is monitored for propagation studies.

Recordings of VLF noise are made for Stanford University, and both VLF noise and ionospheric absorption are measured for the Environmental Science Service Laboratory of the National Bureau of Standards at Boulder. The data obtained is coordinated with similar material from the Byrd Station in Antarctica, which is at the geomagnetic conjugate point to Great Whale.

National Aeronautical Establishment (NAE)

NAE is largely responsible for the activities of the Sub-Committee on Space Vehicles and Propulsion, which was set up in March 1970 by the Interdepartmental Committee on Space (ICS). As part of the ICS study of the NASA invitation (December 1969) to participate in the U.S. post-Apollo program, the Sub-Committee has examined the Canadian R and D and industrial potential which could be related to the technology of advanced space transportation systems and made recommendations to the ICS regarding the desirable scope of a possible Canadian participation in the U.S. program. To carry its work in an efficient manner, the Sub-Committee has set up Working Groups in several technological areas, which directly correspond to the U.S. Working Groups under the NASA-OART Space Shuttle Steering Group. These areas are: Aerothermodynamics, Dynamics and Aeroelasticity, Structures and Materials, Propulsion, Integrated Electronics, Human Factors and Operations--Maintenance-Safety. A direct contact has been established between the Canadian and the NASA Working Groups.

Among current NAE projects related to the technology of space transportation systems, the following may be mentioned: a study of the dynamic characteristics of a family of slender bodies at supersonic and hypersonic speeds (partially suggested by a NASA contract); an investigation of the stability derivatives of the space shuttle during abort separation maneuver (in cooperation with NASA-Langley Field Research Center); a preliminary investigation into the possibility of adapting to the U.S. NASTRAN computing program to utilize the more advanced final element methods developed at NAE.

Half Models of Space Shuttle (Booster and Orbiter)
Mounted on Reflection Plate of NAE 30-inch Supersonic Wind Tunnel

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 coordination of the planning, the optimum use of resources and the balance of development of all federal government space activities. At the present time, there is federal space effort in the areas of scientific research, communications, defence, meteorology and resource management.

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:

Science Secretariat/Privy Council Office;
Treasury Board Secretariat.

The main concern of the ICS during 1970 has been consideration of the invitation to participate in the United States Post-Appollo Program. Four sub-committees were formed - one on Space Research, one on Space Vehicles and Propulsion, one on Satellite Applications and Technology and one on International Relations. Reports on Post-Apollo have now been submitted, and it is expected that recommendations for interim action will be made early in 1971.

It should be noted that the Associate Committee on Space Research was reconstituted at its meeting in March 1970, and although retaining its title and organizational status as a National Research Council committee, it is, in fact, acting as the Sub-Committee on Scientific Research of the ICS. However, it continues to be the Canadian national committee from the scientific standpoint, and its Scientific Evaluation Panel is still the screening body for experiments proposed for the space research program.

DEPARTMENT OF EXTERNAL AFFAIRS

United Nations Division

United Nations Committee on the Peaceful Uses of Outer Space

Canada is continuing to participate actively in the work of this Committee, the thirteenth session of which opened in New York in January and resumed again in September 1970.

The Working Group on Direct Broadcast Satellites established in 1968 held its third session from 11 to 22 May 1970. The first session held in New York in February 1969 dealt with the technological aspects of the subject. The second session in 1969 considered the social, cultural, legal and other implications of direct broadcasting from satellites. Canada and Sweden produced a joint paper for each session. The third session discussed issues relating to the effective and equitable utilization of this new method of broadcasting and, in particular, questions concerning program content and of participation in direct broadcast satellite systems.

The Committee's Legal Sub-Committee held its ninth session in Geneva in June and July 1970. Its agenda consisted of:

1) a draft liability agreement for damage caused by objects launched into outer space; and

2) a study of (a) the definition of outer space; (b) the utilization of outer space and celestial bodies.

The Legal Sub-Committee was unable, after intensive negotiations, to reach agreement on its first item, and consultations are continuing with respect to the draft terms of a liability agreement. The Sub-Committee did not have time to deal with the other items on its agenda.

The Scientific and Technical Sub-Committee, which met in New York from 14 to 24 April 1970, discussed the following topics:

1) Technical aspects of the registration of objects launched into outer space;

2) A report of the Secretary-General to ECOSOC on natural resources satellites; and

3) The use of remote-sensors in earth orbit for the discovery, inventory, evaluation, development and conservation of the earth's natural resources.

The Fourteenth Session of the United Nations Committee on the Peaceful Uses of Outer Space will be held early in 1971.

TELESAT CANADA

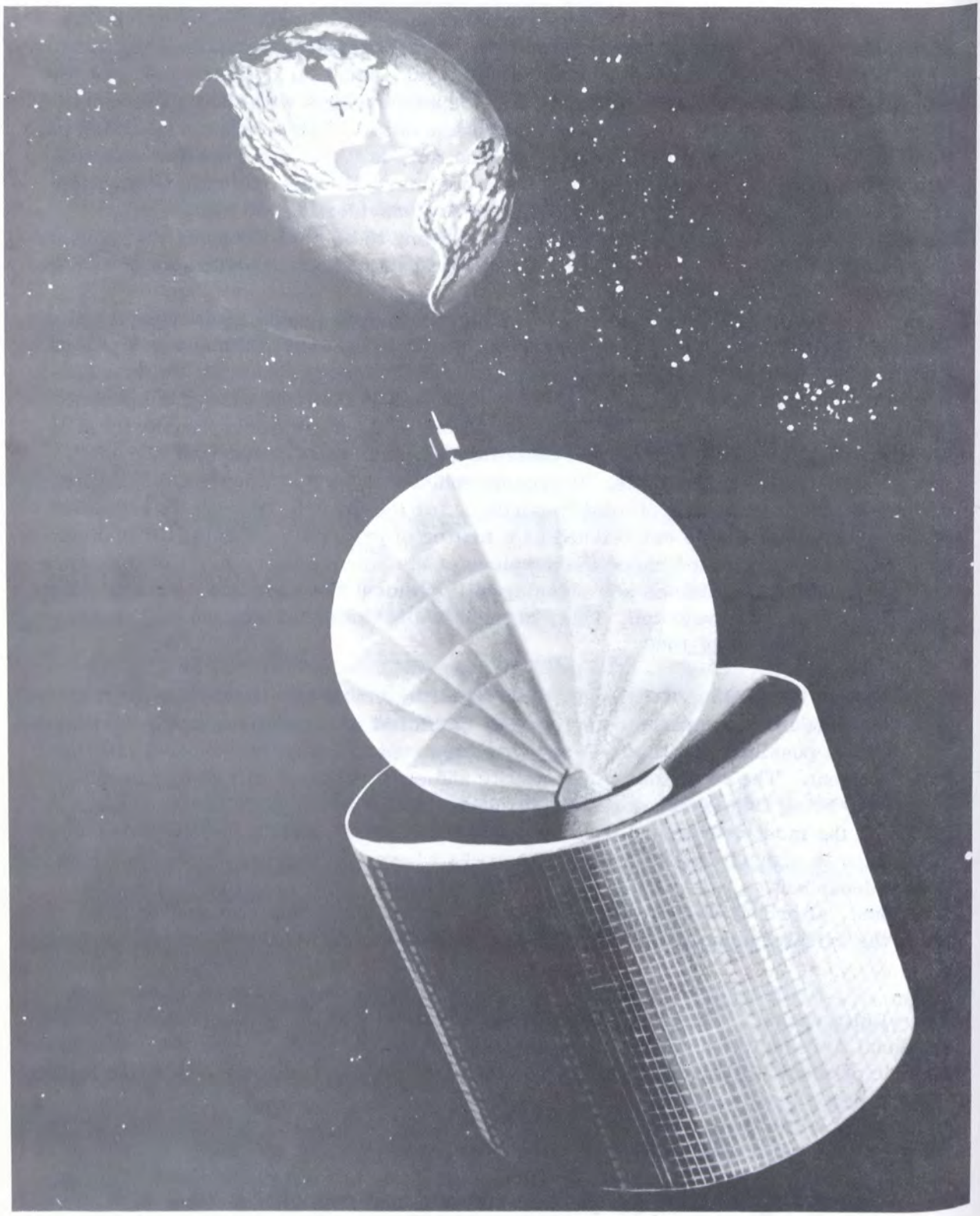
Telesat Canada is a Canadian company charged with the responsibility of establishing and maintaining a commercial domestic satellite system for Canada. The Act incorporating the company received Royal Assent on 27 June 1969, and the company began its corporate existence on 1 September 1969 with the appointment of David A. Golden as president and member of the board of directors. The object of the company, as set out in the Telesat Canada Act, is " . . . to establish satellite telecommunication systems providing, on a commercial basis, telecommunication services between locations in Canada". The Act provides for the ownership of Telesat Canada, which is not a Crown Corporation, to be shared among the federal government, approved common carriers and the public through ownership of shares.

