SCIENCE SECRETARIAT

Special Study No 1

Upper Atmosphere and Space Programs in Canada

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UPPER ATMOSPHERE AND SPACE

PROGRAMS IN CANADA

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SCIENCE SECRETARIAT
PRIVY COUNCIL OFFICE
OTTAWA

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PREFACE

1. Terms of Reference

(a) To review existing Canadian-financed research and development related to space and the upper atmosphere. To assess the significance of the various projects in respect to their contributions to scientific knowledge, education and technological training, and to the Country's economic interests, both immediate and long-term. The study will take into account a report by the Department of Industry on the space industry, which is understood to be nearing completion.

(b) To study the aims and objectives of space research in Canada. To delineate the main themes which, by reason of geography, tradition, special talents, or national policy, have particular relevance for Canada and can serve as guidelines for future programs. To establish a basis for a Canadian policy on space research.

(c) The study will consider, among other things:

(i) The broad interrelationships which obtain, or in the future might obtain, among Canadian Government, University, and Industry Agencies in the conduct of the space program, in distribution of effort, in funding, in liaison, and in organization.

(ii) The relationship of the above to foreign space programs and policy, particularly those of the United States. The maintenance abroad of a good image for Canada in international space research.

Note:

The definition of upper atmosphere and space research assumed for this study will include research conducted by means of rockets, satellites, high altitude balloons and gun-launched probes in the upper atmosphere. For this purpose, the lower limit of the upper atmosphere is arbitrarily set at 50 kilometres. Ground-based research on the upper atmosphere or in support of high altitude or space probes will be included in the study.

1. Mandat

(a) Passer en revue la recherche et le développement actuel financés par le Canada et ayant trait à l'espace et à la haute atmosphère. Évaluer la portée des divers projets quant à leur contribution à la connaissance scientifique, à l'enseignement et à la formation technologique, ainsi qu'aux intérêts économiques du pays, et immédiats et à longue portée. Cette étude tiendra compte d'un rapport du ministère de l'Industrie sur l'industrie spatiale, qui est sur le point d'être terminé.

(b) Étudier les buts et objectifs de la recherche spatiale du Canada. Déterminer les principaux thèmes qui, à cause de la situation géographique, de la tradition, des talents spéciaux, ou de la ligne de conduite nationale, s'appliquent particulièrement au Canada et peuvent servir de principes directeurs quant aux programmes futurs. Établir une norme pour la ligne de conduite du Canada sur la recherche spatiale.

(c) Cette étude tiendra compte, entre autres choses,

(i) des vastes corrélations qui existent actuellement ou pourraient exister à l'avenir, entre le gouvernement canadien, les universités et les organismes de l'industrie dans la poursuite du programme spatial, dans la répartition des efforts, dans les subventions, dans la liaison et dans l'organisation.

(ii) de la relation entre ce qui précède et les méthodes et programmes spatiaux de l'étranger, tout particulièrement ceux des États-Unis; ainsi que du maintien de la belle réputation dont jouit le Canada dans la recherche spatiale sur le plan international.

Remarque:

La définition des recherches en haute atmosphère et dans l'espace adoptée pour la présente étude comprendra les recherches effectuées au moyen de fusées, satellites, ballons à haute altitude et sondes lancées par canons dans la haute atmosphère. A cette fin, la limite la plus basse de la haute atmosphère est fixée de façon arbitraire à 50 kilomètres. Les recherches au sol sur la haute atmosphère ou pour aider le travail des sondes à haute altitude ou dans l'espace feront partie de cette étude.

2. Study Procedure

The Study Group was appointed in May, 1966. Requests for information on present and future upper atmosphere and space programs, and invitations to present briefs, were sent to all government departments, industrial corporations, universities and technical associations thought to have any interests in the field.

Hearings were held in Halifax, Quebec, Montreal, Ottawa, Toronto, London, Winnipeg, Saskatoon, Calgary, Edmonton and Vancouver, during the period from 30 June to 31 October 1966. A total of 112 briefs and other communications were received, as listed in Appendix B.

A visit was made by the whole Study Group to NASA Headquarters in Washington, and members of the Group visited European and Japanese space facilities.

A special study of the potential of existing Canadian programs for the development of orbital launch vehicles was set up under the direction of the Dean of Engineering of Carleton University, to provide information for the members of the Study Group.

The information on projects, on the case for a Canadian space program, on the outlook for the future and the needs for organization and facilities were taken directly from the briefs, sometimes verbatim. Statistical information on program expenditures was compiled largely from briefs and questionnaires, supplemented where necessary by direct requests to the responsible agency. In fact, the bulk of the Report was not written by the Study Group, but by persons from one coast to the other.

The members of the Study Group recognize their indebtedness to all of those who put so much work and thought into their presentations, and are deeply appreciative. Nevertheless, the Study Group accepts full responsibility for the way in which the information was presented in this Report, and the specific recommendations given in the final chapter.

Ottawa
December 1966

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PART II CANADIAN INTERNATIONAL SPACE PROGRAMS. Texts of Agreements, Memoranda of Understanding and Other International Arrangements in Force 31 October 1966

PART III HARP-McGILL

ABBREVIATIONS

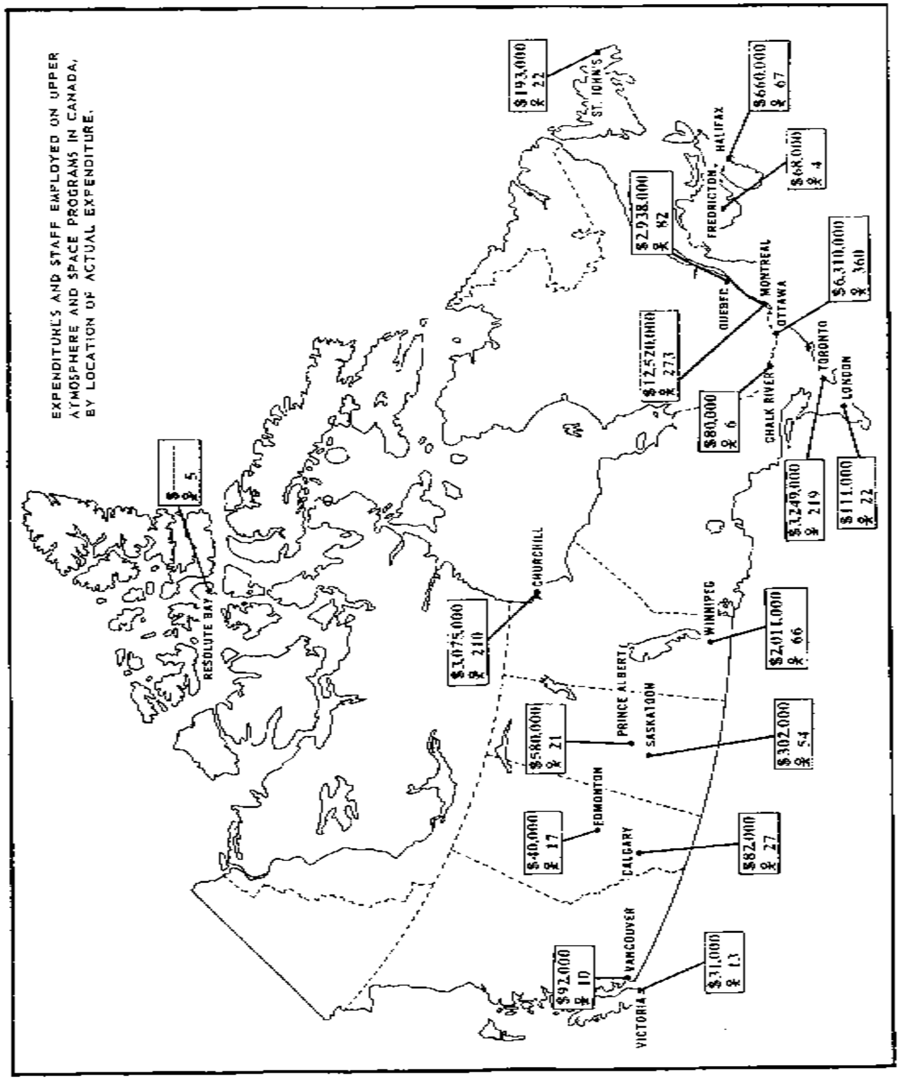
AECB	Atomic Energy Control Board
AECL	Atomic Energy of Canada Limited
AEL	Aviation Electric Limited
AFCRL	See USAF/AFCRL
APL	Applied Physics Laboratory (Johns Hopkins University)
APT	Automatic Picture Transmission
ARPA	Advanced Research Projects Agency (US)
ATS	Applications Technology Satellite (NASA)
BAIL	Bristol Aero Industries Limited
BAL	Bristol Aerospace Limited
BRL	Ballistic Research Laboratory (US Army)
CAF	Canadian Armed Forces
CANSAT	Canadian Satellite Corporation
CARDE	Canadian Armament Research and Development Establishment (DRB)
CASI	Canadian Aeronautics and Space Institute
CBA	Canadian Bristol Aerojet Limited
CBC	Canadian Broadcasting Corporation
CCIR	International Radio Consultative Committee (ITU)
CCITT	International Telegraph and Telephone Consultative Committee (ITU)
CDC	Computing Devices of Canada Limited
CDF	Canadian Defence Forces
CIL	Canadian Industries Limited
CNES	Centre National Des Etudes Spatiales (France)
COMSAT	Communications Satellite Corporation
COSPAR	Committee on Space Research
COTC	Canadian Overseas Telecommunications Corporation
CRR	Churchill Research Range
DDD	Direct Distance Dialing
DDP	Department of Defence Production
DIR	Directorate of Industrial Research (DRB)
DND	Department of National Defence
DOD	Department of Defence (US)
DOI	Department of Industry
DOT	Department of Transport
DOVAP	Doppler Velocity and Position

DRB	Defence Research Board
DRNL	Defence Research Northern Laboratories
DRTE	Defence Research Telecommunications Establishment (DRB)
EMIC	EMI Cossor Electronics Limited
ETR	Eastern Test Range (US)
ETV	Educational Television
EVA	Extra-vehicular Activity
FCC	Federal Communications Commission (US)
FM	Frequency Modulation
GNP	Gross National Product
HARP	High Altitude Research Program (McGill University)
HARP-McGill	Canada-US-funded portion of HARP at McGill University (see p. 1, Part III)
HARP-US	US-funded portion of HARP (see p. 1, Part III)
HF	High Frequency
ICSC	Interim Communications Satellite Committee
IGY	International Geophysical Year
IQSY	International Quiet Sun Year
ISAS	Institute of Space and Atmospheric Studies (University of Saskatchewan)
ISIS	International Satellites for Ionospheric Studies
ITU	International Telecommunications Union
JATO	Jet-assisted Take-off
JPL	Jet Propulsion Laboratory (US)
LAHIVE	Low Altitude High Velocity
NAE	National Aeronautical Establishment (NRC)
NASA	National Aeronautics and Space Administration (US)
NRC	National Research Council
NRE	Naval Research Establishment (DRB)
NRL	Naval Research Laboratory (US)
OCRD	Office of Chief of Research and Development (US Army)
OECD	Organization for Economic Co-operation and Development
ONR	See USN/ONR
PAIT	Program for Advancement of Industrial Technology (DOI)
PARL	Prince Albert Radar Laboratory (DRB)
PERT	Program Evaluation Review Technique
PTV	Propulsion Test Vehicle
RCAF	Royal Canadian Air Force
REED	Radio and Electrical Engineering Division (NRC)

RF	Radio Frequency
SATCOM	Satellite Communication
SED	Space Engineering Division (University of Saskatchewan)
SIP	Space Indoctrination Program (DND)
SRFB	Space Research Facilities Branch (NRC)
SRI	Space Research Institute of McGill University
STADAN	Satellite Tracking and Data Acquisition Network
STEM	Storable Tubular Extendible Member
TMA	Trimethylaluminum
TV	Television
USAF/AFCRL	US Air Force Cambridge Research Laboratories
USAF/AFOSR	US Air Force Office of Scientific Research
USAF/ARL	US Air Force Aerospace Research Laboratory
USAF/CRC	US Air Force Cambridge Research Center
USAF/RTD	US Air Force Research and Technology Division
USN/ONR	US Office of Naval Research
UTIAS	University of Toronto Institute for Aerospace Studies
VHF	Very High Frequency
VLF	Very Low Frequency
UHF	Ultra High Frequency
UN	United Nations

Part I

FINDINGS AND RECOMMENDATIONS



Chapter I

INTRODUCTION

This is the first time that the various Canadian programs in space science have been brought together in one place. Of course, space science is not a new discipline in itself but merely the use of a recently developed and very complicated technology to resolve problems that have attracted the attention of scientists for centuries.

Our commission directed us to examine scientific, technological, economic, and other benefits from space science.

The common denominator which provided the incentive for performing the study is the need for expensive facilities, rocket ranges, environmental testing facilities, ground stations for satellite telemetry, laboratories for designing and fabricating rocket and satellite payloads, as well as for the launching vehicles, rockets, balloons, or guns. These facilities are usually common to a number of programs, and without them there can be no program.

Because it would be impossible to separate the rocket and satellite experiments, and their experimental objectives, from more indirect measurements on the upper atmosphere of nearby space, we considered that space simulation research in the laboratory on the ground belonged with investigations in space-borne payloads, as part of the technology of space.

The ultimate objective of the study was then to review the present position, determine the reasons for a space program in Canada, and, if these were sufficient, to forecast future programs and outline the elements of good organization – in other words to ask the questions, what are we doing now, what capability do we have for work in the future, and how can we organize to give the best co-ordinated effort?

Inherent in the study are questions of "make or buy". Why should Canada involve itself in these expensive facilities? Why should valuable manpower be committed to research in space, or to building launch vehicles?

Canada occupies a unique geographical position. Services are needed to develop this vast land, or to oversee its weather. Particular scientific problems may exist here which present unique difficulties and which other countries have no incentive to solve; or the opposite may apply, problems that exist here may be so basic to other countries that they insist that attempts be made to solve them in Canada.

Canada's struggle to retain an independent identity while at the same time providing an acceptable standard of living for its people, leads us to develop competitive technologies, to train and educate scientists and engineers, and to resist firmly the erosion of national control over the essential fabric of our national structure.

We have distilled the essential arguments on these issues from the 112 briefs received by the Study Group from agencies and individuals in government, industry, universities and scientific associations. We have attempted to develop the rationale of Canada's position in space activities, and appropriate policies both domestically and in relations with other countries.

In this report, we first review the achievements of Canada since the Space Age opened on 4 October 1957, when the USSR launched the first Sputnik. Most of the activity in Canada has taken place in the last 5 years, from 1961 to 1966. We then assemble the forecasts given to us for the next 5 years, to 1971 and attempt to assess their impact on organization and facilities. We conclude with a series of specific recommendations.

Chapter 2

GOVERNMENT PROGRAMS

2.1 CURRENT GOVERNMENT PROGRAMS

Within the various branches of the departments of Government in Canada there has been for many years a widespread interest in space research and in the applications of space technology to the assigned areas of responsibility of each organization. The Defence Research Board (DRB) and the National Research Council (NRC) understandably have taken the lead in the development of programs.

Defence Research Board

Since the beginning of DRB – a period of twenty years – there has been an active research program in the physics of the upper reaches of the atmosphere, particularly the ionosphere. At first the Defence Research Telecommunications Establishment (DRTE) carried out this program by means of ground-based radio measurements, and the Defence Research Northern Laboratories (DRNL) and the Canadian Armament Research and Development Establishment (CARDE) by means of ground-level and balloon-borne optical measurements. Summaries of expenditures by DRB and of staff employed on these programs are given in Appendix D, figures I, II and III.

Beginning with the International Geophysical Year (IGY) in 1957, rockets were used first by CARDE and later by DRTE to investigate spectroscopic and ionic characteristics of the upper atmosphere. The work at DRTE has been directed toward 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 mm to many km have been made in conjunction with rocket and satellite measurements. Man-made radio waves as well as those of natural origin have been used. The absorption, reflection, partial reflection, scattering, dispersion and polarization of such waves have been measured in order to deduce the variations of electron density and collisional frequency as a function of height, and to understand the terrestrial, interplanetary and solar physical processes that determine these parameters. A complementary program of communications research has proceeded with frequent interaction between the pure and applied aspects.

Two major programs, the Alouette/ISIS scientific satellite program, and the program on satellite communications are described in more detail in sections 2.2 and 2.3.

At CARDE there have been 2 programs on missile re-entry research and on aerology. The emphasis has been on the study of the mechanisms which govern the interactions of infrared and visible radiation with the atmosphere, with a view to applying the knowledge gained to military techniques involving natural or artificial sources of radiation. A broad program of atmospheric radiation measurements has evolved using rockets, balloons and aircraft. Much of the program is conducted co-operatively with US military agencies. The direct high-altitude measurements began in 1957-58 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 at CARDE has produced a better understanding of the luminescent and chemical properties of the atmosphere and the possible role that catalytic chemical processes may play in adjusting the energy balance and composition of the atmosphere. The possibility of modifying some of these interactions is now attracting attention since some scientists feel that significant modification of climate by means of human intervention is possible.

Although the Prince Albert Radar Laboratory (PARL) was built and has been operated as one of the necessary facilities for DRTE to carry out its program of ionospheric research, it does merit separate mention. Basically the laboratory comprises a high power ultra-high frequency radar capable of being used in a variety of researches in radio propagation and capable of tracking objects such as satellites at long range. Associated with the radar are a number of auxiliary pieces of equipment for the recording of fluctuations in the earth's magnetic field and variations in ionospheric conditions. The initial program of the laboratory was devoted largely to a study of the propagational factors which affect the detection and radar tracking of vehicles moving in and beyond the ionosphere. The unique capability of the installation for auroral investigations has been exploited only partially. The defence interest in the capability of the installations

has declined. While the ultimate sensitivity of the system for direct ground-based observations of the ionosphere has now been surpassed by other radars, there are many who believe that the location of PARL within radar range of the auroral zone ionosphere, particularly that over Churchill, should be exploited.

National Research Council*

The interest of NRC in ionospheric physics including meteor physics goes back over a longer period than that of DRB. In the Pure Physics Division an early interest in cosmic-ray research has expanded into extensive measurements of energetic particle fluxes in the auroral ionosphere over Churchill using rockets and more widely using satellites. This work, although involving only a few scientists, has been very productive of new knowledge concerning the precipitation of particles into the earth's atmosphere and the variations in the populations of trapped and untrapped particles under the influence of various solar phenomena.

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* The President of NRC outlined current policy as follows on 19 August 1966 "While there had been some support given to university applicants and there was also some 'in-house' activity, principally in the Division of Pure Physics and in the Radio and Electrical Engineering Division during the preceding years, it was not until 1964 when the issue of Canadian operation of the Churchill Research Range had to be settled that it became necessary for NRC formally to define and adopt a policy with respect to upper atmosphere and space research. In August 1964 a special meeting of Council was held to consider what action NRC should take with respect to the continuation (at a greatly increased cost to Canada) of the upper atmosphere research then in progress and being planned, which required the Churchill rocket launching facility. It was decided at this meeting that because of Canada's unique geographical location there existed a moral obligation to pursue research on the upper atmosphere, and Council made to the government a recommendation in strong terms that additional funds be provided to permit Canada to take over operation of the Range.

Consequently, NRC, by virtue of the decision taken at this special meeting, has a clearly defined upper atmosphere research policy. That policy is to support the research work for which Canada is advantageously situated with accessible land areas under the northern auroral zone. In very simple terms, NRC is committed to pursue research below satellite heights over Canadian territory.

"It was recognized that, as soon as Canada began to bear one-half of the Range operating costs at Churchill, we would need to augment our upper atmosphere research program in order to reap a reasonable reward for this enlarged expenditure. Plans were therefore made to step up the scale of support during the three following years.

"It can fairly be stated that NRC, both in its own laboratories and by awards to university researchers will support scientific research work beyond the policy outlined above — for example, NRC will support experiments mounted in US satellites. This support is governed by quality of the researcher and his experiment in relation to the costs which NRC will bear.

"Research workers who perform upper atmosphere experiments require financial support at a much higher level than those in other fields. The total NRC support — including Churchill operations — is now of the order of $100,000 per researcher per year. This is considerably higher than the average amount needed per worker in most branches of science. Consequently, while the council has a clearly defined policy, the level at which upper atmosphere research will be supported will continue to be determined in relation to the funds available and the requirements of competing disciplines."

The early interest in meteor physics in the Radio and Electrical Engineering Division (REED) grew into a more general interest in upper atmospheric physics with emphasis on auroral physics. A number of rockets, instrumented to study electron densities and temperatures have been flown. Others have counted the number of micrometeorites encountered. In another, related ground-based study, auroral radars were operated at a number of northern stations during IGY and some of these have been continued to the present time. Although this work too is carried out by a relatively small number of scientists, much of its value derives from the fact that the program is directed toward measurements of atmospheric parameters which are being measured simultaneously by other groups using different techniques.

Another program at REED involves the reception of satellite telemetry transmissions. Starting with a project undertaken for Professor J. Van Allen to record the transmissions from the Injun III and Injun IV satellites in 1961 and 1962 the work has progressed through a series of measurements with the Alouette I satellite to more recent work with weather satellites. While the first Automatic Picture Transmission (APT) satellites were in operation, receiving stations were set up in Ottawa and at Frobisher Bay. This work was done in co-operation with the Department of Transport (DOT) and the cloud-cover photographs were sent to the meteorological office in Toronto for analysis. The prototype equipment built at NRC led to the manufacture in industry of operational APT equipment which is now being used at Toronto and Halifax.

At the National Aeronautical Establishment (NAE) several facilities exist which are capable of being used for support of the development of rocket vehicles. Most important of these is the NAE 5 ft x 5 ft trisonic wind tunnel which already has been used extensively in the Black Brant development program. Other test facilities include a 5 in x 5 in trisonic wind tunnel and a 12-inch hypersonic gun tunnel. In addition to the operation of these facilities the personnel of NAE have taken part in a number of rocket firings to investigate structural heating and other aerodynamic phenomena.

In the Mechanical Engineering Division, shock-tube work of possible interest to space programs is being carried out. In addition this division is carrying on an interesting program of research into the factors which influence the ignition and combustion of liquid hydrogen at low pressures, as applied to small high-specific-impulse liquid-fuel rocket motors.

For a number of years the Space Electronics Section of REED provided the payload engineering support necessary for the rocket experiments carried out by NRC and by the universities. This work included, in addition to payload integration, the provision of range documentation for the countdown and the directives for data reception during flight. Launch-support teams were also provided for payload and vehicle check-out and to determine when geophysical conditions were suitable for a launching. After each flight the data received via telemetry were converted from magnetic tape into forms more suitable for scientific analysis and trajectory information was supplied. During 1966 the responsibility for all of this work was taken over by the Space Research Facilities Branch (SRFB) of NRC. This latter group is described separately in connection with the Churchill Rocket Range (CRR).

The expenditures by NRC on these programs, and the staff employed are summarized in Appendix D, figures V and VI.

Other Government Departments

The Department of Energy, Mines and Resources has several groups interested in the potential use of space techniques but most of the present work is concentrated in the Dominion Observatories Branch. A long-standing program of meteor studies contributes directly to knowledge of the upper atmosphere and indirectly to a knowledge of the intensity of radiation within the solar system. The Solar Group in co-operation with the National Aeronautics and Space Administration (NASA) of the US operates its Solar Flare Patrol Program in which a watch is kept on the sun for flare activity in order to provide a warning of increase in solar radiation and hence of disturbed conditions in the earth's upper atmosphere. Both visual and photographic observations of satellites have been made, starting with the first Russian satellite. In each case the results are reported to the appropriate World Data Centre. In the Geophysical Division several continuing programs, notably that in geomagnetism, contribute useful information related to ionospheric phenomena. The Surveys and Mapping Branch has co-operated with the US Coast and Geodetic Satellite Triangulation Program by helping to install 8 satellite photography stations in Canada with a view to improving the Canadian geodetic network and its connections to other networks. Among topics in which there is an active interest but no present program are the detailed interaction of local gravity variations and perturbations of satellite orbits. Other such areas include the application of information gained from satellite-borne sensors to the particular areas of interest of the Geographical Branch, the Geological Survey, the Marine Sciences Branch, the Mines Branch and the Water Research and Water Resources Branches.

DOT has an active program in its Meteorological Branch. In addition to the weather satellite observations which are described under NRC's activities, it is taking part in the standard meteorological rocketsonde network and in a program of noctilucent cloud observations. Rockets are being launched routinely to sound the atmosphere to a height of about 60 km to obtain information on wind, temperature and pressure at this height. Only Churchill is now being used for meteorological rocketsondes but is is intended that 4 more Canadian stations be operated as part of the North American network of rocketsonde stations.

Visual reports of noctilucent clouds are now made from about 70 stations in Canada and the results reported to the Regional Data Centre in College Alaska. The objective of this work is to study the dynamics of the region near 80 km in height where the clouds are formed. Since noctilucent clouds are generally observed only between latitudes 45° and 75°, Canada is favorably situated for these studies.

While there is some uncertainty as to whether or not the field of cosmic ray research should normally be considered to be part of space research, the close relationship between these two areas in the Pure Physics Division of NRC has been mentioned earlier. Another small group (about 3 professionals and 3 technicians) that has made substantial contributions to the study of cosmic radiation and its relationship to interplanetary space is located in the Atomic Energy of Canada Limited laboratories (AECL) at Chalk River. This group has pioneered the design and development of large neutron monitors which have been widely accepted for use all over the world. These studies, to be effective, must be carried out over large geographic areas and involve much international co-operation. The Canadian group has taken an active part and has been able to demonstrate the value of cosmic-ray measurements in studies of the interplanetary magnetic field. At the present time neutron and meson counters are installed at Deep River (the largest such installation in the world and the internationally-accepted reference standard), at Sulphur Mountain in Alberta and at Inuvik, Goose Bay and Alert. A mobile station has also been used to investigate the latitude dependence of cosmic-ray intensity. Expenditures and staff employed on the program are summarized in Appendix D, figure IV.

The Department of National Defence (DND) has some activity in addition to that carried out by DRB. There has been, since 1958, a conscious effort to monitor the impact of military space achievements on Canadian defence. For several years officers have been seconded

to US agencies to take part in space programs, in the Space Indoctrination Program (SIP). Besides making a contribution to US projects it has resulted in more than 55 professional man-years of experience over the broad spectrum of US military space technology. In the life sciences area, the Air Force Institute of Aviation Medicine has had 50 professional man-years of relevant activities. Since 1961, 10 programs covering aerospace and anti-satellite studies have been completed, and 6 programs are continuing. These have cost an estimated $7,958,000.

2.2 THE ALOUETTE-ISIS SATELLITE PROGRAM

Historical Résumé

Following acceptance by NASA of a DRB suggestion that a satellite containing a topside sounder should be launched, work started at DRTE on the design of such a satellite in January 1959. The satellite, known as Alouette I, was launched 29 September 1962 into a 1000-km circular orbit at an inclination of 80°. It contained 4 experiments. These were the topside sounder, a cosmic-noise experiment, a very low frequency (VLF) receiver, and an energetic particle experiment. This satellite was entirely an in-house effort, with the energetic particle experiment being supplied by NRC. After over 4 years in orbit this satellite continues to work as planned, and in spite of expected radiation-caused degradation of solar cells, continues to transmit 3 hours of useful scientific data each day.

Following the success of Alouette I, agreement was reached between the US and Canada to embark on a joint program of launching 4 further satellites, which would constitute the ionospheric research satellite program of both the US and Canada.* This program was to be known as the ISIS (International Satellites for Ionospheric Studies) Program, and the individual satellites would be named Alouette II, ISIS-A, ISIS-B, and ISIS-C. They were to be built in Canada and launched by NASA at intervals during the half cycle of sunspot activity from 1964 to 1969. One of the conditions made by the Canadian Government was that industry should be brought into this program to the fullest extent with the aim that by the end of the program a skilled industry should exist in Canada for spacecraft development. A special parliamentary vote was provided to fund the program.

* The Memorandum of Understanding between DRB and NASA is reproduced in Part II of this report.

The Alouette II Satellite

Work on Alouette II commenced at DRTE in March 1963, and almost simultaneously briefings were held to acquaint industry with the program and, in conjunction with the Department of Defence Production (DDP), select suitable companies for the work. The RCA Victor Company Limited, Montreal, was selected as prime contractor, with the de Havilland Aircraft of Canada Limited in Toronto as associate prime contractor. It was planned to use Alouette II as a training ground for industry, and industrial personnel commenced work at DRTE in September 1963.