In 1967, a report by John H. Chapman (now a provisional director of Telesat) dealing with Upper Atmosphere and Space Programs in Canada was published. This study, and the great interest shown in domestic satellite communications by a number of commercial organizations, led to the formation of the Prime Minister's Task Force on satellites. The report of the Task Force, in the form of a White Paper entitled "A Domestic Satellite Communication System for Canada", was published in March of 1968. It recommended that " . . . a domestic satellite communications system is of vital importance for the growth, prosperity and unity of Canada, and should be established as a matter of priority". A Satellite Project Office was then organized under the auspices of the Science Secretariat of the Secretary of State to begin studies and planning to implement the Canadian domestic satellite communications program. This, in turn, led to the establishment of Telesat Canada in September of 1969.

The orbiting of Telesat's first satellite, ANIK I (an Eskimo word for brother), late in 1972 and the completion of the initial earth stations in the system will make it possible, for the first time, to electronically link the entire Canadian sub-continent. The combination of satellite and earth stations will enable broadcasters to bring live, network television programming to all parts of the country, including the most remote and inaccessible areas. It will enable the telephone companies to provide reliable service to areas where this form of communications is now dependent on favorable atmospheric conditions. The system will provide additional, alternate capacity for television, telephone and data communications along the existing heavy east-west traffic routes.

ANIK I will be launched from Cape Kennedy using a thrust-augmented, Thor-Delta rocket. The launch and the spacecraft will be under the control of NASA (National Aeronautics and Space Administration) until a transfer orbit with a minimum altitude of about 322 kms (200 miles) is achieved. At this time, control of the spacecraft will be turned over to Telesat's Satellite Control Division, which will direct it to its eventual station, a point some 35,880 kms (22,300 miles) over the Equator in roughly the longitude of Winnipeg. From this point ANIK and the earth will rotate at the same speed so that the satellite will appear to be stationary, the beam of its antenna illuminating Canada from Atlantic to Pacific and Pole to U. S. border.

CONFIGURATION OF ANIK I COMMUNICATIONS SATELLITE



Four classes of earth station, from complex, manned, heavy-route stations to serve the high-volume, east-west traffic routes, to smaller un-manned, TV receive-only stations in more remote areas, will send and/or receive satellite signals. Television broadcasting, telephone and data transmission facilities connected to the earth stations will relay the signals, which can then be received in homes and offices. This system will make live television programming available in all parts of the country, including those which cannot now be economically served by conventional means. It would permit telephone service to many of these same areas and would increase our capacity for the transmission of television, telephone and data communications over long distances in areas now served by terrestrial networks.

THE CANADIAN DOMESTIC SATELLITE COMMUNICATIONS SYSTEM

On 31 July 1970, Telesat Canada was authorized to open negotiations with the Hughes Aircraft Company of California for construction of the spacecraft to implement Telesat's domestic satellite communications systems. A formal agreement was signed on 30 September. Initial requirements are for three spacecraft, with two to be placed in orbit and the third held in reserve on the ground. In addition, Hughes will also provide launch support services and the supply and installation of certain telemetry, tracking and command ground control equipment. Included in the Hughes' proposal is the use of two Canadian companies - Northern Electric Company and Spar Aerospace Products Ltd. - as major subcontractors. Northern Electric will provide the complete electronics systems for the flight spacecraft, and Spar will provide the spacecraft structure. This inclusion will provide a Canadian content in the spacecraft program of approximately 20 per cent, and Telesat will seek to maximize, to the greatest extent possible, Canadian content in both the space and ground segments of its program. In addition, Hughes has undertaken to include participation by Northern Electric and Spar Aerospace Products as subcontractors on up to 15 other similar spacecraft which it expects to sell in world markets.

Delivery schedule for the initial spacecraft will provide for first launch in approximately two years' time, and it is expected that the system will go into operation by the end of 1972. The spacecraft chosen by Telesat will provide a total of 12 radio frequency channels, 10 of which would be available for commercial use, with 2 on stand-by. Each radio frequency channel can carry one color television signal, or the equivalent in message traffic. This can be as high as 960 one-way voice channels, depending upon its use. All 12 radio frequency channels in the satellite are the same, providing complete flexibility so that any mix of television, voice or data transmission can be carried on the system. The spacecraft will be launched from Cape Kennedy by the U. S. National Aeronautics and Space Administration (NASA).

The total cost of the entire initial Telesat Canada system is estimated at approximately $90 million. It includes a network of earth stations to handle transmissions to and from the orbiting satellite. Present plans call for two heavy-route

stations capable of passing all forms of transmission to and from the satellite. The master station, which will also contain the telemetry, tracking and command installation to control the spacecraft, is planned for Allan Park, about 113 kilometers (70 miles) northwest of Toronto, and the other heavy-route station for Lake Cowichan, 64 kilometers (40 miles) north of Victoria, B. C.

There will be five regional, network-quality television earth stations, located near Edmonton, Regina, Winnipeg, Halifax and St. John's, Newfoundland. These will feed live, network television into conventional terrestrial broadcast systems. Their design will permit upgrading of their capability to include voice and data transmission as required in the future. Some 25 television, receive-only (TVRO) stations are planned for isolated communities in the northern parts of Canada. The design of the TVRO stations is also compatible with future upgrading as required. Initial plans also call for two northern telecommunications earth stations. In addition to being capable of receiving network television, these stations will also provide voice circuits for telephone service. The first northern telecommunications stations will serve the communities of Frobisher Bay and Resolute Bay in the Canadian Arctic.

The spacecraft design and location of the earth stations reflect the initial requirements of Telesat's customers, the CBC, Trans-Canada Telephone System, Bell Canada Ltd., and CN-CP Telecommunications, and provide for expansion to meet additional customer needs.

INTERNATIONAL SATELLITE COMMUNICATIONS

The Canadian Overseas Telecommunication Corporation is planning construction of a new fully commercial satellite communication earth station to be ready for operation via the INTELSAT IV satellite over the Pacific Ocean in mid-1972. The new station will be located near Lake Cowichan on Vancouver Island.

The "Lake Cowichan" Earth Station will be equipped initially for simultaneous reception of 8 frequency-modulated carriers anywhere in the band 3.7 to 4.2 GHz and simultaneous transmission of 3 frequency-modulated carriers in the band 5.925 to 6.425 GHz, including facilities for the transmission and reception of a television video channel.

The first in the series of new INTELSAT IV satellites is scheduled to be ready for operation over the Atlantic Ocean in 1971. To take advantage of the increased communication capability afforded by this new satellite, additional facilities are being installed in the communication satellite earth station at Mill Village, Nova Scotia, which is also owned and operated by the Canadian Overseas Telecommunication Corporation. With these additional facilities, the "Mill Village" Earth Station will have the capability for simultaneous reception of 14 rf carriers and transmission of 4 multi-destination rf carriers, all with frequency modulation, plus facilities for transmission and reception of 12 pairs of PCM/PSK* "demand assigned" single channel rf carriers.