Alouette II was launched on 29 November 1965, into a 500-km by 3000-km orbit. A year after launch it is operating perfectly and providing 7 hours of data per day. A sister satellite, Explorer XXXI, was launched by the same vehicle and is in nearly the same orbit as Alouette II. On 29 January 1966 the 2 satellites were 540 km apart and were separating at a rate of 8 to 9 km per day. Explorer XXXI contains ion and electron probes, and an electrostatic probe identical with the electrostatic probes on Alouette II.

The purpose of the dual launch was to permit nearly simultaneous comparisons between the data obtained by the sounder, VLF, and electrostatic probe experiments in Alouette II and the probes in Explorer XXXI, and to provide ion and electron temperature and ion composition data at the height of the satellite for use with the sounder data.

The ISIS-A Spacecraft

Work on ISIS-A commenced in March 1964. DRTE retained responsibility for the spacecraft system design, command system design, and the spin maintenance and attitude control system design.

The contractor was made responsible for design of the other systems (sounder electronics, telemetry, power, spacecraft construction, and ground support), construction, integration, and testing. At present, integration of the engineering model is nearly complete, construction of the flight model is underway, and launch is planned for the end of 1967 or early 1968 into a 90° inclination orbit of 500 km perigee, 3500 km apogee.

ISIS-A will carry 10 experiments. These are a swept frequency sounder, a fixed frequency sounder, a very low frequency VLF receiver, a cosmic-noise experiment, energetic particle detectors, a soft electron spectrometer, a cylindrical electrostatic or Langmuir probe, an ion probe, an ion mass spectrometer and a very high frequency (VHF) beacon.

The ISIS-B Spacecraft

The experiments and orbit for ISIS-B have recently been selected, and work is now commencing. Twelve experiments will be carried on the spacecraft which is to be injected into a 1700-km circular orbit of 75° inclination. Ten of these experiments will perform the same measurements as those on ISIS-A, although the experimental details will in many cases be different, while the remaining 2 will investigate the behavior of certain optical lines in the aurora. Planning is based on a launch date in 1969. The industrial contractor will be made responsible to DRTE for all aspects of design, construction, integration, and test.

The ISIS-C Spacecraft

At the present time ISIS-C is largely unspecified except that it has been decided that it will be put into a highly eccentric orbit reaching out to between 6 and 10 earth radii in order to study the ionosphere out to the magnetospheric boundary. Preliminary considerations show that a considerable amount of research and advance development work will be necessary for this satellite, consequently it is not thought possible to launch it before 1971 or 1972.

In addition to the satellites that have been described, the program entails the operation of 2 telemetry stations, one at Ottawa and one at Resolute Bay, the Data Processing Centre at Ottawa, and the Satellite Control Centre, also at Ottawa.

Engineering and Economic Benefits from Alouette/ISIS Program

As a direct result of the program, there is a team of engineers at DRTE that is skilled in reliable spacecraft design both in its mechanical and its electronic aspects, that is accustomed to operating with industry both in Canada and in the US that knows the NASA organization and is familiar with it, and that is in the habit of using advanced management techniques. In industry there is now a spacecraft center at the RCA Victor Company Limited in Montreal that is staffed by a good engineering and management team and that is capable of designing, constructing, and testing quite complex spacecraft.

In addition, there have been sales to the US of spacecraft components such as extendible booms, and telemetry transmitters, the value of which has amounted to several million dollars.

2.3 SATELLITE COMMUNICATIONS

Introduction

The use of satellite communications for domestic television network distribution and telephone systems to tie isolated communities into the national telecommunications network has been the subject of a considerable amount of study in Government and industry. In this chapter, we discuss external communications, domestic communications and finally military communications.

International satellite systems for air navigation, air-ground communications and air traffic control are also being studied.

Canadian Participation in the Commercial INTELSAT System and NASA Experimental Communication Satellite Work

Following the early success of the US satellite communication projects, Telstar and Relay, DOT entered into an agreement with NASA in August 1963 under which Canada would participate in the testing of experimental communications satellites launched by NASA.* The agreement included a commitment to build a ground station. With the objective of enhancing government and industrial capability in this technology, work was started on the design and construction of an experimental communication satellite ground station near Mill Village, Nova Scotia, approximately 80 miles south-west of Halifax. The technical design was based on the expected use of the NASA Applications Technology Satellite (ATS) to be launched in about 2 years time. RCA Victor was the contractor for systems integration. Significant Canadian content and engineering involvement was an important objective.

The Communications Satellite Corporation (COMSAT) was established in the US following the passing of the Satellite Communications Act by Congress in 1962. The US then took the initiative for the establishment of an international organization for the purpose of building and operating a global satellite system, although much consultation on the subject had taken place between Britain and European countries. The present arrangements are laid down in the Agreement Establishing Interim Arrangements for a Global Commercial Communications Satellite System, while the details are contained in the so-called Special Agreement.** These agreements were arrived at as a result of intense activity on the part of a group of

*The Memorandum of Understanding between DOT and NASA is reproduced in Part II of this report.

**The Agreements are given in Part II of this report.

12 countries (including Canada) having in 1964 the largest overseas telephone traffic, and they were opened for signature by any International Telecommunications Union (ITU) member in August of that year. The main feature of these arrangements was the establishment of an Interim Communications Satellite Committee (ICSC) which is responsible for establishing the space segment of the system, and operating arrangements including co-ordination with separately owned earth stations.

This global satellite communications organization is now commonly referred to as INTELSAT. The INTELSAT system is financed on an international basis with investment roughly in proportion to overseas traffic. It was originally assumed that the cost of establishing the space segment, including auxiliary facilities such as tracking and control stations, etc would be around $200,000,000. However, with the agreement to adopt synchronous satellites only for the period up to 1970, and because the probabilities of a successful launch continue to increase, the cost is now expected to be somewhat less.

Canada has an investment quota of 3.75% in INTELSAT and has a seat on ICSC. Canada is represented on ICSC by the Canadian Overseas Telecommunication Corporation (COTC), while an engineer from DOT participates along with COTC in the Technical Committee of ICSC. Under the present arrangements the US has a very dominant position in INTELSAT, as the US has a quota of 56% in the organization. Any country or combination of countries with a quota of more than 1.5% is entitled to a seat on ICSC. To avoid complete US domination of ICSC, certain important questions can only be decided by the vote of the largest quota owner (US) plus the votes of other countries with quotas totalling 12½%.

COMSAT acts as manager for ICSC in addition to being the US representative in INTELSAT. There are now 52 member nations in INTELSAT, although so far no communist country has joined. ICSC is committed to submit a recommendation on the future organization of INTELSAT not later than 1 January 1969 and will consider, among other things, whether the interim arrangements should be continued indefinitely or whether a permanent international organization with a general conference and an international administrative and technical staff should be established.

It is expected that the future organization of INTELSAT will be the subject of extensive international debate between now and 1969. Undoubtedly many European countries wish to reduce the US control of ICSC. Another important question is how to induce countries now ouside INTELSAT, particularly the USSR, whose international traffic is so small that she could justify only a small quota of ownership to join that organization. Canada's position in this matter is being considered jointly by the Department of External Affairs, DOT and COTC.

Late in 1964 ICSC approved a project know as Early Bird, an experimental commercial synchronous satellite located over the Atlantic to provide communications between North America and Europe. This later became known as INTELSAT I. As soon as these plans were accepted, the design of the Canadian station was changed so that it would be capable of operating in a limited manner with this satellite in addition to ATS. It was also arranged that COTC would be responsible for commercial operations until COTC was able to construct a station of its own, and that COTC would maintain and operate the Mill Village station even when it was being used by DOT for experimental purposes.

COTC is now completing arrangements for limited commercial operation which will include a role for the Mill Village station as a backup for the American station at Andover, which at the present time is carrying all of the US and Canadian commercial communications satellite circuits to Europe. The number of circuits is only about 70 at the present time because there is still spare cable capacity. However, the demand is increasing rapidly. In Europe the operations are shared in time sequence among 4 ground stations in Britain, France, Germany and Italy.

The provision of a greatly increased number of international circuits is very strongly tied up with the so-called World Plan of ITU. Starting around 1970, direct distance dialing (DDD) will be introduced on an intercontinental basis, leading eventually to the creation of a global DDD system. All early thinking and planning for the introduction of communications satellites to provide international circuits was based on the concept of "cables in the sky", that is, all overseas telecommunications traffic for a relatively large geographical area would be routed over terrestrial facilities to one satellite ground station, which would transmit all of this traffic to another large station on another continent whence it would be distributed by landline.

With the development of multiple-access systems, many ground stations will now be in communication with each other via the same communication satellites. These developments will have a very marked effect on the plans so far developed by ITU for local telephone networks and the global telephone switching concept. These factors are mentioned here to point up the need for a high degree of co-operation between the ITU and ICSC.

A major difficulty in the early organization of a global satellite communications system is the peculiar status of COMSAT acting in 3 different capacities: (a) as manager for ICSC, (b) as US representative on ICSC and (c) as a US common carrier company subject to the jurisdiction of the Federal Communications Commission (FCC). With the best of intent on the part of COMSAT to discharge its responsibilities in all of these 3 roles to the best of its ability, it is nevertheless unavoidable that a conflict of interest will arise. Inherent in this arrangement is also a tendency on the part of other ICSC members to be especially skeptical regarding COMSAT's ability to maintain an objective point of view in questions where US political or economic interests are involved.*

In order to indicate the anticipated growth of circuits, the requirements for which are expected to be met in part by satellite communications, the following figures are presented, showing the Atlantic and Pacific requirements for international purposes for the years 1966 through 1969.

Number of circuits required in year commencing

Area	1966		1967		1968		1969	
	COTC	Total	COTC	Total	COTC	Total	COTC	Total
Atlantic....	60	254	81	484	101	1244	120	3500
Pacific	–	19	–	68	4	221	5	306

These figures do not include any requirements for circuits from North America and Europe to the Indian subcontinent, which may be met by a satellite positioned over the Indian Ocean, nor do they include capacity required for domestic telephone, telegraph and TV requirements.

Domestic Satellite Communications

The term domestic satellite telecommunications via satellites refers to traffic originating from points within Canada and destined for other points within Canada, but may also include internal extensions of external circuits. The principal uses for domestic satellite communications in Canada would be:

(a) for telephone, telegraph and data communication with remote communities in Canada which are not at present served by landlines or terrestrial radio relay facilities. Satellite ground stations

*"COMSAT is both a profit-seeking corporation and a chosen instrument of the (US) Government. In important ways, COMSAT represents the US Government and performs foreign policy functions" 89th Congress House Report 2318.

would also be capable of receiving TV and radio programs for retransmission through local broadcasting or over a cable distribution system;

(b) for distribution of TV and radio programs from central satellite ground transmitters, beamed from the satellite to receiving stations which would receive the signals and feed them to local TV and radio transmitters or distribution cables. This type of distribution service does not broadcast programs directly to homes, since the receiving equipment is too expensive for use by the general public. A TV and radio distribution network of this nature would have the tremendous advantage that programs could be received at any point in Canada as far north as 78°. For the first time it would become possible to provide a truly national TV and radio program service to people in all parts of Canada.

Such receiving and rebroadcast facilities may be economically practicable for communities having a population of not less than 300 but the opportunity would of course exist for making the service available in even smaller communities if national or other considerations should make this desirable. Because of Canada's vast expanses in the east-west direction, it would be necessary to broadcast the English language TV and radio programs in 6 time zones and French language programs in at least 3 time zones, with a possible future need to provide French programming in 6 time zones;

(c) for long-distance general telecommunications traffic in an east-west direction. It would appear that telecommunications circuits provided via satellites would be more economical than long-distance service provided over terrestrial radio relay systems for distances in excess of 1500 miles. Traffic over the transcontinental radio relay system of the trans Canada telephone service increased 25% in 1965, and there is every reason to expect that the future growth rate will be at least as high. A satellite communication system of this nature could provide bulk service between major cities. It might, for instance, be feasible to carry 600 or more telephone circuits from Montreal to Winnipeg or Vancouver by this means;

(d) for direct broadcast to homes or schools. There is a growing demand for educational television (ETV) channels in Canada. There is little doubt that ETV provided via communications satellites can be of immense benefit to many isolated communities and rural areas in Canada. Programs may be transmitted

over satellites to such communities via the local TV distribution system or the latter system may be used for distributing taped programs from a local studio during morning hours.

The present opinion of telecommunications authorities in the US and Canada appears to be that direct broadcasting to home TV receivers from communications satellites is still some time off.

The possibility is much greater that broadcasting of frequency modulation (FM) radio programs directly to homes and automotive receivers may be introduced within a few years. It would, for instance, be quite feasible to transmit continuous music to all of North America from a high-power satellite using only a single frequency.

The type of satellite circuits being discussed for domestic telecommunications would employ geo-stationary satellites in an equatorial orbit.

The Canadian telephone industry has shown interest in constructing satellite communications systems which would provide telephone, teletype and TV service to northern communities. In particular, the Northern Electric Company Limited Research and Development Laboratories have commenced work on light satellite ground stations which will be suitable for such use. A domestic satellite communications system could be capable of carrying all forms of telecommunications, that is, telephony, telegraphy, Telex, TWX, TV relay to broadcasting stations, facsimile and data traffic generally. These are all services traditionally provided by the Canadian common carrier companies via their landlines and terrestrial microwave systems. However, both private broadcasters and the Canadian Broadcasting Corporation (CBC) are prepared to use satellite circuits for television distribution independently of the common carriers. There is as yet no decision as to who may own satellites for domestic Canadian use.

Because of the present unsettled state of US policy on domestic satellite communications it will be difficult for the US and Canada to reach an agreement on questions relating to the purchase, leasing and launching of satellites to serve domestic Canadian purposes. A certain delay in this question, which calls for a bilateral agreement between the US and Canada, need not, however, delay planning a domestic Canadian satellite communications system and proceeding with experimental ground station work.

It has been predicted that the establishment of a domestic satellite communications system could have a revolutionary impact on life in isolated northern communities, though this may depend on the extent to which the system is also used in the more densely-populated areas. The parts of Canada which have so far been without reliable communications could within a few years be connected to the national DDD telephone network and enjoy the benefits of TV. It may well be that the provision of greatly improved telecommunications facilities will prove to be a major factor in accelerating the development of resources in isolated regions of Canada.