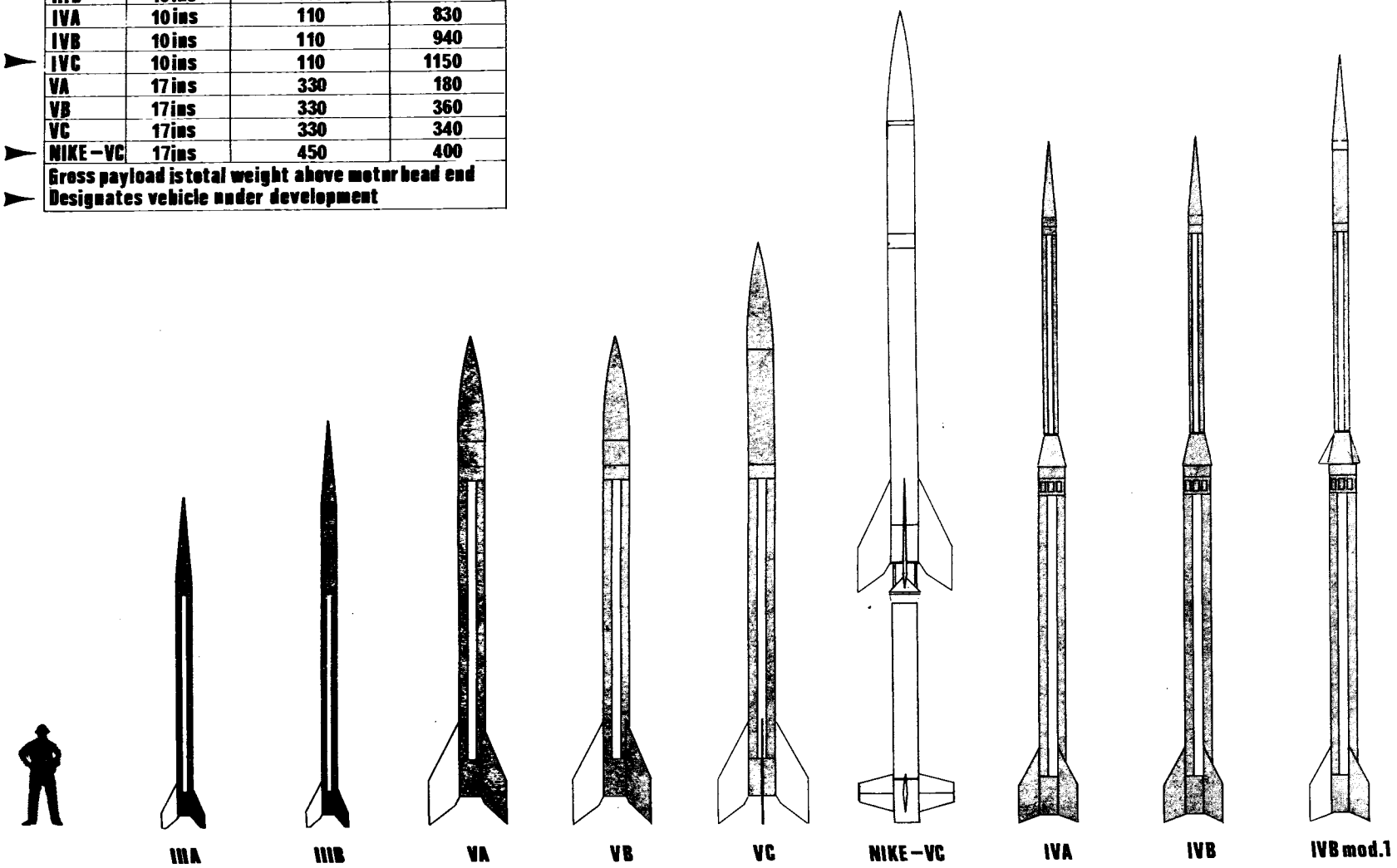
*Pulse code modulated/Phase shift keying.

BLACK BRANT ROCKET SYSTEMS

VEHICLE	PAYLOAD DIAMETER	NOMINAL GROSS PAYLOAD (lbs)	ALTITUDE KILOMETERS
IIIA	10 ins	110	165
IIIB	10 ins	110	235
IVA	10 ins	110	830
IVB	10 ins	110	940
➤ IVC	10 ins	110	1150
VA	17 ins	330	180
VB	17 ins	330	360
VC	17 ins	330	340
➤ NIKE–VC	17 ins	450	400

Gross payload is total weight above motor head end

➤ Designates vehicle under development



Black Brant rocket systems

diagram

ACTIVITIES IN INDUSTRY

BRISTOL AEROSPACE (1968) LIMITED, WINNIPEG, MANITOBA

The Black Brant family of high altitude research rockets has been used widely by the Canadian Space Program. There are now seven different models of the Black Brants manufactured by Bristol Aerospace (1968) Limited for use by the scientific community and two other vehicles are in development.

In addition to vehicle production, a continuing program of product research and improvement has resulted in the development of a complete line of rocket telemetry equipment, as well as payload integration and checkout facilities. Accessory equipment, such as mechanical despin systems, recovery systems, payload separation systems and split nose fairings, are available.

New Vehicle Developments

1) Now in the final stages of development is a new version of the Black Brant VB, designated the Black Brant VC. This vehicle incorporates the well-proven Black Brant VB solid propellant motor with a four-fin tail assembly. (This configuration was designed in order to allow the vehicle to be launched from the Aerobee towers at White Sands Missile Range and Wallops Island. With the addition of standard launch lugs, the vehicle can be launched from a rail type launcher.) The first flight of the Black Brant VC is scheduled from White Sands Missile Range in early 1971.

2) In the design concept stage is a new member of the Black Brant IV series, designated the Black Brant IVC. This vehicle will use the fully developed Black Brant IIIB motor as second stage, and the first stage will be a newly developed high impulse motor. In order to accommodate very long payloads, fins will be added to the second stage conical stabilizer of the vehicle.

3) In the engineering stage of development is a Black Brant VC, boosted by a NIKE motor. This vehicle will also be capable of being launched from the Aerobee towers. The estimated performance of this vehicle is 400 kilograms carrying a gross payload weight of 204 kilograms (450 lbs.).

The use of highly sophisticated and specialized payloads, such as those for solar and stellar research, is increasing. These payloads demand that attitude control systems be flown. Now available for use on the Black Brants are several proven attitude control systems which provide two or three axis stabilization, as well as stellar and solar pointing capabilities.

The Black Brants are gaining international popularity and have been used by several research agencies in North America and Europe. Their simplicity and ease of launch make them ideal for use from ranges with a minimum of facilities or from remote sites.

Twenty-three Black Brant rocket launches were carried out in 1970. Included in these were four Black Brant IIIA rockets from a temporary base near East Quoddy, Nova Scotia, during the 1970 eclipse. Another very successful campaign was the launch of five Black Brant VA and two Black Brant IVA rockets from Andoya, Norway, for the Federal Republic of Germany.

A total of 189 Black Brants have been launched to date, comprised of the following:

Black Brant I	17
Black Brant II	51
Black Brant IIIA	43
Black Brant IIIB	6
Black Brant IVA	26
Black Brant IVB	1
Black Brant VA	21
Black Brant VB	24

COMPUTING DEVICES OF CANADA LTD., OTTAWA, ONTARIO

Two research programs are currently being undertaken on behalf of the U. S. National Aeronautics and Space Administration. The first program has served to verify earlier theoretical predictions, made by Computing Devices engineers, that the flash of light produced during meteoroid impact on a target surface can be spectroscopically analyzed to provide information about the meteoroid's composition, size and velocity. Actual meteorite fragments have been launched against prepared targets in the company's hypervelocity ballistic range facility. The "flash" is diagnosed using simulated spacecraft instrumentation, which is being added to during the present phase of the program.

The second program consists of a feasibility evaluation of alternative means of achieving artificial meteor trails in the earth's atmosphere. In this concept a simulated meteoroid payload is accelerated to high velocity outside the atmosphere prior to re-entry. Current feasibility studies are being undertaken in conjunction with Bristol Aerospace Limited, Winnipeg.

NORTHERN ELECTRIC COMPANY LIMITED

ANIK Satellite

On 31 July 1970, Communications Minister The Honorable Eric Kierans confirmed the choice of Northern Electric as principal subcontractor in the contract awarded to Hughes Aircraft of California for the first three Canadian communications satellites. Northern Electric will supply the entire electronics package under a subcontract valued at $5.25 million. Included in the package are production, integration and testing of the communications sub-systems, telemetry and command, antenna despin electronics, power electronics, batteries and harness. Northern Electric will design the ground control electronics and a simulator for the training of personnel prior to the satellite launch in 1972.

This effort, coupled with the space frame subcontract to Spar Aerospace, Toronto, realizes a Canadian content of 20 percent of the $28 million project, of which 18 percent is the responsibility of Northern Electric, representing 100 percent of the electronics in the spacecraft and 50 percent of the total hardware. Under terms of the agreement, ten Northern Electric design and development engineers are assigned to Hughes Aircraft in Los Angeles in the first half of 1971.

In addition to the work on Canada's domestic satellite, Northern Electric has guarantees from Hughes Aircraft for additional electronics subcontracts on up to 15 similar spacecraft which the California firm expects to sell in world markets in the next five to seven years.

Intelsat IV

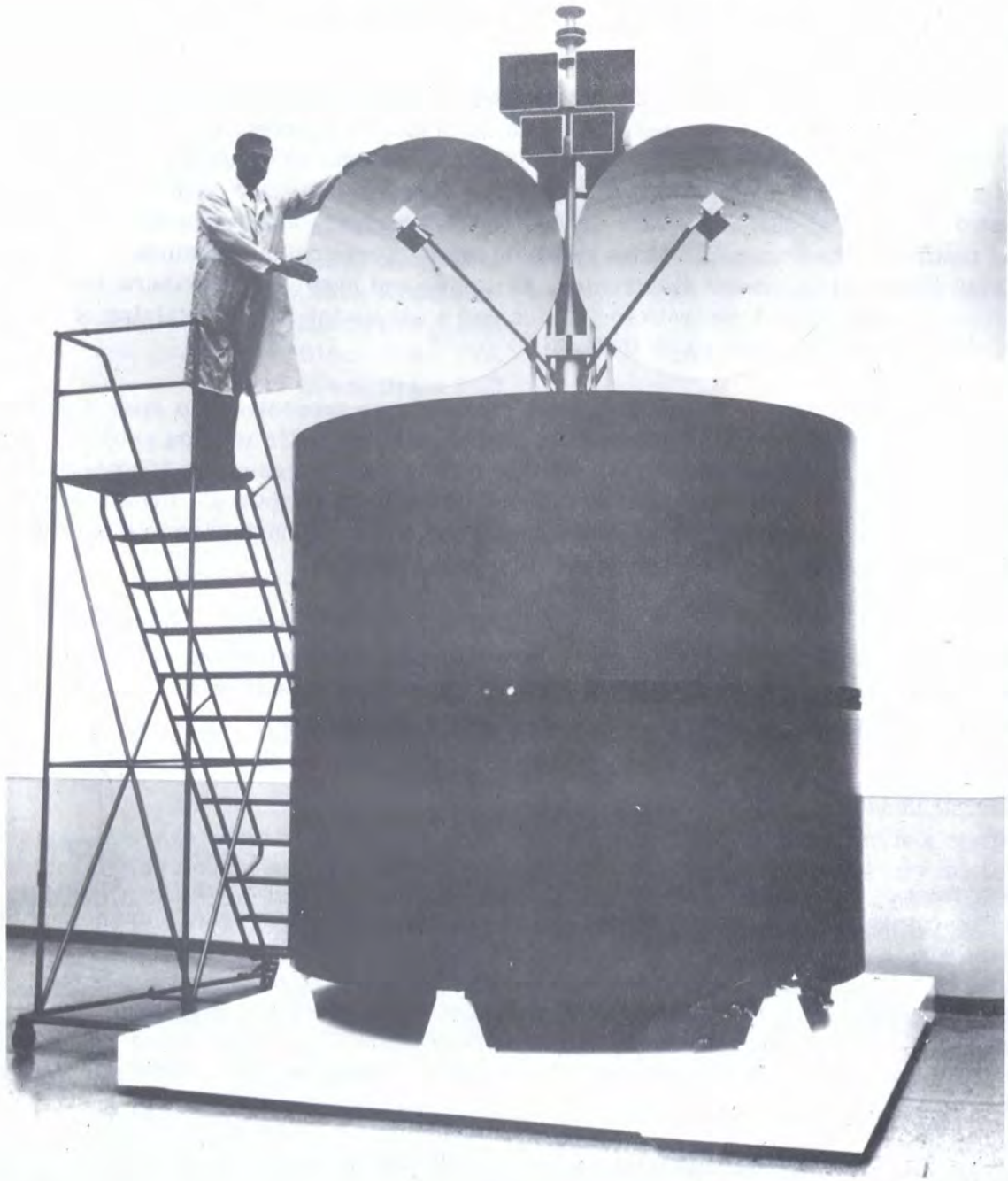
The Belleville works of Northern Electric are presently involved in the manufacture of transponders for the Intelsat IV series of satellites, as Canada's representative in the project, under contract from Hughes Aircraft. Launching of these spacecraft is expected in 1971 for international communications use. The capacity of these satellites is 6,000 two-way telephone circuits, five times that of the preceding Intelsat III series. Life spans of these satellites have also been increasing. The life expectancy anticipated for Intelsat IV is seven years vs. five years for its predecessor, a factor which will contribute to lower costs per circuit year.

The Northern Electric work contributing to this program is carried out under near-surgical conditions in special clean room facilities at Belleville. Assembly and test, and integration on the electronics platform require custom engineering methods seldom found outside of a research and development model shop.

New Aerospace Production Facility

Construction started in November 1970 on a $12 million Northern Electric aerospace plant in Lucerne, Quebec. The first 150,000 square feet of floor space,

INTELSAT IV COMMUNICATIONS SATELLITE



Northern Electric Belleville works are engaged in the assembly and test of transponder sub-assemblies for the giant Intelsat IV communications satellite. The main earth coverage is provided by the four horn antennas at the top, and the two large parabolic dish antennas serve heavy communications traffic from high density areas such as Western Europe and Eastern North America.

fully operational by March 1971, will be enlarged eventually to 600,000 square feet, at which time it will represent an investment of $35 million. This project is dedicated to production of satellite and earth station sub-systems, as well as microwave and cable transmission systems. Among its first products will be electronic packages for the ANIK communications satellite. The 180-acre site, located across the Ottawa River opposite the western outskirts of the capital city, is in close proximity to the corresponding research and development laboratories in Kanata.

New Research Corporation

The highlight of 1970, in terms of future implications, was the announcement in November that Northern Electric Laboratories, Canada's largest industrial research and development organization, would become a separate corporation on 1 January 1971. Named Bell-Northern Research, the new corporation is directed at a greater concentration of expertise in the field of domestic and international telecommunications.

The new venture incorporates the nucleus of some 1400 scientific and technical staff of the Northern Electric Laboratories, the former Research and Development Division of Canada's primary manufacturer of telecommunications equipment. The outstanding thirteen-year record of scientific achievements will be continued with further programs in metallurgy, solid state physics, chemistry, acoustics electronics, microwave technology, magnetic materials, computer utilization, communications ecology, human engineering and systems design.

BELL-NORTHERN RESEARCH

Headquartered at its main laboratories in Ottawa and integrating additional research and development centres in six other Canadian locations, Canada's newest research corporation starts with a 1971 budget of $36 million, a figure which ranks the enterprise as the largest industrial research organization in Canada and among the top one percent of research organizations in North America.

Achievement of corporate status by the former Northern Electric Laboratories furthers a continuing development on the part of the telecommunications industry in general, and of Bell Canada and Northern Electric in particular, aimed at concentrating creative technology into indigenous Canadian design to meet Canadian needs. Equity in the new corporation is retained by the parent companies in the proportion of 51 percent Bell and 49 percent Northern.

Regional laboratories are located at Montreal and Lachine, in Quebec, and at London, Bramalea, Belleville and Kanata, in Ontario. The main responsibility for work directly related to the aerospace field is centered in the Kanata Laboratory.

Parametric Amplifier

To enhance the reliability and performance of communications satellite ground stations, a parametric amplifier which operates at room temperature has been developed. Featuring a 500 MHz bandwidth in the 3.7 to 4.2 GHz range, the fully solid state amplifier is believed to be a world leader. Low noise performance has been further improved to 100° K with a gain of 30 dB through a three-stage cascaded paramp. It achieves this performance without the use of multiple-tuned broadbanding circuits which, together with its simple straightforward design, enhances the system availability and complies well with the unattended operation philosophy of modern earth stations.