The provision of domestic satellite communications systems to provide both telecommunications to isolated areas and a truly national TV coverage in both French and English should be considered to be a major aim of the Federal Government. It may therefore be expected that DOT in co-operation with other Government departments, agencies and Crown corporations and the Canadian common carrier industry will encourage the establishment of a domestic satellite communications system at the earliest possible date.

Military Satellite Communications

In 1962 the Royal Canadian Air Force (RCAF) began a study of an air-transportable Satellite Communications Ground Terminal, for which proposals were later solicited from industry. In 1965 the project was terminated after going through various phases of project definition, study, proposal reviews, etc.

At the present time a Canadian National/Canadian Pacific Telecommunications consulting group is examining in detail the fixed non-tactical communications requirements of the Canadian Armed Forces (CAF) until 1980. That some advantageous requirements will be established is most probable in, for example, long range communications with long range maritime patrol and transport aircraft, communications with ships and United Nations (UN) peace-keeping forces which currently depend on relatively unreliable high-frequency (HF) propagation, and for relatively invulnerable communications for survival operations. It is unlikely, however, that a sufficient requirement will be established to justify the deployment of a communications satellite network exclusively for Canadian military non-tactical needs. It is conceivable that the limited requirement could be met through agreements with other countries for the sharing of Satellite Communication (SATCOM) communications circuits. However, despite the introduction of improved modulation techniques, for example, spread spectrum, the extent of CAF's access to the system is dependent upon the degree of control imposed on circuit utilization resulting from these agreements.

The conclusion has been reached that the stringent military requirements with respect to security, reaction time, accessibility, survivability, etc, for military communications demand a communications satellite system having different parameters that those of the most cost-effective system for commercial needs.

With regard to tactical requirements, the type of equipment and techniques necessary and, in the case of small military formations, the feasibility of suitably small ground terminals, have yet to be established. Thus, although the complete Canadian military requirements for satellite communications are not yet known, studies now underway or soon to be commenced will determine future requirements.

DRB has a satellite communications program under way at DRTE. This has 2 facets. One is the investigation of atmospheric and tropospheric effects on the satellite communications under non-optimum and marginal conditions and using frequencies higher than those now assigned for space communications. A fruitful 5-year program on atmospheric effects is foreseen. The other aspect is that of optimising the use of communications satellites and, in particular, using the US Initial Defence Communications Satellites for systems development for loosely-controlled multiple simultaneous access to satellite repeaters.

2.4 RESEARCH ROCKET FACILITIES

The Churchill Research Range and Space Research Facilities Branch

Churchill, Manitoba, has long been known as a center for studies of the aurora and related upper atmospheric and ionospheric topics. Churchill lies near the middle of the zone of maximum auroral activity which, since it is centered on the geomagnetic pole, extends far south into central Canada. With this advantage and with good transportation, scientific studies at Churchill increased steadily from small beginnings in the 1920's until a major observing station of the IGY was established there in the late 1950's. The use of rockets to carry scientific instruments into intimate contact with high-altitude phenomena necessitated a large impact area, for which Hudson Bay was ideal.

CRR was first used for scientific rocket-borne experiments during 1956 in preparation for IGY, and was operated by the US Army for the joint benefit of American and Canadian scientists. Reopened in 1959 after a year's inactivity, it was greatly damaged by fire in 1961 and was again reopened in 1962, this time under the management of the Office of Aerospace Research, USAF. In 1965 a new intergovernmental agreement provided for the transfer of CRR to civilian agencies and for its management by NRC.* The co-operating agencies of the 2 governments are NRC of Canada and NASA of the US and costs are shared equitably between the 2 countries. This new agreement came into force in July 1965 and the transfer from USAF to NRC was completed on 31 December 1965. In the first 6 months of 1966, 53 small Arcas synoptic meteorological sounding rockets, and 21 larger scientific rockets were launched. The rate of firing was approximately the same as that during similar periods in other years. Range facilities include 3 launchers for larger solid-fuel rockets, one for liquid-fuel rockets and one for the Arcas rockets. Three sophisticated radars keep track of the rockets during flight and a Doppler velocity and position (DOVAP) system can also be employed. Data from rockets is received at the main and backup telemetry stations. Nose cone recovery can be accomplished by range-operated helicopters. A meteorological section determines wind conditions for flight safety at higher altitudes and for prediction of rocket impact locations. Impact is normally on land south and east of Churchill for smaller rockets and for recovery of payloads, while much of Hudson Bay is available for the impact of larger, higher-altitude rockets. An extensive supply, maintenance, and transport organization, together with heating and power generating plant and a capability for minor construction work also form part of CRR.

The control of CRR is vested in SRFB. Under the intergovernmental agreement all policy decisions including the decisions to fire specific rockets and payloads are made by the Joint Range Policy Committee, consisting at present of 8 members, of which 4, including one co-chairman, are nominated by each country. Each co-chairman presides at alternate meetings. The present Canadian membership consists of 3 representatives from NRC, including a co-chairman, and one from the Department of Public Works. The US membership consists of 2 representatives of NASA, including a co-chairman, and 2 from the USAF. CRR is operated for NRC by Pan-American World Airways with about 210 employees. There are 18 NRC staff members at Churchill. Of these, 5 are in charge of scheduling and supervising rocket launchings, 3 are in range safety, including flight, launch pad, and industrial safety, and 6 carry out administration and contract supervision. The remaining 4 work in the Technical Support Section.

At CRR the Technical Support Section contains a drafting office, a photographic studio, machine shops and instrument calibration facilities. It carries out ground-based observations of the aurora borealis using photographic and spectroscopic methods. It furnishes auroral forecasting services to range users and provides optical and other instrumental coverage of events studied by means of rocket-borne experiments. The Technical Support Section is located in the former DRNL where this kind of scientific investigation and support service were carried out under DRNL auspices. The section includes both NRC and contractor employees. Synoptic data furnished by this group are used by range users, by NRC, by DRB and by other government and university scientists. As part of this support activity remote stations are operated at Twin Lake, Digges Siding, O'Day, Belcher, Seal River and Caribou River, locations which range from a few km to about 100 km from the launch site. The principal use of these remote sites is to permit simultaneous photographs to be taken of auroral forms or of artificially produced luminous clouds caused by chemicals released from rockets. Photographs are taken from several positions on the ground so that the location of the luminosity in space can be determined by triangulation.

*The Agreement is reproduced in Part II of this report.

The smallest of the rockets regularly launched at CRR is the Arcas which is 4½ in in diameter, 5 ft long and carries 12 lb to 50 miles altitude. Meteorological instruments are ejected at maximum altitude and descend by parachute. Three of these Arcas rockets are fired each week in support of the World Rocket Meteorological Network. Larger, solid-fuel rockets include the Nike-boosted series, the Cajun, Apache, and Tomahawk, and carry about 100 lb to 110 miles. These are used by various US agencies for scientific measurements. Less common is the 2-stage Astrobee 250 carrying 400 lb to 195 miles. The largest rocket handled by CRR is the 4-stage Javelin, about 48 ft long, which carries 125 lb to 500 miles. The only liquid-fuel rocket fired is the Aerobee 150, commonly used at CRR and at other ranges for scientific payloads, and capable of carrying 300 lb to just over 100 miles. Canadian scientific experiments are carried in the Black Brant series of rockets.

In order to protect the rockets and their temperature-sensitive instrumentation, it was necessary to develop a special temperature-controlled environment. All the rockets are launched from within specially designed buildings, enabling the technicians, scientists and engineers to prepare the rockets in a comfortable environment, protected from the extreme cold. At the time of launch the roof of the launch building is opened to provide for the rocket's exit. In many cases when a prepared rocket must be held in a launch attitude for several hours waiting for the occurrence of a specific atmospheric phenomenon, the proper temperature for the rocket is maintained by a specially designed heat shield. This shield encloses the rocket completely and maintains the rocket at room temperature in spite of low ambient temperatures, often below −30°F. The opening of the shield is remotely controlled. In addition, the 2 largest launchers are capable of being adjusted in azimuth and this adjustment can be made, if necessary, late in the countdown.

CRR is budgeted for a total expenditure each year of $4,000,000 US and for the existing program this figure will not be exceeded for at least 2 or even 3 years. In the subsequent 2 or 3 years, marginal increases due primarily to inflationary pressures are expected. At the present time costs are shared about equally between Canada and the US but the agreement permits adjustments to be made to conform with changes in relative use. Details of expenditures are shown in Appendix D, figure V. This agreement expires on 30 June 1970.

In addition to its direct responsibilities for CRR, SRFB has other, more general responsibilities with regard to the rocket program. Before presentation for approval to the Joint Range Policy Committee each Canadian rocket payload goes through a complex process of scientific and engineering discussion and evaluation. The scientific proposal is first discussed in the Scientific Program Group, a committee of potential rocket users drawn from the interested governmental, industrial and university laboratories. Proposals for specific payloads, which generally include experiments involving several different experimenters, go from the Scientific Program Group to the NRC Associate Committee on Space Research, where approval is given by the Committee or its executive. At this point direct co-operation begins between SRFB and the individual experimenters.

SRFB has for the Sounding Rocket Program a small headquarters with 2 engineers and 2 technical officers together with administrative staff. It draws directly on the Space Engineering Division (SED) of the University of Saskatchewan, which provides, under contract to NRC, engineering skills for the integration and fabrication of rocket payloads on behalf of any scientists whose experiments are part of the approved program. The extent of the fabrication work in SED is deliberately limited to an amount considered adequate to provide specialized training for an appropriate number of graduate students, and to permit SED also to handle effectively the complex problems of data reduction. The intention is to provide at least one integrated group in Canada which is competent to carry out the whole process of design, fabrication, launch support, and data reduction associated with a rocket-borne payload. The remainder of SRFB's design and fabrication capabilities are obtained by contract with industry and in

particular with Bristol Aerospace Limited (BAL) which provides the rocket motors and most of the mechanical components for the rockets and which has a demonstrated competence in payload construction.

Other resources are available to SRFB but in a less formal fashion. These are located within several divisions of NRC, NAE, the Division of Pure Physics, and REED. Also individual scientists participate in the programs.

SRFB has financial responsibility for providing vehicles, components and other services as described above using funds made available from NRC operating votes. The user scientists provide the experimental equipment both for integration into rocket payloads and for ancillary ground-based or balloon-borne experiments. They provide specialized checkout equipment and are responsible for their own travel and subsistence arrangements. In the case of university scientists the funds for these purposes are often obtained from grants made through the regular NRC university grants program. Expenditures by NRC in this program are summarized in Appendix D, figures VI and VII.

For each rocket there is a project scientist, designated by an organization utilizing a whole rocket, or else chosen by those of his colleagues who jointly use a multi-experiment payload. It is the responsibility of the project scientist to determine launch criteria suitable to all those whose experiments are flown together. It is also his responsibility to see that each scientist meets the deadlines for experimental hardware and is kept fully acquainted with the process of integration and preparations for launch. The project scientist has the final authority in determining that a rocket is ready to be launched. This authority cannot be overruled by the range although the range may decide that a rocket cannot be launched for reasons of safety or for other causes.

SRFB is responsible for providing rockets at the appropriate times, for control of the payload integration process as scheduled, and for the provision of a vehicle manager who ensures that the complete vehicle and payload are ready and operating correctly before the project scientist takes over responsibility.

It is interesting to note that during the summer of 1966 SRFB undertook the task of establishing a temporary launching facility at Resolute Bay in the Far North. Two Black Brant III rockets were flown successfully from that site in July. The rockets carried experiments built at the University of Calgary and in the laboratories of NRC.

Chapter 3

UNIVERSITY PROGRAMS

3.1 CURRENT UNIVERSITY PROGRAMS

Introduction

The upper atmosphere and space research programs at various Canadian universities will be considered in the chronological order in which the work was initiated.

University of Toronto

The active involvement of the University of Toronto in the aerospace sciences began during World War I (1914–18), when a laboratory for aeronautical research and development was established. The main item of equipment was a wind tunnel with a test section 4 ft square and a maximum speed of 80 mph. For 10 years following the war this laboratory was the major center of aeronautical research in Canada. The program included investigations of problems for RCAF. Responsibility for this work was undertaken in 1929 by NRC.

An aeronautics option in the Department of Mechanical Engineering was inaugurated in 1928. The first graduate students received their MASc degrees in 1929. This option was transferred to the Engineering Physics course in 1935, and for the next 10 years, including World War II, this course made use of the laboratory facilities and was the only one of its kind in Canada.

In 1946 research on re-entry physics was initiated. This project in co-operation with Princeton University and the University of Michigan produced the first tube to be used for the investigation of shock waves of high strength. The shock tube was developed as a supersonic wind tunnel by the group at the University of Toronto, and the potential of this device for the study of hypersonic flows was established soon after. A proposal emerged from this research group in 1947 for the establishment of an aeronautical and astronautical laboratory, and in 1949 an enabling grant was received from DRB for the establishment of an autonomous division of the University of Toronto to be called the Institute of Aerophysics, now known as the Institute for Aerospace Studies (UTIAS) with G.N. Patterson as its founder and first director. This organization was to be responsible for research in the aerospace sciences and for the training of graduate students in co-operation with the teaching departments of the University of Toronto. In order to devote funds primarily to the construction of large research facilities, a hangar building at Downsview Airport, Toronto, was made available on loan by DRB and minimum alterations for occupancy were made. In 1950 the new laboratory was opened, the major facilities being a large supersonic wind tunnel capable of speeds up to 5 times the speed of sound in a 17-inch square test section and a complex of shock tubes for the study of shock waves, hypersonic flight and re-entry physics.

The absence of administrative constraints allowed UTIAS to find its own level and during the next 8 years it developed naturally into an organization which gave equal emphasis to research and teaching. The research program expanded with the gradual increase in staff to include the mechanics of rarefied gases, aerospace propulsion, aerodynamic noise, flight dynamics and plasma dynamics, as well as shock tube (hypersonic) and supersonic investigations. At the time Sputnik I went into orbit in 1957, UTIAS had the only hypersonic, low-density tunnel which could simulate the molecular flow of orbital and sub-orbital flight. Another outstanding contribution was the discovery that the properties of the ionosphere could be reproduced in a high-performance shock tube. Financial support for the research program then became available from US agencies. During this period also UTIAS assumed responsibility for the aerospace option in the engineering science course at the University of Toronto and the Department of Aerospace Studies in the School of Graduate Studies.