Wideband FM Demodulator

Another development for multi-channel or television receive-only earth stations, the wideband FM demodulator will go into service in North America in 1971 and has aroused widespread interest for communications satellite systems. The demodulator avoids the inherent bandwidth limitations of tuned networks by using a pulse integration technique which converts the frequency modulated carrier into pulses which it subsequently integrates to produce a baseband signal. The high linearity thus obtained is equivalent to very low noise contribution. State of the art thick-film techniques are now being applied to the demodulator to further improve reliability and reduce the size of the package. The demodulator has also found application in the new 100 percent solid state RA-3 terrestrial microwave radio family of systems.

Common Waveguide Multiplexer

This recently announced multiplexer uses a new technique to simplify construction and tuning while also reducing the overall weight and size of complex micro-

wave components used in the transponder portion of communications satellites. The heart of the new 3.7 to 4.2 GHz multiplexer design is a complex filter which is a combination bandpass and bandstop design. The complex filter portion of the multiplexer is extremely versatile since the component blocks can be tuned independently and physically separated without affecting their electrical performance. This latter feature provides mechanical flexibility in the design and layout of the communications platform of the spacecraft.

Although developed primarily for satellite transponder use, the new technique can be used in all systems where bandpass filters are required and will find application in heavy route satellite earth stations where one common antenna is used for more than one transmitting channel.

Duplexer Polarizer

A recently developed duplexer polarizer for earth station antennas has been supplied for pilot program use for the proposed U.S. domestic satellite system which could come into service in 1973 and for possible use with the Canadian domestic satellite system. The polarizer forms part of the earth station antenna and performs the function of combining and separating transmitters and receivers.

Systems Engineering

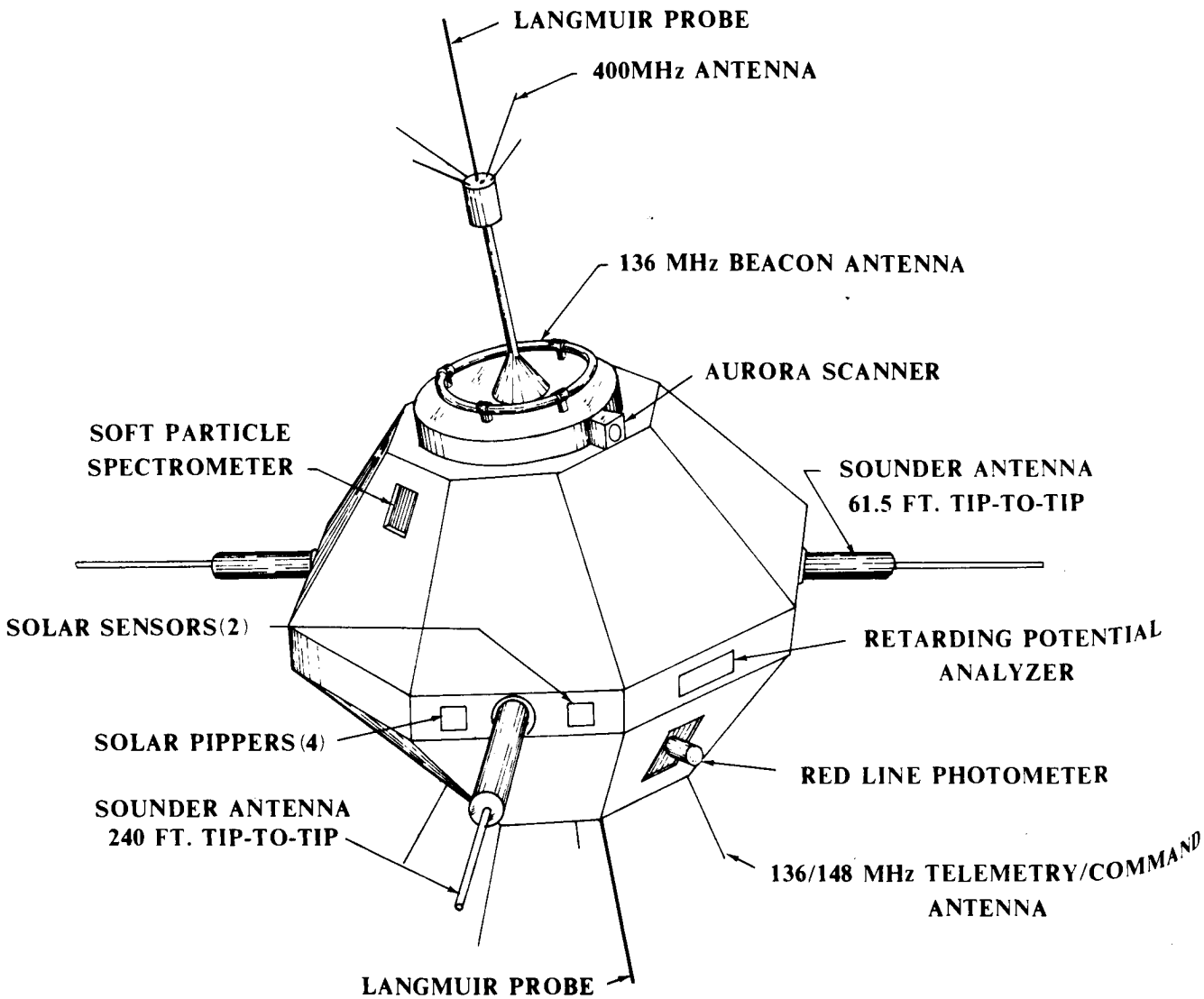
Continuing systems engineering studies related to aerospace communications are exploring such questions as the integration of satellite facilities into the Canadian telecommunications network, the achievable performance of international systems, and satellite systems for developing countries. In addition, studies are now in progress on communications by satellite to the far north and digital communications by satellite.

ANCOM SYSTEMS LIMITED

A new company, Ancom Systems Limited, was formed in October 1970 for the marketing, design and installation of satellite communication ground stations. The new organization has its head office in Ottawa and expects to eventually employ up to 100 people. It is equally owned by Northern Electric and Automatic Electric (Canada) Limited.

Automatic Electric and its subsidiary, Lenkurt Electric Company of Canada Limited, are prominent Canadian telecommunications equipment manufacturers, and through their international affiliation have many years of experience in telecommunications and ground station activities throughout the world.

This 50/50 joint venture combines the broad experience of both organizations in establishing a Canadian company capable of providing strong Canadian competition in the domestic and export markets for satellite communication earth stations.


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

SPACE RESEARCH AT RCA LIMITED, MONTREAL, QUEBEC

General

RCA has experience in space electronics extending from 1959 with over 49 programs fulfilled by the company since that time to a value of $62 million for 18 agencies in 12 countries.

The work has primarily been in the fields of earth stations and satellites. Additionally, RCA Research Laboratories in Montreal have discharged a large number of programs for the Canadian and U. S. governments and is the research base that enables the company's work in earth stations and satellites to meet changing world requirements.

Satellites

RCA has maintained a Canadian industry leadership in the design and fabrication of unmanned spacecraft since 1961, when RCA Space Systems was selected to develop and supply the communications transponder system for the RELAY satellite, the first NASA satellite to provide transatlantic television service. The experience and organization developed on advance semiconductor device research were successfully used to furnish telemetry transmitters for Alouette I and for two NASA scientific satellites, Explorer XX and Pegasus.

In 1963, RCA was selected as the contractor to the Defence Research Board (now Communications Research Centre) responsible for Canadian industry participation in the Alouette II program and, subsequently, as prime contractor, with full design, manufacture and test responsibility for the ISIS-I and ISIS-B satellites. ISIS-I has been in orbit since January 1969, and ISIS-B was shipped from RCA Space Systems in October 1970 for final environmental tests at Goddard Space Flight Center.

In addition to its experience and achievements on equipment and services for scientific satellites, RCA Limited has performed basic and applied research studies on a wide variety of topics related to satellite design and application. Among these are included the Study for the Design of a Canadian Domestic Communications Satellite, completed in 1969 for the Canadian Department of Industry, and the work performed on the Project Definition Phase of the Telesat Canada Communications Satellite.

RCA Aerospace Facility

RCA's new aerospace facilities comprise a special office, laboratory, spacecraft fabrication and environmental testing complex under one roof and is built to meet the exacting requirements of satellite production. It is located at the western end of RCA's newly erected Canadian Headquarters complex at Ste. Anne de Bellevue, some 20 miles west of Montreal. Total area of the facility is 66,000 square feet.

The building consists of a basement housing environmental laboratory equipment to simulate vibration, temperature and vacuum conditions of spacecraft during launch and in orbit. The ground floor contains sophisticated machining and special process areas, including facilities for fabrication and assembly of precision and high reliability parts and printed circuits. The upper floor houses engineering offices, library, conference rooms, systems and development laboratories. The rear portion of the building comprises a 250,000 cubic foot integration laboratory for final assembly and test of spacecraft. The structure is screened against electromagnetic interference at radio frequencies.

Requirements for cleanliness are a special consideration, and all laboratories have been constructed to meet Federal Standard 205, Class 100,000, clean room conditions. Provision has been made for laminar flow work stations where higher levels of cleanliness are required. Accurate temperature and humidity control is provided in the clean area. In addition, special handling and loading facilities exist to ensure safety in handling spacecraft equipment.

Of interest is the proximity of the enginnering offices, program direction and control offices, engineering laboratory and integration and test facilities. This environment provides creative and controlled working conditions in a spacecraft facility, which is the only one of its kind in Canada and one of the most sophisticated and up to date in North America.

Earth Stations

RCA experience in satellite earth stations began in 1959 with 6 successive contracts for Jet Propulsion Laboratory for investigation, study, development and supply of antenna feed systems for NASA's Deep Space Instrumental Facility in the Mojave desert. This included work on the 210-foot diameter tracking facility. In succeeding years, over 20 other satellite earth station assignments have been performed.

Early earth station work included supply of equipment to NASA in 1963 for a network of stations involved in the RELAY and TELSTAR pioneer communication satellite systems. This was followed by design and supply of a 1200 channel AM/FM solid state receiving system for NASA's ATS experiment, in which the equipment was used at tracking stations at Rosman, N. C., Mojave, and Toowoomba, Australia.

Work on complete earth stations began in 1963 with the appointment of RCA as prime contractor for Canada's first satellite terminal for commercial transatlantic service. This was one of the pioneer large earth stations, following ones established at Goonhilly, U.K., Andover, Plemeur Bado, France and Raisting in Germany. The station was erected at Mill Village, N. S., and employed an 85-foot diameter antenna enclosed in an inflated radome. This station pioneered the use of cooled, wideband parametric amplifiers for earth stations.

RCA furnished the second station at Mill Village for Canadian Overseas Telecommunications Corporation. This was completed in February 1969. It uses a

97-foot diameter, exposed antenna employing electrically-heated surface panels to overcome effects of ice and snow. This station has facilities for simultaneous reception of 9 multi-channel RF carriers and transmission of 2 RF carriers.

In 1970, RCA Limited was completing India's first commercial satellite terminal facility at Arvi. The work included the supply of a rearward microwave link to the international switching center at Bombay. Early in 1970, RCA Limited commenced work on two large earth stations for the Government of Pakistan to provide high quality, high capacity communications between the two wings of the country, as well as for external service. One station is being built near Karachi in West Pakistan, the other near Chittagong in East Pakistan. These stations employ a 30-meter diameter antenna with a wheel-and-track azimuth drive system, instead of the king-post configuration.

RCA Cassegrain feed systems using a single horn and the multimode principle, and RCA solid-state ground communication equipment, using double conversion for reduction of spurious effects, are two earth station subsystems that have had worldwide acceptance by other earth station contractors. One or both of these RCA subsystems are employed in stations in Argentina, Brazil, Morocco, Panama, Phillipines, Thailand, and Andover.

An interesting late 1970 contract to RCA Space Systems involved the supply of the ground communications equipment to Hughes Aircraft for three 30-foot diameter transportable earth stations for NASA's ATS-(F) program.

Research

Research related to space exploration and electronics has been conducted by the RCA Limited research labs for over 10 years. The knowledge and experience gained has been used in consultation and advisory services to several projects described above, particularly those related to satellites.

In the technological area, the Research Laboratories contributed the following: the telemetry transmitters for Alouette I, the design of PCM encoders for ISIS-I, for ISIS-B the design and engineering models for the oxygen red-line photometer (Dr. G. Shepherd) and the auroral scanning photometer (Dr. C. D. Anger) and the design and testing of a sealed-off CO_2 laser tube for space communications and laser radar.

In scientific areas, activities have covered a very wide spectrum. The Research Laboratories have obtained contracts from Canadian and United States government agencies for work on the following problems: the theoretical interpretation of the resonance relaxation spikes observed on Alouette ionograms, a theoretical and experimental investigation of the $\vec{V} \times \vec{B}$ sheaths surrounding the long Alouette antennas, a laboratory simulation of the magnetosphere and investigation of the magnetopause boundary, a study of the charging mechanisms and equilibrium potential of the proposed NASA outer planets explorer satellite, experimental and theoretical studies of the impedance of a dipole antenna in a plasma, a large program to investigate the

radar return from a turbulent plasma with direct application to bodies re-entering the earth's atmosphere, laser propagation in a turbulent media and antenna studies, along with an ionospheric model for a VLF, ELF satellite. At present, studies are underway on remote sensing from a satellite with a radiometer at 180 GHz, further antenna in plasma studies, a satellite borne CO_2 laser radar investigation, and consultation work, such as for the definition phase of the communications technology satellite.

30-meter Diameter Wheel-and-Track Antenna Used for Two Satellite Communications Earth Stations Being Supplied to East and West Pakistan by RCA Limited, Montreal

SPAR AEROSPACE PRODUCTS

During 1970 there has been a marked upswing in the amount of space business being conducted by the Company. This has occurred in three particular areas - design of complete satellites, design and manufacture of equipment for the manned space program and in a variety of STEM equipment for international space programs.

Spar Aerospace Products is a major subcontractor to the Hughes Aircraft Company of California for the design and manufacture of Telesat I (Anik). Seventeen Spar engineers are presently working in the Hughes design office on the thermal, mechanical and structural design, thermal design, propulsion system and power system. Apart from design activities, Spar is also acquiring skills in the specialized manufacturing techniques used by Hughes. This work will culminate in the manufacture at Spar of the structure for the Telesat spacecraft.

On the proposed Canadian Communications Technology Satellite project, a team of 15 Spar engineers and designers have spent most of the year at the Communications Research Centre engaged in the basic layout of the spacecraft, the structural, thermal and mechanical design and the detail design of the three-axis attitude control system and the power system, including the long deployable solar cell panels.

Throughout the year, Spar has collaborated closely with the Lockheed Missiles and Space Company as a key member of the international team which Lockheed has assembled to finalize a design for an advanced Communications Satellite. Spar is responsible for the complete extendible solar cell panel design, including the sophisticated rotary power transfer joint, sun tracking system and caging and release mechanism.

In connection with the NASA manned space program, Spar's activities have expanded considerably since last year. For the lunar missions from Apollo 15 onwards, the Apollo service module will be equipped with two Spar 2-inch steel booms used to extend separately a mass spectrometer and a gamma ray spectrometer to a 25-foot radius from the spacecraft.

An even more important manned space program in which Spar has participated is the Skylab Orbital Workshop, which will be placed in earth orbit in 1972. A key activity in the success of this mission is the transfer of film packages from the airlock to the sun pointing telescope, which forms the prime experiment of the mission. Spar has provided 2-inch boom units to NASA Marshall Space Flight Centre for evaluation by astronauts in the full-scale neutral buoyancy tank and thus established feasibility of conducting this task with a BI-STEM Unit.

The development work on large size booms has also resulted in an order from the Martin Marietta Company for an evaluation unit of the Viking soil sampler boom. Despite the two-year delay in launch which was announced in January, this program is continuing at a reduced pace, and Spar has worked closely with NASA

Langley Research Centre and Martin in the development of a specialized unit for this mission.

Spar has also been involved in joint study work with NASA and American companies to assess feasibility of the STEM approach in cargo handling for the fuel tanks and other cargos which must be transferred from the space shuttle to the space station. The Company has benefited in programs such as these from the support given by the DIR contract with Defence Research Board, which has enabled long-term research to be conducted within the Company.

In the field of more conventional STEM products, 1970 has seen a trend toward more international programs than in previous years, as the European space program gets more firmly under way. Antenna units were sold to England and Germany for their national space programs, and extensive proposal work is under way for future ESRO* satellites. Manufacturing work is also proceeding on the sounder antennas for the Japanese Ionospheric Sounding Satellite program.