In 1959 UTIAS moved to a permanent 18-acre site provided by the University of Toronto about 14 miles north of the campus. A new building was constructed under a grant from DRB and the new laboratory was officially opened on 14 October 1959, by A.H. Zimmerman, Chairman of DRB.

At this time 2 new divisions of the research program began to appear. In 1960 a rocket research laboratory was initiated so that laboratory experiments could be extrapolated to the upper atmosphere. The first rocket was designed to test a free-molecule probe developed in the UTIAS low-density tunnel to measure pressure directly in the upper atmosphere. A plasma dynamics laboratory was also established with equipment for the study of simulated ionospheric flight, magnetogasdynamic propulsion and energy conversion, and the properties of plasmas at very high temperature. During this period the calibre of work began to attract substantial US support. Among other successes UTIAS won international recognition for its development of the electron gun for space applications. Further extensions of the building which doubled the floor area were made in 1961 and 1963 using funds provided by the University of Toronto and the Ford Foundation, respectively. This new accommodation made possible the addition of 2 further areas of research: human pilot dynamics and a hypervelocity laboratory for the simulation of space flight in planetary atmospheres and interplanetary space.

UTIAS now has a permanent professorial staff of 12 with full-time appointments. The UTIAS Progress Report for 1966 lists 67 projects specifically related to upper-atmosphere and space research on which reports will be written. The major fields are: mechanics of suborbital flight, plasma dynamics, upper atmospheric simulations, hypersonic gas dynamics and re-entry physics, plasma propulsion and energy conversion, aerodynamic and jet noise investigations, aerospace flight dynamics, aerospace materials science, upper-atmosphere research, molecular beams and surface interactions, simulation of space flight. Details are given in Appendix C. Fifty graduate students are involved in these projects. The research funds from grants and contracts to support this program total $640,000 for 1966-67. These funds were obtained from 12 Canadian and US agencies, 57% being from US sources.

University of Saskatchewan

An interest in atmospheric investigations at the University of Saskatchewan became evident in 1932-33 when a graduate student made parallactic measurements on the height of the aurora over Saskatoon, and a member of the staff of the Department of Physics participated on behalf of Canada in the Second International Polar Years. During the following 15 years, data on aurora, earth-current and related phenomena, collected by the Canadian expeditions of 1932-33, were analysed in the Department of Physics by the staff and graduate students. The location of the University of Saskatchewan proved to be an excellent one for the study of auroral phenomena. Advances were made in electronic, spectrographic and other techniques which could be applied in upper-atmospheric investigations. This was also a period of increasing awareness that ionospheric investigations were important to Canada's communications system and to the defence of this country.

A grant and a loan of radar equipment were made to the Department of Physics of the University of Saskatchewan by DRB in 1948 for a study of radio reflections from the aurora. Shortly thereafter a contract was received from the United States Air Force Cambridge Research Center (USAF/CRC) for fundamental investigations on auroral and airglow emission. During the following years further support from these 2 agencies led to the development of various types of spectrometric and photoelectric equipment, auroral intensity recorders, all-sky auroral cameras and magnetic variometers incorporating many of the recent advances in electronic and optical techniques. A number of papers on auroral and airglow emissions, auroral morphology, radio reflections from aurora and ionospheric and magnetic disturbances were published in the 10-year period following the initial grant from DRB. Outstanding advances were reported in the whole field of atmospheric processes associated with auroral zone phenomena and, as a result, the Department of Physics at the University of Saskatchewan became well known for its work in this sphere.

In 1957 the Institute of Space and Atmospheric Studies (ISAS), then called the Institute of Atmospheric Physics attached to the Department of Physics, was established under an enabling grant from DRB with B.W. Currie as founder and first director. ISAS gave coherence to the existing group of researchers, and during the subsequent years helped to maintain a high level of productivity both in published papers on upper-atmospheric phenomena and in the number of students graduated with post-graduate degrees. In 1960 work was initiated to obtain experience in the design and development of experiments suitable for use with rockets. Two rocket experiments, one on electron densities and the other on electric fields, were performed successfully at CRR in 1962. At the same time attention was given to optical experiments using balloons rising to the 100,000-ft level. When NRC assumed responsibility for CRR, increased grants were made available to stimulate rocket research.

In 1965 the University of Saskatchewan accepted a contract from NRC according to which the University is required under the direction and control of NRC to construct rocket payloads and instrument packages for recognized research groups elsewhere in Canada. This contract led to the formation of SED of ISAS.

ISAS is housed in the Physics Building at the University of Saskatchewan and SED occupies a rented building at the airport. A 160-acre site 27 miles west of Saskatoon free from serious radio noise has been leased. Nine members of the professorial staff with permanent appointments in the Department of Physics have a major interest in the work of the Institute. The Institute currently has 23 projects under way listed under radio techniques, optical methods, rocket and balloon experiments and other investigations. For further details see Appendix C. About 21 graduate students are participating in this program. The research funds from grants received by ISAS for 1966-67 total $260,000, about 94% being received from NRC and DRB and the remainder from the USAF. The value of the contract under which the Space Research Division was established is $285,000.

McGill University

The interest of McGill University in the aerospace sciences has extended over many years. During and following World War II the Department of Mechanical Engineering contributed extensively in the field of combustion and propulsion, initially under support from DRB. Later this department extended its interests to include shock-tube research, low-speed aerodynamics and plasma physics. During this period the Department of Chemistry achieved success in the field of the chemistry of the upper atmosphere.

The research project at McGill University that led ultimately to the formation of an institute was the High Altitude Research Program (HARP), initiated in 1962 under a contract from the US Army Ballistic Research Laboratories (BRL). The broad objective of this program is to use high-acceleration, gun-launch systems to probe the upper atmosphere and ultimately to act as a first booster stage in an orbital launching facility. Specific objectives include: a test of the full capability of the gun-launch system for atmospheric sounding and orbital research, the development of laboratory facilities to support the program, application of the developed technology to defence and space research, integration of activities to provide a program of graduate research and to assist industrial support agencies in creating and developing new productive capabilities. In 1964 the Canadian DDP joined the project as a financial supporter. It will be appreciated that HARP-McGill* is a costly project, and it represents the only venture of a Canadian university into the field of launching facilities. For this reason it is discussed in this report under a separate heading (Ref. 3.2).

The Space Research Institute (SRI) of McGill University was organized in 1964 to bring together related activities in the space sciences. Facilities at this time included the headquarters at McGill

*For distinction between "HARP" and "HARP-McGill" see Part III, Introduction

University in Montreal, a large free-flight firing range in Barbados (HARP) and an impact laboratory (light-gas-gun ranges) at Highwater, Quebec. The founder and first director is G.V. Bull.

The work of SRI is the basis of thesis projects for graduate students enrolled in various departments of the University (mainly Mechanical Engineering). Special courses are now being given by SRI to support this program in plasma dynamics, upper-atmospheric physics, payload and vehicle engineering, and fluid dynamics. About 20 students are involved in this program. Details are listed in Appendix C. Support for this work has come form both Canadian and US sources.

University of Western Ontario

The Department of Physics, University of Western Ontario has been engaged in upper-atmospheric and space research since 1951 when staff members showed an active interest in spectroscopy related to upper-atmospheric physics. This activity developed into laboratory experiments related to meteor oblation and later into rocket experiments on the spectroscopic features of the aurora and airglow.

A parallel development at the University of Western Ontario occured in the field of radio science. During and immediately following World War II a series of experimental radio programs were undertaken by G.A. Woonton and R.C. Dearle. The first objective of much of this work was improvement of radar systems but the program soon broadened into more fundamental areas. The need for people well-trained in both the theoretical and technical aspects of radio physics led to the establishment of a radio physics program as one of the options in Honours Physics and Mathematics. In the 20 years of its existence this radio physics program produced a number of graduates who have gone on to become prominent in space research both in Canada and in the US. Early in the 1950's the radio research at the University of Western Ontario turned to ionospheric problems and this aspect has expanded until it now includes a wide variety of experiments using rocket-borne and satellite-borne radio sources as well as a network of ground-based equipment stretching from Greenwood, Nova Scotia, to Winnipeg, Manitoba, and from Great Whale River, Quebec, in the north to Burlington, Vermont, in the south. The program is now under the direction of P.A. Forsyth, Professor and Head of the Department of Physics.

Details of the program are given in Appendix C. Twelve members of the professorial staff of the Department of Physics and 24 graduate

students are engaged full-time on this research. Grants for this work in 1966 totalled $144,900 provided by NRC, DRB and the University of Western Ontario.

Université Laval

The Université Laval began research related to atmospheric physics in 1945. In the Laboratoire de Physique Atomique et Moléculaire, Département de Physique, now directed by Paul Marmet, an improvement of an ionic focalization system for a mass spectrometer made possible a series of measurements on the structure of the atmosphere using new experimental techniques. Experiments were undertaken which simulated ionic and molecular conditions characteristic of the upper atmosphere. These investigations included hydrogen, helium and nitrogen at low pressure. A resumé of research subjects is given in Appendix C.

Three members of the professorial staff and 8 graduate students are associated with this program. Yearly research grants currently total $27,000 from NRC and DRB, with further support from the University and the Quebec Provincial Government amounting to about $16,500 per annum.

University of British Columbia

The Institute of Earth Sciences, University of British Columbia, established in 1957 under the directorship of J.A. Jacobs, includes research in the upper atmosphere as part of its overall program. The aspect of interest is the transmission and morphology of geomagnetic disturbances, particularly geomagnetic micropulsations. Three members of the professorial staff and 5 graduate students are engaged in the work of the Institute. The construction of the Queen Elizabeth Telescope in British Columbia some 250 miles from Vancouver, and the decision to transfer the government astronomical laboratories to the campus of the University of British Columbia will undoubtedly influence the direction of space research interests at this University.

York University

The inauguration of graduate work in the physical sciences at York University in 1965 led to the formation of an interdisciplinary organization under the directorship of R.W. Nicholls called the Center for Research in Experimental Space Sciences, in which research and graduate work is done in the broad area of experimental and theoretical physics and chemistry of the earth's atmosphere, other planetary atmospheres and astrophysical phenomena. Some of the staff for the new Center have been drawn from the upper-atmospheric chemistry group at McGill University and the laboratory astrophysics molecular excitation group at the University of Western Ontario. In much of this work the basic experimental techniques involved are those of optical and mass spectroscopy, ion beam spectroscopy, shock tubes, lasers and interferometry, and gas phase kinetic chemistry. Quantum mechanics and computers are used in the theoretical program.

Ten members of the professorial staff holding appointments in undergraduate departments are associated with the Center. About a dozen students are already engaged in its programs. Space has been allotted to the Center in a new building to be occupied in 1968.

Other University Groups

Many small but highly qualified groups in universities across Canada are engaged with plans or active participation in a wide range of subjects in the upper-atmosphere and space field. The universities involved are Dalhousie University, Nova Scotia Technical College, University of New Brunswick, Departments of Mechanical Engineering, Physics and Meteorology at McGill University, Université de Montréal, Department of Chemistry at the University of Toronto, University of Manitoba, Departments of Electrical Engineering and Physics at the University of Alberta, University of Calgary, University of Victoria and the Canadian Services College at Royal Roads. The following areas have attracted their interest: time variation studies on meson and photon components near sea level (cosmic rays), model simulation of solar wind interaction with the magnetosphere, relation of the energy of charged particles in the Van Allen radiation belt to local acceleration mechanisms in the magnetosphere, distribution functions of auroral electrons, wave propagation in ionized media, photometric ground-based observations of twilight sodium emission from the upper atmosphere, the natural electromagnetic background particularly at low frequencies, attenuation due to rain in a communication link between a ground station and a satellite, reaction of active nitrogen with fluorocarbons, free-radical and ion-molecule reactions, polar-night jet-stream zonal wind system, study of size, momentum and spatial distribution of micrometeorites, development of a device for accelerating micron-sized particles, effects of ion bombardment on metals and other materials, supersonic ramjets and plasma propulsion, stress analysis of solid-propellant rocket motors, aerial imagery systems for earth and lunar mapping, culturing of green plant tissues to produce oxygen by photosynthesis. The total numbers of university professors and students involved in the various projects are about 20 and 30,

respectively. The total annual operating funds amount to $155,000, exclusive of equipment items.

Canadian government support of this program totalled $740,000 in 1966, mainly from DRB and NRC. In addition various US agencies have supported research in Canadian universities, mainly at SRI, UTIAS, York University and the University of Western Ontario. For example, this support amounted to $410,000 in 1966 in addition to the $1,150,000 to HARP. The charts in Appendix D, figure VII, show this information. Two research contracts to SRI from NASA in 1963 and 1965 totalling $217,000 were not included in the charts as these seemed to be special non-recurring cases which would have confused the trends.

3.2 HARP-McGILL*

The HARP-McGill Program started early in 1962 as an engineering research effort to utilize large-bore guns to launch projectiles to high altitudes. Work started under G.V. Bull in the McGill University Department of Mechanical Engineering, with a contract from the US BRL. A 16-inch vertically-firing gun was installed on the island of Barbados, and firings commenced early in 1963. The vehicles, called Martlets, were designed by McGill and fall into 2 categories, ballistic glide vehicles and rocket vehicles.

The 2 types of ballistic glide vehicles, Martlets 1 and 2, which are characterized by high muzzle velocities and high ballistic coefficients, are sub-calibre and are fired with a wooden sabot which supports them in the barrel.

The rocket vehicles are called Martlets 3 and 4. The gun effectively replaces the first stage booster and guidance and control system of a multi-stage rocket. These vehicles are launched with generally lower muzzle velocities, the earlier vehicles being sub-calibre and sabot-launched, the more recent designs being full-bore with flipout fins.

The primary problem relating to the vehicle and its payload is that it must survive the very high launch accelerations experienced in the gun barrel. Typically, these peak accelerations range from a few thousand up to 60,000g** depending on gun calibre and vehicle weight.

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* For distinction between "HARP" and "HARP-McGill" see Part III, Introduction

** This means with an acceleration 60,000 times the acceleration due to gravity.

In 1964 the Canadian Government joined the program, and funding was increased substantially by a sharing arrangement between the US Army and the Department of Industry (DOI). This Canadian participation will terminate in June 1967 at which time the Canadian Government investment in the program will have been $4,300,000, and the US Army will have invested $3,716,000.

The development of the ballistic glide vehicle has been rapid. Over the past 2 years, about 100 to 150 firings per annum have been conducted with the operational Martlet 2C, which can carry a 30-lb chemical payload to altitudes of 165 km. This will be replaced next year by a more nearly optimum vehicle, the Martlet 2G, with a higher capability.