The United States still remains the main source of export business, and during the year boom units have been sold for a micrometeorite detection system and to Comsat and Hughes for solar panel actuators. Flight antennas for the IMP** satellite were ready for launch late in the year, and additional gravity gradient rods were supplied for classified military programs.

Further areas of spacecraft work include coulometer charge control equipment, recently flown in the Frog Otolith experiment, and photometer equipment for the ISIS-B spacecraft.

In the new field of earth-resources surveying from spacecraft, Spar has a contract for breadboard hardware for a new camera concept operating in the visual and near infrared wavelengths, which is capable of having its spatial and spectral resolution altered on ground command.

---

*ESRO - European Space Research Organization
**IMP - Interplanetary Monitoring Platform

DETAILS OF ROCKET LAUNCHINGS AND EXPERIMENTS - 1970

VEHICLE	NOSE CONE Kgs.	FINS	PLACE TIME DATE	Effective Launch Elevation	Apogee Kms.	Apogee Time in sec	Max & Final Roll Rate rps	ROCKET PERFORMANCE	LAUNCH CONDITIONS	EXPERIMENTS	EXPERIMENTERS	EXPERIMENT RESULTS
ADF-VB-29	194.5	V	CRR 2341 13.1.70	61.0°	127.7	186	-	Normal	Auroral activity, clear night, no moon, low angle trajectory	Plasma probes (4) Auroral photometer Pitch angle detector Ionospheric Inhomogeniety Electric field spin probes (2) Micrometeroid detector	A.G. McNamara A.G. McNamara E.E. Budzinski P.A. Forsyth A. Kavadas R. Wlochowicz	Good data from experiments except for probes which were to be ejected and the forward plasma probes caused by non-deployment of clamshells. SRFB 041
AAD-IV-23	51.2	IV	CRR 0119 24.2.70	83°	795.9	465.4	2.5/ 1.1	Normal	Intensity II aurora	Energetic particle detectors (2) Energetic particle detector VLF noise observations	B.A. Whalen E.E. Budzinski R.E. Barrington	Good data obtained from all experiments SRFB 042
AAF-IIIA-42	54	III	East Quoddy, N.S. 1340:38.4 7.3.70	84°	154.4	186.0	7.9/ 1.383	Normal	Solar Eclipse	Plasma probe Radio frequency partial reflection X-ray lyman alpha	A.G. McNamara J.S. Belrose J.E. Hall	Good data were obtained from all the experiments carried SRFB 043
AAF-IIIA-43	54	III	East Quoddy, N.S. 1455:40.8 7.3.70	84°	148.8	182.5	7.5/ 0.652	Normal	Solar Eclipse	Plasma probe Radio frequency partial reflection X-ray lyman alpha	A.G. McNamara J.S. Belrose J.E. Hall	Good data were obtained from all the experiments carried SRFB 043
AAF-IIIA-44	54	III	East Quoddy, N.S. 1457:41 7.3.70	84°	151.4	184.2	8.2/ 0.665	Normal	Solar Eclipse	Plasma probe Radio frequency partial reflection X-ray lyman alpha	A.G.McNamara J.S. Belrose J.E. Hall	Good data were obtained from all the experiments carried SRFB 043

TABLE 1

DETAILS OF ROCKET LAUNCHINGS AND EXPERIMENTS - 1970 (Contd)

VEHICLE	NOSE CONE Kgs	FINS	PLACE TIME DATE	Effective Launch Elevation	Apogee Kms	Apogee Time in sec	Max & Final Roll Rate rps	ROCKET PERFORMANCE	LAUNCH CONDITIONS	EXPERIMENTS	EXPERIMENTERS	EXPERIMENT RESULTS
AAF-IIIA-45	54	III	East Quoddy N.S. 1503:40.5 7.3.70	84°	153.6	185.2	8.9/ 0.635	Normal	Solar Eclipse	Plasma probe Radio frequency partial reflection X-ray lyman alpha	A. G. McNamara J. S. Belrose J. E. Hall	Good data were obtained from all the experiments carried SRFB 043
AEF-II-121	180	II	CRR 0211 22.4.70	83.9°	14.1	125	-	Normal until T+18 sec	Night time, moon 1/10 or greater & visual aurora	Rotational temp. & potential density Molecular oxygen, nitrogen & atomic oxygen Atmos. composition & temp. Micrometeoroid impacts Ionospheric Inhomogenieties Plasma probe	J. H. deLeeuw A. Haasz P. Chin R. Tennyson P. A. Forsyth A. G. McNamara	Nil results due to payload failure at T+18 seconds SRFB 044
AMD-VB-25	225	V	CRR 1852 23.4.70	86°	288	275	-	Normal	Quiet conditions sun 5-10° above the horizon	Photometer (dayglow measurements) Temp & energy distribution of electrons Plasma probes (4) Photoelectric detector	G. G. Shepherd G. G. Cloutier A. G. McNamara P. B. Hays	Good data were obtained from some experiments SRFB 045
ADD-VB-31	225	V	CRR 2256 16.8.70		267	259	3.67/ 0.55	Normal	Night time critical launch window, some aurora	Electric field measurements Plasma probes Soft electron spectrometer Barium cloud	A. Kavadas H. Fahleson F. Mozer A. G. McNamara D. J. McEwen G. Haerendel	Good data were obtained from experiments SRFB 046

TABLE 1

DETAILS OF ROCKET LAUNCHINGS AND EXPERIMENTS - 1970 (Contd)

VEHICLE	NOSE CONE Kgs	FINS	PLACE TIME DATE	Effective Launch Elevation	Apogee Kms	Apogee Time in sec	Max & Final Roll Rate rps	ROCKET PERFOR-MANCE	LAUNCH CONDITIONS	EXPERIMENTS	EXPERIMENTERS	EXPERIMENT RESULTS
AMM-S 2-09	5.9	-	CRR 1527 13/11/70	82.6	97.9	150	-	Normal	Quiet less than 1 db	Oxygen Atom Probes	Schiff/Megill Sullivan	Limited due to telemetry failure at T+75 seconds SRFB 047
AKI-IVA-19	61.2	IV	CRR 1534 7/12/70	Details not available at time of going to print				Normal	Twilight Quiet	Height profile of OH and He 1 X-ray Spectrum Measurements	Harrison Wilson	Good data were obtained from experiments SRFB 050
AAD-VB-30	176.9	V	CRR 0402 14/12/70	Details not available at time of going to print				Normal	Geminid Meteor Shower	Micrometeoroid acoustic detectors Acoustic & impact detectors Impact detectors Photomultipler Flash Detectors Plasma Probes Electrostatic Ballistic Probe	Wlochowicz Alexander Lindblad Tennyson Zacharov Simek Berg McNamara Burbank	Good data were obtained from all experiments SRFB 051

TABLE II

ROCKETS AND EXPERIMENTS PLANNED FOR 1971

Vehicle No.	Pr. Scientist	Engineering	Launch Period	Conditions	Experimenters	Experiments	Remarks
AMF-II-115	Nicholls	BAL	Jan-Mar 71	Visual aurora	McEwen McNamara Nicholls	Vacuum ultraviolet measurements Ionization profiles Auroral photography and photometry	FIRM Recovery
AAD-II-124	Jones	SED/U of S	Jan-Mar 71	Dayglow	Jones/ Llewellyn McNamara Miller/ Ryder (UK) Wlochowicz	OH emission profile Ionization density Ozone height profile Micrometeoroid detection	FIRM Azimuth spin stabilization and recovery
AND-III-41	Gush	SED/U of S	Jan-Mar 71	Solar lunar darkness	Gush	Background cosmic radiation	FIRM
AKF-IVA-18	Anger	BAL	Jan-Mar 71	Major breakup	Anger McNamara Whalen	3914, 5577 and 6300 Å emission measurements Electron density and temperature Electron, neutral and charged proton and neutral singly and doubly charged particle measurements	FIRM
ADD-VB-24	McEwen	SED/U of S	Jan-Mar 71	Type A aurora	Anger Jones/ Llewellyn Judge (USA) McEwen McNamara Wlochowicz	Auroral X-ray and optical emissions Height distribution of auroral emissions Proton density Soft electron measurements Electron density Micrometeoroid detection	FIRM Despinning