The main unknown with rocket vehicles is their capability of withstanding the high launch accelerations. The early rocket program was devoted to this problem for solid propellants, and a range of sub-calibre vehicles (Martlets 3A, 3B and 3C) were fired. By 1965, solid rocket motors with relatively long grains had successfully withstood launch accelerations as high as 11,000g. Work is now progressing on the more nearly optimum full-bore rocket vehicles. The Martlet 3D is a 16-inch vehicle capable of firing 200 lb of payload to an altitude of 700 nautical miles, and the Martlet 3E is a 7-inch vehicle capable of firing 10 lb of payload to an altitude of 250 nautical miles.

Currently guns of 3 sizes are used in the HARP program: the BRL 5-inch gun, a 7-inch gun and the 16-inch guns. The 5-inch gun has been installed in a number of locations including Barbados, Highwater, Wallops Station, Virginia, White Sands Missile Range, New Mexico, and Fort Greely, Alaska, for synoptic meteorological measurements, and data is now being fed into the metsonde network. The 7-inch gun was modified by SRI and will be used to fire the Martlet 3E.

A considerable amount of development has gone into the improvement of the 16-inch guns to increase muzzle velocity. The gun at Barbados was extended to 120 ft in 1965, and now a complete range facility exists there, including tracking stations on other islands, integrated with the Eastern Test Range. Installations of 16-inch guns now exist at Highwater for horizontal test firings at Yuma Proving Grounds, Arizona, for vertical firings. The Yuma facility is used for vehicle development because the vehicles can be recovered after firing.

The effects of scale are significant in charting the future of HARP. In general, vehicle weight can be increased as the cube of diameter for similar trajectory performance and internal ballistics. The peak launch acceleration decreases inversely with increasing diameter. For this reason, future efforts will likely be devoted to a 32-inch gun design. This leads to a very large installation since gun optimization studies show that lengths of 200 to 300 calibres are desirable.

Future HARP vehicles will have orbital capabilities. Two approaches are being pursued; first, a relatively light vehicle launched at high muzzle velocities; and second, a relatively heavy vehicle launched at lower velocities. The first vehicle, called the Martlet 2G-1, is sub-calibre and will carry a 350- to 400-lb 2-stage rocket motor. It will glide to an apogee of about 100 miles, at which point the motor is to be fired to attain orbital velocity. A 16-lb payload may be orbited by this method in 1967. The second is a full-bore 16-inch vehicle called the Martlet 4. It is a 3-stage rocket capable of orbiting 60 lb at 300 miles in an all-solid propellant version, or 100 lb at 300 miles with 2 liquid propellant upper stages. No liquid rocket engine has yet been successfully fired from a gun, hence it is likely that completion of the Martlet 4 orbital vehicle is still some time away.

An attitude control system is being developed by Aviation Electric Limited to control the altitude of Martlet 4 prior to second and third stage ignition. This system has been under development for 3 years. All of the components have been launch-tested using a 6-inch gun located at Nicolet, Quebec. The first complete system will be fired in a Martlet 2E in 1967. Parts of this system will be used in the Martlet 2G-1.

The application of the HARP vehicles has been in upper-atmosphere scientific programs and military research. The Martlet 2C has been used to release a stream of trimethylaluminum (TMA) to determine wind shear and relate this to ionosphere drift measurements. This application has involved a large number of firings, where measurements of other parameters have also been undertaken to investigate correlative phenomena. Numerous military experiments and studies have also been conducted; for example the Martlet 2G-1 has been studied as a re-entry target for Nike X, where the vehicle is reoriented at apogee and fired downward to create re-entry phenomena.

HARP is truly an international program, and there is very close integration between SRI and the US agencies such as BRL. SRI have stated that the cessation of Canadian Government funding will not materially affect current programs in progress, and that HARP-McGill will be fully supported by the US Army beyond 30 June 1967. A summary of expenditures on the project is given in Appendix D, figure VIII.

Because of the extensive discussion of the HARP project within the scientific community, a more thorough study of this project was made than was deemed necessary in the case of other projects. The results of this study are presented as a separate source document in Part III of this Report.

Chapter 4

INDUSTRIAL PROGRAMS

4.1 CURRENT INDUSTRIAL PROGRAMS

This section is intended to present a comprehensive view of the history and present status of industrial upper atmosphere and space activities. These activities have arisen, at least initially, from programs generated by the Canadian Government; although, particularly in the area of communications, the domestic commercial market is of sufficient magnitude to generate company-sponsored programs quite outside of government-generated activities. In many cases Canadian Government programs created the skills and facilities necessary for the companies to broaden their activities significantly into export markets. This situation is of such significance to Canada that it will be dwelt upon at greater length elsewhere in this report.

Due to limitations of space in this report, only the highlights of the current industrial programs are touched upon. In the main, only companies with upper atmosphere and/or space activities are covered; although some mention is made of industrial capabilities hitherto not involved directly in these areas where these capabilities have direct applicability to future Canadian efforts. The companies with the major programs are dealt with first.

RCA Victor Company Limited

Since about 1960, RCA Victor has made a progressively deeper commitment in space work. This has covered 34 programs of space research by scientists in the Research Laboratories, 7 programs of design and manufacture of satellite systems, and 16 programs of design and/or manufacture of earth station systems in support of satellites. Over the past 6 years space work at RCA Victor has been performed for 31 separate agencies to a total value of almost $29,000,000. Almost $9,000,000 of space work was performed by the Company in 1965.

RCA Victor divides its space activities into 3 main areas:

(a) space research,
(b) satellite work,
(c) earth-based facilities in support of satellites.

(a) Space Research

A large proportion of the work being undertaken at the RCA Victor Research Laboratories is related to space activities. This work covers a broad spectrum including plasma research, studies of satellite/field interactions, re-entry wake phenomena, communications and telemetry, lasers, solid-state detectors and electronic system design. A total of 22 scientific personnel and 8 non-professionals are currently involved in space research (1966). Broadly, this work falls under the following headings:

Radar properties of re-entry plasma wakes, effects of plasmas on antennas, simulation of geophysical phenomena, cyclotron harmonics for magnetic-field measurements, research on gaseous plasmas and plasma lasers, studies of ionic propulsion for space vehicles, bubble boundary-layer instability, flame plasma effects, chemical seeding of flowing plasmas, radio spectrum from 10Gc to 300Gc in aerospace communications, circuit research, satellite telemetry development, ISIS, infrared detectors for upper-atmosphere studies, plasma, microwave and nuclear particle instrumentation (developed for other projects but applied to space as well).

The facilities utilized for this research are valued at $1,000,000, and include:

Three experimental facilities for studying solar wind-magnetosphere interactions, experimental facilities for investigations of satellite-induced perturbations, re-entry wake phenomena, free-space microwave interaction with plasmas, for measuring antenna behavior in the ionosphere and for construction, measurements, and operation of gaseous lasers.

About 50% of space research at RCA Victor is for US space agencies, and the remainder is related to the current domestic activities on space. Total value of the space research programs from 1960 to 1966 is about $4,100,000.

(b) Satellite Work

Satellite work started at RCA Victor in 1961, with the development and manufacture of repeaters, beacons and simulators for the Relay communications satellite. This was followed by the design,

development and manufacture of solid-state true FM telemetry transmitters for the Alouette I and Explorer XX satellites.

In September 1963 RCA Victor competitively won the prime contractor role for the Alouette II and ISIS-A satellite programs. Activities on the Alouette II involved the development and manufacture of telemetry and tracking transmitter equipment, as well as assistance to DRTE in phases of design, construction, testing and launching of the spacecraft. On the ISIS-A Program, RCA Victor carries the management responsibility for spacecraft design, development, manufacturing, integration, test and launching. Certain major aspects are sub-contracted, but the final satellites are integrated and prepared for launching at RCA Victor facilities. Early planning and design work is now starting on the ISIS-B satellite.

Facilities for design and manufacture of satellite systems include a special engineering office and laboratory, a "clean" spacecraft integration area, special test equipment worth about $400,000 and a spacecraft component assembly area. In addition, RCA Victor has an environmental test laboratory, valued at about $500,000, which contains equipment capable of testing components and systems through many of the space environmental requirements.

The RCA Victor satellite work is valued at $10,800,000 from 1960 to 1966, of which about $2,000,000 has been for US programs, the balance has been in Canadian programs. In 1966 a total of 44 graduate engineers are involved.

(c) Earth-Based Facilities in Support of Satellites

Work related to satellite earth stations started at RCA Victor in 1959 with engineering studies and investigations on antenna feeds for deep probes. This resulted in the supply of feed systems for the 85–ft diameter antenna for the Mariner IV Venus probe, and preliminary design studies of the feed for the Jet Propulsion Laboratory (JPL) 200–ft diameter Deep Space Probe Facility. In 1961 to 1962, RCA Victor engineered and supplied the 26–bay tracking control console of the Prince Albert tracking station, and conducted a program definition phase for the Mark 1B US military transportable communications satellite earth station.

Other important programs include the development and supply of equipment for 3 ATS satellite earth stations, evaluation of components for, and the design and supply of, a satellite simulator for NASA. RCA Victor also checked out the ground stations at Goonhilly, Plemeur Bodou, Ruccino, Mojave, Butley and Rio for operations with Relay I and II.

The major Canadian activity on earth stations has been the systems integration, management, sub-system design and manufacture for DOT's communications satellite earth station at Mill Village, Nova Scotia. This work was completed in February 1966. RCA Victor has also conducted a 50/50 cost sharing program under DOI covering the development of low-noise equipment and devices for communications satellites. These activities have involved expenditures of over $11,500,000 in the past 4 years.

As a company-sponsored venture, RCA Victor designed and developed an APT ground station for receiving pictures from the Tiros and Nimbus weather satellites in 1964.

Since the completion of the Mill Village station, work has been devoted to the design and manufacture of equipment for COMSAT earth stations, company-sponsored system engineering activities, and proposal and marketing work related to new facilities, both domestic and foreign, which may be potential business in the near future.

The facilities for earth station work involve engineering offices and laboratories, test equipment valued at $350,000 and an enechoic chamber. A total of 63 graduate engineers were employed in this area at the peak of the Mill Village work in 1964, and the total business volume over the years 1960 to 1966 has been $14,000,000.

The de Havilland Aircraft of Canada Limited, Special Products and Applied Research Division.

Activities related to upper atmosphere and space began at de Havilland in 1960 with the inception of the Alouette I spaceframe design contract with DRTE. Coincidentally, de Havilland also undertook the design, installation and operation of radiometric equipment in CF–100 aircraft for use in rocket re-entry and exhaust studies, and atmosphere transmission measurements.

The unique sounder antenna requirements of Alouette I led de Havilland to exploit a concept, originally conceived by George Klein of NRC, for unfurling long overlapped metal tubes stored as a flat tape on a drum in the satellite. This technique led to a family of devices known as the Storable Tubular Extendible Member (STEM), and this has become a major export item for the Company over the past 5 years.

Today, de Havilland divides its space-related activities under three headings:

(a) space systems,
(b) aerospace STEM products,

(c) electro-optical systems.

During the period 1960 to 1966, over $6,000,000 of business has been executed in those areas which have *direct* space relationships. This has involved approximately 50 professional and 25 non-professional personnel during the past year. The space systems activities relate solely to Canadian programs, representing about $1,700,000; the balance of about $4,300,000 has been export business.

(a) Space Systems

This activity has been carried out entirely in support of the Canadian scientific satellite program of DRTE. It started in 1960 with the design, development, manufacture and test of the Alouette I spacecraft structure and its associated sounder antennas. During this program a separate Javelin rocket nose cone payload was developed, built and flown to test the integrity and design of the satellite sounder antennas, which had a tip-to-tip extended length of 150 ft.

Since 1963, de Havilland has been the associate contractor for the Alouette II/ISIS program, with RCA Victor as prime contractor. The responsibilities of de Havilland center around the spacecraft structure, as in Alouette I, but have been extended to complete spacecraft structural layout and design, thermal design, antenna and other device mechanical design, orbit calculations and vehicle dynamic analyses. On Alouette II de Havilland provided manufacturing services, sounder antennas and support personnel at DRTE and at the launching range. On ISIS-A the structure and mechanical devices, including handling and support equipment, were built, tested and integrated by de Havilland, and personnel have been provided on a continuing basis in the Systems Management Office at RCA Victor. De Havilland also provided staff for the satellite payload teams which will follow the spacecraft through assembly, integration, testing and launching. Planning and preliminary design work is now starting on ISIS-B.

(b) Aerospace STEM Products

Starting with the Canadian Alouette I satellite, these devices, in one form or another, have found their way into many of the major U.S.A. space programs. Over 100 satellites have been successfully placed into orbit carrying STEMs, some of which use many of these devices. Both the Carpenter and the Schirra Mercury flights used 2 STEM antennas. The high frequency (HF) orbital and recovery antennas of project Gemini, and the two UHF antennas were STEMs. In addition, some flights carried STEMs as magnetometer booms and dipole antennas for special purposes. Also, the Agena rendezvous vehicle used a STEM for supporting the transponder antenna. This boom, with its spiral cable feed to the antenna, has been most prominent in the widely published photographs of Agena taken by the astronauts during extra vehicular activity (EVA) operations.

The recovery antenna of project Apollo will be a STEM; all of the Alouette-ISIS satellites use STEMs as the sounder antennas; the ATS satellites will use 5 STEM booms as stabilizers in certain of the gravity-gradient versions; the gravity-gradient stabilizer in the Transit navigation satellite series employs a STEM; satellite experiments using STEMs have been flown in Pogo and Explorer XX.

A number of Naval Research Laboratory (NRL) satellites and rockets have used STEMs as antennas and gravity gradient rods, such as Lofti, and the dodecahedron satellite. The latter used 12 self-erecting STEMs on each vehicle as a passive reflector; Applied Physics Laboratory (APL) satellites such as the TRAAC, GEOS, and DODGE use STEMs. In addition a wide variety of agencies aside from those listed have tested or flown STEMs on satellites and rockets. STEMs have also been purchased by the Paris Observatory, and flown successfully in its rockets.

STEMs have been used for a broad range of applications, which include antennas, support booms, gravity-gradient rods, actuators, space structures, space-rendezvous and grappling devices, and distance-sensing systems. Currently the technology assembled in this activity is also being applied to the application of STEMs on the ground for use on vehicles and fixed installations.