TABLE II

Rockets and Experiments Planned for 1971 - Continued

Vehicle No.	Pr. Scientist	Engineering	Launch Period	Conditions	Experimenters	Experiments	Remarks
AMD-VB-26	Shepherd	SED/U of S	Jan-Mar 71	Quiet-twilight	Cloutier/Brooks Hayes (USA) McNamara Shepherd	Electron temp and distribution Energy distribution of photo electrons Two P17 plasma probes, planar trap and ejected probe Photometry	FIRM Azimuth spin stabilization and recovery
AKD-VB-27	Anger	SED/U of S	Jan-Mar 71	Dark-aurora	Anger Cloutier/Brooks Kavadas McNamara Whalen	5577/3914 Å scanning photometer Mk IV Electron temp and distribution Electric field measurement Electron density Electron and proton measurements	FIRM Low angle launch
AAF-VB-32	Whalen	BAL	Jan-Mar 71	Visual aurora	Kavadas/Koehler/Rostoker/Whalen/Visentin/DeLeeuw/Davis/Cloutier/Brooks/McNamara/Wlochowicz	Electric field measurements	FIRM
AMF-IIIA-52	Schiff	BAL		Quiet < 1db	Schiff/Megill/Young	Height profile of nitrogen atoms	FIRM
AKF-IVB-24	Harrison	BAL		Twilight-disturbed	Barrington Harrison Wlochowicz	Impedance of long dipole antenna in ionosphere Helium (1.083μ) emissions in sunlit aurora Micrometeoroid detection	FIRM

ABBREVIATIONS

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
CARDE	Canadian Armament Research and Development Establishment
CF	Canadian Forces
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
DCBRE	Defence Chemical & Biological Research Establishment
DOC	Department of Communications
DOT	Department of Transport
DRB	Defence Research Board
DREV	Defence Research Establishment Valcartier (ex CARDE)
DRIR	Direct Reading Infrared Readout
DRTE	Defence Research Telecommunications Establishment (now CRC)
EMR	Department of Energy, Mines and Resources
ERB	Radio and Electrical Engineering Division Report
ESSA	Environmental Science Services Administration
GMT	Greenwich Mean Time

Abbreviations (Continued)

GSC	Geological Survey of Canada
GSFC	Goddard Space Flight Center
IGY	International Geophysical Year
INTELSAT	International Communications Satellite Consortium
ISAS	Institute of Space and Atmospheric Studies
ISIS	International Satellites for Ionospheric Studies
ITU	International Telecommunications Union
Laser	Light amplification by simulated emission of radiation
Maser	Microwave amplification by simulated emission of radiation
Met	Meteorological
NAE	National Aeronautical Establishment
NASA	National Aeronautics and Space Administration
NIMBUS	Cloud formation (Latin)
NRC	National Research Council of Canada
NLC	Noctilucent cloud
N. W. T.	Northwest Territories
OGO	Orbiting Geophysical Observatory
OSO	Orbiting Solar Observatory
PCA	Polar Cap Absorption
PCM	Pulse Code Modulated
PSK	Phased Shift Keying
RADINT	Radial Doppler Interferometer
RCA	Radio Corporation of America
REED	Radio and Electrical Engineering Division
SED	Space Engineering Division
SRFB	Space Research Facilities Branch
SSCC	Spin-Scan Cloud Camera
STADAN	Space Tracking and Data Acquisition Network
STEM	Storeable Tubular Extendable Member

Abbreviations (Continued)

TELESAT	Telecommunications Satellite
TIROS	Television Infrared Observational Satellite
TOS	TIROS Operations System
URSI	International Union of Radio Science
USA	United States of America
WEFAX	Weather facsimile
WMO	World Meteorological Organization

SYMBOLS

α	alpha
Å	angstrom
AGC	automatic gain control
BeV	billion electronvolt
cm	centimeter
e/cc	electrons per cubic centimeter
eV	electronvolt
FM	frequency modulated/modulation
ft	foot/feet
H_β	hydrogen beta
i/cc	ions per cubic centimeter
Hz	hertz
GHz	gigahertz
kHz	kilohertz
MHz	megahertz
°K	degrees Kelvin
km	kilometer
KeV	kiloelectronvolt
lb	pound
MeV	megaelectronvolt
mm	millimeter
N_2^+	ionized nitrogen molecule
OH	Hydroxyl
$O_2(^1\Delta)$	term used in spectroscopy
$O_2\ ^1\Delta\ g$	term used in spectroscopy
$(OI)_{32}$	state of oxygen atom
PCM	pulse code modulated
PSK	phase shift keying
RF	radio frequency

Symbols (Continued)

SCO	subcarrier oscillator
μ	micro-micron
λ	wavelength
VLF	very low frequency
w	units of power
10^3	thousands
10^6	millions

ANNEX V

Statement of Federal Government Expenditures on Space Activities ($ Millions), 1970-71 and 1971 - 72 (estimated)

Department of Communications	1970-71	1971-72
Spacecraft Technology and Satellite Operations	6.335[1]	6.690[2]
Satellite Communications Systems	0.911[3]	1.210[3]
Scientific Research Utilizing Sounding Rockets and Satellites	0.742	0.640
TOTALS	7.988	8.540

[1] 0.080 recoverable from Telesat Canada included

[2] 0.035 " " " " "

[3] 0.225 " " DND/DRB not included

Department of Energy, Mines and Resources	1970-71	1971-72
Lunar Rock Sample Studies	0.014	0.015
Satellite Geomagnetic Studies	0.030	0.005
Resource Satellites	0.450	4.187
TOTALS	0.494	4.207

Department of Industry, Trade and Commerce	1970-71	1971-72
Satellite Communications Systems (Industrial Grants)	0.582	0.400
Rocket Development (Industrial Grants)	0.575	0.700
TOTALS	1.157	1.100

Ministry of Transport	1970-71	1971-72
Satellite Communications and Surveillance Systems	0.088	0.090
Space Related Meteorological Activities	0.060	0.070[1]
TOTALS	0.148	0.160

[1] Under Bill C.207 meteorological activities will be transferred to the Department of the Environment.

Department of National Defence/Defence Research Board	1970-71	1971-72
Rocket Technology	0.090	0.090
Satellite Communications	0.350[1]	0.350[1]
Space Related Research	0.319	0.354
TOTALS	0.759	0.794

[1] Includes 0.225 for work undertaken by the Communications Research Centre/DOC

National Research Council	1970-71	1971-72
Space Research Facilities Branch[1]	2.300	2.500
Scientific Divisions (Rocket and Satellite Experiments)	0.375	0.325
Awards to University Staff	0.600	0.400
TOTALS	3.275	3.225

[1] Support of sounding rocket program and operation of ranges.

	1970-71	1971-72
GRAND TOTALS	13.821[1]	18.026[2]

15.600

[1] Down 1.779 from 1969-70

[2] Up 4.205 from 1970-71

DISTRIBUTION

Interdepartmental Committee on Space

SECOND ANNUAL REPORT - DISTRIBUTION

Secretary, CC on Science, Culture and Information (Mr. F. Tanguay)

Hon. C.M. Drury, President of the Treasury Board

Dr. R.J. Uffen, Chief Science Advisor to the Cabinet

Chairman, ICS - Dr. D.W.R. McKinley	NRC

Members ICS -

Dr. J.H. Chapman	DOC
Mr. J. Gratwick	MOT
Dr. L.W. Morley	EMR
Dr. H. Sheffer	DND/DRB
Mr. P. Tremblay	EA
Dr. S. Wagner	ITandC

Alternates ICS -

Mr. F.L. Bentley	MOT
Mr. R.K. Brown	ITandC
Dr. I.B. McDiarmid	NRC
Mr. R.E. Reynolds	EA
Dr. E.F. Roots	EMR
Mr. B.A. Walker	DOC
Mr. G.D.Watson	DND/DRB

Observers -

Dr. J.D. Keys	TB
Dr. E.A. Watkinson	NHW
Dr. J.R. Whitehead	SciSec

Chairmen of Sub-Committees -

Dr. I.B. McDiarmid (also Alternate)	NRC
Mr. F.R. Thurston	NRC
Mr. B.A. Walker (also Alternate)	DOC
Mr. W.K. Wardroper	EA