(c) Electro-Optical Systems

Since 1954, de Havilland has been involved in the field of infrared detection systems. Part of this work was directed to the development of vehicle-borne radiometric and spectrometric equipment for detecting and measuring emission from aircraft and rockets. This has involved participation in a number of US programs in which de Havilland designed, developed, supplied and operated special airborne electro-optical equipment. Current work involves the development of interferometric spectroscopic and laser-type instruments, and small, closed-cycle, cryogenic cooling systems suitable for use with electro-optic detectors.

Bristol Aerospace Limited

In 1960 BAIL entered into a contract with the Canadian Government under which, in consideration of a market survey, 3 rockets were to be designed and developed in the following sequence:

Black Brant III a small rocket with limited payload volume to be used mainly for single-user experiments with a design objective of 40 lb to 110 miles.

Black Brant IV a 2-stage rocket utilizing the CARDE developed 15KS25000 engine used in Black Brant I as a booster for Black Brant III with a design objective of 40 lb to 600 miles.

Black Brant V a large single-stage rocket with a nominal performance of 150 lb to over 200 miles.

In return for Government funding of this program, BAIL undertook to construct a solid propellant plant at Rockwood near Winnipeg, Manitoba. Work on this plant commenced in 1961, and the plant was opened for production in 1963. The details of the Black Brant program are covered in Section 4.2.

BAL, in addition to carrying on the rocket development program, has undertaken to establish payload integration and range services. At the same time, BAL acquired the skills and experience necessary to launch rockets from ranges throughout North America, so that a team of highly qualified engineers and technicians can take Black Brant vehicles to launch sites, prepare them for use, conduct the final check-out of vehicles and payload and assist the ranges in launch operations. Several experimenters have had their packages completely developed by BAL.

After co-ordinating the future requirements of a number of agencies involved in meteorological work, the US Army has initiated a program to develop 2 small rocket systems, and negotiations are being conducted between Canada and the US for a joint project, with BAL as prime contractor. Portions of the work will be done by CARDE and the US Army Technical Commands.

The Rockwood propellant plant manufactures not only Black Brant rocket motors but also jet-assisted take-off (JATO) motors for the military forces of Canada, US, Norway and Belgium. Since 1963 CBA–BAL filled or is filling 11,481 motors.

BAL has become a qualified development source for new propellant and propulsion systems. Programs to demonstrate the capability of the plant to produce the items to specification are undertaken on a continuing basis.

The Bell Telephone Company of Canada

Bell Canada has undertaken to participate in research and development programs and to acquire and develop the engineering skills essential to the economic exploitation of new communications techniques. The successful operation of active satellites for communications purposes by Bell Telephone Laboratories and others has led to specific technical and economic studies by Bell Canada on questions relating to the application of satellite communications techniques as a means of providing for Canadian domestic requirements.

In the large sparsely settled area of the eastern half of the Canadian Arctic Bell Canada has been actively constructing a telecommunications network suitable for carrying out local communications and for providing connections to the populated areas to the south. This has been accomplished by the creation of an HF radio system connected to the main telephone network via backbone line-of-sight and troposcatter radio relay systems. This network will require reinforcement during the 1970's to keep pace with growing requirements for a full range of services with adequate transmission quality. Recent studies comparing possible communications systems for this northern service have indicates that a communications satellite system is the most promising approach.

Design requirements have been established by Bell Canada for an arctic satellite communications system, and a decision was made to undertake a major effort in this new field by developing a unique earth station, specifically tailored to the environment of northern Canada. Northern Electric Company Limited Research and Development Laboratories have contracted to design and construct a prototype of this station to be installed at Bouchette, Quebec, about 50 miles north of Ottawa. The station is to be ready for testing in 1968, and evaluation is to be completed in 1969 for service in 1970 as the first northern site. It will then become the main southern control terminal for the system to the north.

The northern Canadian environment imposes unique requirements on system design introduced by weather conditions, remoteness of sites, the small size of the communities to be served and low circuit requirements.

Northern Electric Company Limited, Research and Development Laboratories

The space activities of Northern Electric have been primarily devoted to the development and manufacture of ground terminal equipment. Beginning in 1961, the Company undertook studies in the state of the art of communications by satellite including investigation of modulation methods and of multiple-access techniques. In 1962 it carried out an exploratory evaluation of proposed system techniques

on behalf of, and partially funded by, RCAF. An extensive proposal for a tactical transportable ground terminal of unique design was provided to RCAF in 1963. Between 1964 and 1966 a precision 30–ft satellite-tracking antenna was designed and manufactured for DRTE at Shirley Bay. A considerable amount of design experience and capability was drawn from another Government financed military radar program having some complementary areas of interest.

In 1965 and in co-operation with Bell Canada, a technical and economic study was made of a satellite communications system to provide telephone, teletype and TV service to communities in Canada's Far North. This study culminated in a decision in mid-1966 to proceed on an experimental basis with Bell Canada on the first phase of this project: the design of an unattended arctic terminal for field trial at Bouchette, Quebec. This station is described under the Bell Telephone Company of Canada, above.

A study is being carried on to develop the best transmitting, receiving and modulation techniques for multiple-access satellite-communications systems. This involves application of communications theory and a study of the use of digital communications in satellite communications.

This program is oriented specifically to Canadian requirements and is being carried on in close association with the Telephone Association of Canada and DOT. However, a foreign market exists for such ground stations, particularly in countries in similar geographical and population distribution characteristics to Canada.

The Telephone Association of Canada

The Telephone Association of Canada consists of 13 member companies which collectively account for 94% of Canadian telephones.

The Association holds membership in the consultative committees of ITU namely, the International Telegraph and Telephone Consultative Committee (CCITT) and the International Radio Consultative Committee (CCIR), and takes an active part in the work of these bodies.

In 1965 the Association conducted a test program to determine the probable reaction of Canadian subscribers to telephone connections involving intercontinental facilities with transmission delays. The intercontinental facilities considered included submarine cable, medium altitude satellite systems and synchronous satellite systems, in combination with national extension circuits ranging up to 6,000 km in length.

The test program was conducted on the basis of simulating the various intercontinental facilities and national extension circuits by building out a Montreal-Toronto telephone circuit to exhibit the appropriate transmission delays and noise. In addition, the test circuit was equipped with echo-suppressors to simulate those included in the intercontinental facilities and in some cases with 2 echo-suppressors in tandem to simulate situations involving an inter-continental circuit in tandem with a long national extension circuit equipped with an echo-suppressor.

The built-out telephone test circuit was arranged to carry regular telephone traffic between Montreal and Toronto. Subscribers making calls over this test circuit were interviewed shortly after completing their call and requested to reply to specific questions concerning the quality of transmission rendered.

The results of this test program were made available to CCITT in January 1966. CCITT used this along with other similar tests to recommend application areas of satellites to telephony, in order of desirability and preference.

Canadian Overseas Telecommunication Corporation

COTC is a Crown corporation, and started active work on communications satellites in 1961 by participating in a Commonwealth Satellite Communication Team. This was a 15-month feasibility study conducted in the United Kingdom, and had representatives from Australia, New Zealand, Canada, India and the United Kingdom.

In 1964 COTC, in conjunction with 10 other signatories, was an original signatory to the agreement establishing ICSC, described in Section 2.3.

COTC will maintain and operate the DOT Mill Village, Nova Scotia, tracking station in the near future, for an interim period, in order to work with the Early Bird satellite on a time-sharing basis with Andover. For this purpose, a broadband microwave interconnection has been provided between Mill Village and Andover. Also, broadband rearward communications from Mill Village to the COTC International Maintenance Center in Montreal have been provided. When the Apollo communications satellites, INTELSAT II, are launched in the fall of 1966, some capacity will be available for commercial purposes, and it is anticipated that Mill Village will, on the days it is not using INTELSAT I (Early Bird), provide TV service when required via the INTELSAT II satellite.

COTC participated in the evaluation of the proposals and final decision of the type of system to be provided for the INTELSAT III interim global system. Since the Mill Village station was planned, ICSC has defined the parameters of a "standard" earth station. COTC will shortly be soliciting tenders in response to specified requirements for such a commercial station, to be located near Mill Village and available for the INTELSAT III interim system late in 1968.

Computing Devices of Canada Limited

Computing Devices of Canada (CDC) began its work in aerophysics in 1956 with the assignment of 6 people to the Velvet Glove missile project at CARDE. With the subsequent growth of the CARDE light gas-gun program, the number of CDC people at CARDE grew to some 70 or 80 persons.

In 1961 a light gas-gun range and associated small aerophysics laboratories were established at Stittsville, Ontario to provide an industrial base from which aerophysics work using gas-gun techniques could be done on a commercial basis. This became the Space Sciences Division in 1965, and now employs some 200 technical people, 50 of whom are at Stittsville, 75 at CARDE, 50 on the management contract for the HARP Barbados Range and the remainder in field stations at Cold Lake and Resolute Bay, Northwest Territories.

The Canadian Government support of the Company's work in aerophysics has consisted in the main of one grant from DRB, matched by the Company, to do hypervelocity impact studies during the period 1963 to 1966. In 1964 a 50/50 DOI/CDC program was started to support the development of high-g telemetry, and to conduct design studies leading to improvements in light gas-gun design. A 250 mc transmitter has been developed and prototypes are to be tested shortly on the McGill 16-in gun at Barbados.

A direct result of the gun design work was the award of a NASA contract for the manufacture and installation of a micrometeoroid simulation device at Huntsville, Alabama. This will be installed in 1966, and work is proceeding on a possible program to develop a further improvement to achieve a higher gun velocity (50,000 ft per sec). NASA has also awarded a contract for the supply of prototype FM transmitters which can withstand a high-level impact shock.

The majority of people employed at CARDE are supplied under contract to the US Army, Redstone Arsenal, in support of the CARDE program of light gas-gun firings to study turbulent wakes created by high-velocity projectiles.

The in-house research and development efforts have been centered on ballistics: internal, external and terminal. Work has also been carried out on fluid flow, aerodynamics and re-entry physics research. Currently a program is being planned to develop a meteorological probe for measurement of atmospheric conditions in the 100- to 300,000-ft altitude band using gun-launched probes instead of rockets. A decision to pursue this program has yet to be made.

Aviation Electric Limited

In 1963 Aviation Electric Limited (AEL) started work on the design and development of an orbit injection control system suitable for use with the HARP Martlet 4 space vehicle. The details of this program are discussed in Part III of this report. This program currently involves 5 professional and 5 non-professional people, and the expenditures to May 1966 have been $315,000.

E.M.I. Cossor Electronics Limited

Work at EMI Cossor (EMIC) has been directed primarily to the design and manufacture of ionosondes and HF communications equipment. In 1962 the company undertook the development of a commercial pulsed sounding system (Ionosonde Type 8000).

EMIC has undertaken a broad research program in the field of effective measurement and use of HF communications channels. The company has recently developed equipment for the CURTS system, under contract to the US Navy, and designed the so-called optimum frequency detector for the USAF Rome Air Development Center.

A Directorate of Industrial Research (DIR) research program carried out during the last 2 years is now approaching completion. This program was prompted by the need for improvements in the EMIC ionospheric sounders development activities, following the development of the Ionosonde Type 8000. This equipment was based on the use of standard sounding pulses, and accordingly the main objective of the research was to study the linear-integration techniques which could lead to the improvement in the signal-to-noise ratio of a system of this nature. Recently, a new technique based on the matched-filter principle has been incorporated in the ionospheric sounders for CURTS. This technique greatly improved the sounder's performance, but further improvements can still be effected. A new research program is being planned to investigate a variety of other techniques.

Development funding for EMIC since 1964 has been shared with the Crown, by means of a DOI contract. This development led to the production of the CURTS system, referred to above, which consists of a transmitter, the AN/FPT–11(XN) (V) and a receiver, the AN/UPR–2(XN) (V). Twenty of these receivers and 2 of these transmitters are being provided to the Bureau of Ships, Washington, District of Columbia. Further development work is being planned for a tactical sounding receiver for mobile ground or airborne use.

Currently, EMIC employ 20 professional and 35 non-professional personnel in these areas. In addition, about 23 EMIC personnel man the Minitrack Satellite Tracking and Data Acquisition Network (STADAN) Station near St. John's, Newfoundland for NASA and NRC. Test installations consist of the Hammonds Plains Communications Transmit-Receive and Development Facility, valued at $150,000.

Canadair Limited

Canadair's first venture into upper atmosphere and space work was in 1958 when, in conjunction with CARDE, the design and development of the Black Brant II sounding rocket was undertaken. In support of this basic vehicle, the Company undertook studies of higher altitude performance versions, and also studied and proposed a payload recovery system. As a part of a contract with USAF, an altitude and spin stabilization system for Black Brant II nose cones was designed.

A further effort in the rocket field was a USAF study to determine the feasibility and cost-effectiveness of an air-launched rocket test facility suitable for aerodynamic, thermodynamic and materials testing in anticipated hypervelocity flight paths in the upper atmosphere. The studies showed this method would not compare favorably with available ground test facilities.

In the field of hypervelocity propulsion systems, Canadair studied the feasibility of conducting an in-flight demonstration of a supersonic combustion ramjet (scramjet) with the McGill Propulsion Laboratory. US funding did not materialize, due to the sensitive security aspects of this field within the US.

In 1960 Canadair won a study contract from USAF on emergency escape from multi-crew earth-orbiting vehicles. The results concluded that emergency escape systems were within the capability of Canadian industry, and a further study was undertaken for USAF to refine concepts, and to select the best concept. A proposal for further studies to investigate an expandable-disc re-entry escape concept for space stations was not accepted by USAF.

In the satellite communications field, Canadair applied its capabilities to the area of large antenna structures and their drive systems. The first effort was a bid, with Northern Electric, for the development of an air-transportable terminal for RCAF; and the first contract was for the development of a satellite-tracking antenna for DRTE at Shirley Bay. Canadair and Northern Electric successfully completed this program, and the 30-ft diameter antenna has proved very successful in operation, and has met or exceeded the very stringent performance requirements. Proposals have also been submitted for several other satellite ground-station antennas, including an 85-ft antenna for the COTC east coast terminal.

The total expenditures since 1958 on these various activities have amounted to about $1,800,000.

CAE Industries limited, Electronics Division

The work of CAE commenced in 1963 on the reception of high-grade pictures from weather satellites and general picture improvement techniques which might apply to weather satellite work, or other picture transmitting reconnaissance satellites. This has resulted in the CAE weather satellite APT ground station, 2 of which have been sold to DOT. This work will continue through fiscal year 1966-67, and employs about 1½ professional and 2 non-professional people each year.

Apart from the research and development laboratories, and the electronic plant, CAE has special facilities that are used for satellite TV picture reception and improvement. The Company also operates a special low-noise magnetic test facility at St. Hilaire south of Montreal, Quebec, which would have application to satellite magnetic experiments.

Canadian Westinghouse Company Limited, Electronics Division

Canadian Westinghouse, Electronics Division, has participated in a number of programs involving techniques or capabilities that have relevance to upper-atmosphere and space activities. In addition, several proposals have been put forward by the Company on space-related work which involved significant input and effort on the part of the Electronics Division.

The Canadian Westinghouse facilities include a relatively comprehensive environmental laboratory, research and development laboratory, IBM System 360, Model 50 digital computer, PACE general purpose analogue computer, microwave laboratory, outdoor and indoor microwave antenna ranges and engineering services (technical

publications, model shop, standards and calibration laboratory, etc). About 13 professional and 5 non-professional persons are currently involved in space-related activities.

Sinclair Radio Laboratories Limited

Work carried out by Sinclair Radio Laboratories has been concerned with the development of antennas, filters and cross-over networks. The initial work undertaken was a study contract for antenna systems for Alouette I, in which a recommendation was made as to the basic type of sounding antenna to be used. Work was also carried out on the cross-over network, telemetry antennas and diplexers.

Work was also undertaken to investigate antenna cross-over networks and telemetry diplexing systems for Alouette II, and to investigate the cross-over networks for ISIS–A. DRTE sponsored the Alouette I and II activities, whereas RCA Victor contracted for the work on ISIS–A.

Ferranti-Packard Electric Limited

Ferranti-Packard is conducting 3 research programs which could have relevance to upper-atmosphere and space activities.

The fuel-cell research program is aimed at producing highly reliable, efficient and economic power sources for primarily terrestrial applications. It is centered around the hydrocarbon-air molten carbonate electrolyte system with operating temperatures around 700°C, and envisages power densities of the order of 1/2 kw per cu ft, or one kw per 100 lb of battery. The application could be for remote tracking, transmitting or repeating stations.

Cryogenic research covers activity in superconductivity and cryogenic engineering. Superconducting magnets and low-temperature environment for low-noise maser receivers in communications systems, and superconductivity shielding magnets for satellite protection and certain experiments are potential areas of space application of this work. In cryogenic engineering, the work on super-insulated, multi-shielded dewars is relevant to the engineering of liquid-hydrogen systems.

There is a communications research project which relates to the prevention of errors in data-transmission systems, and could be applied to multi-channel ultra high frequency (UHF) and optical communications systems.

Barringer Research Limited

Barringer Research was approached by NASA in 1964 to submit proposals for the Apollo Applications Program, and after extensive preparatory studies, 2 proposals were submitted in 1965:

(a) spectrometric measurements of trace components of planetary atmospheres, and

(b) Radio Frequency (RF) pulse reflectivity measurements for terrain sensing and mineral exploration of planetary surfaces from orbiting platforms.

It was not possible to obtain Canadian support for these programs, and, in order to qualify for US funding, a US subsidiary was created in July 1965. These programs have since been NASA-funded, although at a reduced level since early 1966, because of Vietnam priorities.

Barringer Research has been involved from its inception in the geochemistry of planetary atmospheres, and special instruments have been developed with extreme sensitivity for the remote sensing of atmospheric gases such as iodine vapour, SO_2, mercury vapour, methane, etc. These instruments include the correlation spectrometer, the Michelson correlation interferometer and the Fabry-Perot correlation interferometer.

The RF work involved the development of a very broad band VHF chirp radar, which produces unique signatures when bounced off multi-layered surfaces. This can be used in the measurement of ice thickness and layering at the surface of planets.

These instruments have application to remote sensing from spacecraft, but are currently being applied to terrestrial systems in Canada.

Canadian Industries Limited

The Explosives and Ammunition Division of CIL has been manufacturing many rocket propellants and grains for the HARP Martlet 3 Program. This activity is currently at a relatively low level. Due to its close connections with Imperial Chemical Industries Limited (ICI) in the United Kingdom, CIL could have access to its technology provided this is established on a government-to-government basis.

Litton Systems (Canada) Limited

There are no active upper atmosphere or space programs currently in being at Litton Systems. Nevertheless, this Company has a major

Canadian industrial facility in the field of inertial navigation systems and components. Precision gyros, accelerometers, integrators, etc, are products of the Company, and this facility could have particular relevance to any future Canadian space program.

Atomic Energy of Canada Limited

The work of the Space Physics Group at AECL, Chalk River, Ontario has been covered in Section 2.1 of this report. The neutron monitor (NM–64) developed by this group has been adopted as a world standard. The neutron counters for this design were manufactured by Electronic Associates of Canada Limited, which has made extensive export sales of these items.

In all, some 30 NM–64 monitors are in operation around the world.

The Commercial Products Division of AECL has also done work in the past on the effects of radiation on rocket propellants and spacecraft components.

Summary

Two industrial assistance votes have been used to support Canadian industry, wherein the company and the Crown share in the costs of specific projects. The DRB DIR has assisted Canadian industrial research efforts in upper-atmosphere and space work in the fields of:

(a) TV signal processing
(b) STEM
(c) crew escape systems
(d) impact protection of satellites
(e) upper-atmosphere and plasma physics.

DOI has assisted Canadian industrial development efforts in upper-atmosphere and space work in the fields of:

(a) satellite communications
(b) satellite ground station systems
(c) APT picture receiving equipment
(d) HF Communications
(e) HARP
(f) aerophysics and high-g telemetry
(g) Black Brant rockets
(h) meteorological rockets.

For the current year approximately 335 industrial professional and 320 non-professional personnel are working directly on upper-atmosphere and space activities in Canada. During the period 1960 to 1966, the total combined value of funded and company-sponsored industrial upper-atmosphere and space programs was about $37,321,000. It was $17,068,000 for the year 1965. The approximate industrial capital investment in plant and facilities in these fields is currently about $17,362,000.

4.2 THE BLACK BRANT ROCKET PROGRAM

Introduction

This program covers the design and development of a family of upper-atmosphere research rockets, known as Black Brants. These rockets cover an altitude range of between 100 and 600 miles and carry payloads of 40 to 500 lb. The program originally began at CARDE, where Black Brants I and II were developed; the more recent rockets, Black Brants III, IV and V, have been the responsibility of BAL, Winnipeg, Manitoba.

Black Brants I and II

In 1956 CARDE[1] undertook a solid-propellant research and development program. This work led to the static testing of motors with 8- and 17-inch diameters. Once fuel development reached this stage, it was necessary to carry out dynamic tests on a flight vehicle.

Motor cases and other parts for such a vehicle were produced by BAIL (Canada) and their parent company, Bristol Aircraft Company (UK), to CARDE specifications. This Propulsion Test Vehicle (PTV) was a relatively heavy rocket, since it was designed to stand up to the use of a wide range of engine burning times, propellant loadings and launch angles associated with fuel development. This vehicle was renamed Black Brant and, once it had proved successful in the propulsion tests, was used for sending a number of scientific experiments into the upper atmosphere.

Propellant test objectives were achieved after 7 trial flights at Churchill in 1959 to 1960. In the period that followed, 10 Black Brant I's were used by CARDE, DRTE and NRC to launch nitric-oxide seeding, polar-cap ionosphere and auroral experiments to a height of 100 miles.

[1]Rocket Research in Canada, R.F. Wilkinson, CASI Journal, April 1959.

Following the success of Black Brant I, a more refined rocket was designed, with a lighter motor casing, larger fins, longer forward body and a more slender nose cone. This increased the available payload volume from 4 to 6 cu ft. Originally called Snow Goose[1], this rocket was renamed Black Brant II. This rocket was developed jointly by CARDE and Canadair to fill the requirements stated by Canadian agencies planning to conduct upper-atmosphere research with rockets.

The rocket motors for Black Brants I and II were developed by CARDE[2,3]. The Black Brant I motor is identified as 15KS25000.* The first static firing was in February 1959; and the first Black Brant I (PTV) was launched in October of the same year.

Black Brant IIA uses the Black Brant I rocket motor, now manufactured by BAL. The altitude performance of these vehicles is somewhat lower than that required for certain experiments. The most direct way to improve this was to increase the burning time of the motor and hence reduce the effects of aerodynamic drag, and to increase the total impulse of the motor. A new motor was developed at CARDE for this requirement, to be used in a vehicle called Black Brant IIB. The motor was identified as 23KS20000; this development[4], which encountered severe axial combustion instability problems, was completed in September 1964 and 4 test flights were conducted over the next few months.

A total of 55 Black Brant IIA's have been fired. NRC has been the main experimental user of this rocket. The first non-Canadian agency was the USAF Cambridge Research Laboratories (USAF/AFCRL).

Black Brants III, IV and V: Background[5]

In November 1959 BAIL submitted a proposal to DDP to make commercially available sounding rockets exploiting the successful

[1]Upper Atmosphere and Space Research in Canada, R.F. Chinnick, CASI Journal, October 1962.

[2]Manufacturing and Testing of Black Brant Engines, I.R. Cameron, Canadian Aeronautics Space Institute Journal, February 1961.

[3]Programmes in Rocket Propulsion at CARDE, I.R. Cameron, Canadian Aeronautics Space Institute Journal, December 1965.

*The 15 stands for the approximate burning time of the engine in seconds, and the 25000 for the approximate average thrust level; hence the total impulse of the engine is about 375,000 lb/sec. The S states that the engine contains a solid propellant, while the K indicates that this propellant is of the composite type. The 15KS25000 engine uses an aluminized ammonium perchlorate-polyurethane propellant which has been called CARDEPLEX.

[4]Development of the 23KS20000 Motor for the Black Brant IIB Vehicle, F. Jackson, Canadian Aeronautics Space Institute Journal, December 1965.

[5]Black Brant, Canadian Bristol Aerojet's family of Sounding Rockets, Flight, January 1965.

development by CARDE of improved solid propellants and rocket engines. The family of rockets is known as Black Brants III, IV and V. The feasibility of the design and development of this family was explored during 1960 and 1961, by BAIL, in co-operation with CARDE, with DDP financial support for 60% of costs.

The Canadian Government continued support of this project beyond 1961 on the basis of full Government funding up to $1,375,000, while BAIL undertook to construct a Canadian solid-propellant manufacturing, filling and static-test facility at an estimated cost of $1,500,000. This facility, which was to have a capacity of 200 tons of propellant per annum and to allow for future expansion, was to be built with technical assistance from the Aerojet General Corporation (Aerojet) of US, and was to use the CARDE propellant. In January 1963 the program was transferred from BAIL to Canadian Bristol Aerojet Limited (CBA) due to a company reorganization.

In November 1963 it was recognized that additional flights beyond those originally envisaged would be necessary to complete the development of these vehicles. In addition, responsibility for development of the Black Brant V motor was transferred from CARDE to CBA. At this stage it was estimated that the Black Brant development cost would rise to a total of $3,040,000 with facility establishment costs rising to a total of $2,074,000.

In June 1964, Crown support was approved for the costs of design and development of the family of Black Brant rockets on the basis of 100% up to an amount equal to the costs incurred by the contractor (with a ceiling of $2,700,000) for the establishment of the CBA manufacturing, filling and static test facility. Development costs thereafter were to be shared on a 50/50 basis by the contractor and the Crown up to a maximum Crown contribution of $3,040,000.

In 1965, the Aerojet interest was purchased by the Bristol Corporation and because of this extra investment, and the fact that the contractor had constructed a Canadian propellant manufacturing, filling and static-test facility at a current cost of over $2,560,000, it was agreed that the Crown would assume 100% of development costs up to a maximum of $3,040,000. On Bristol Corporation's purchase of Aerojet's equity in CBA, the name of the Winnipeg facilities was changed to BAL.

Propellant Plant

Construction of the propellant manufacturing, filling and static-test facility at Rockwood, Manitoba, (20 miles north of Winnipeg) is

complete. The plant was officially opened by the Hon C. M. Drury on 19 September 1963. Approximately 3,000 acres of land was acquired to allow for the required buffer zone and to provide ample space for future expansion. The present plant capacity is over 2,500,000 lb of propellant annually, based on a 2-shift 5-day week operation.

There are a total of 15 separate buildings. Remote-control centers equipped with comprehensive instrumentation and controls are located within concrete and earthen bunkers to add to the safety of the operators and to ensure consistent quality.

In addition to being able to process solid propellants of the CARDE design, the plant is capable of processing JATO units, and some Aerojet General fuels. With modifications it will also be possible to produce other propellants.

Black Brant III

This is a 10–inch diameter single-stage vehicle with a design objective of 40 lb to 110 miles altitude. Black Brant II uses a 9KS1100 rocket motor developed by CARDE[1]. BAIL assumed responsibility for the design and development of the vehicle and its diagnostic instrumentation.

The program proceeded rapidly with flight trials commencing in June 1962. The vehicle development and qualification program is essentially complete and the rocket is in production to fill Canadian and US orders.

It was intended to evolve a simple vehicle of low impact dispersion, yet adequate performance. Therefore is was necessary to develop structures and a propulsion system capable of withstanding very high longitudinal accelerations and aerodynamic heating.

Once the optimum aerodynamic configuration was established, and a motor providing the required performance was under development at CARDE, attention was directed to the severe aerodynamic heating problems. After extensive testing at BAIL and McGill University, an ablative insulation was selected for the structural design. Strength and stiffness tests proved satisfactory.

A total of 53 static motor firings without a failure qualified the motor for the flight trials. The latter began in June 1962, and were generally successful, although they indicated that aero-thermal-elastic effects were more severe than anticipated.

[1] Development of the 9KS1100 Black Brant III Rocket Engine, A.K. Roberts, CASI Journal, June 1962.

After suitable modifications, tests were resumed in December 1962, at which time trouble-free flights to within 1% of predicted altitude were achieved. In 1963 Black Brant III was selected as one of the competitors for the International Quiet Sun Year (IQSY) program. As a consequence, a motor-improvement program consisting of a series of 10 static firings was completed at the CBA facility in 1964 with satisfactory results. The new motor, which has now been proven in flight, achieves an altitude 20 miles in excess of the original motor, as a result of a reduction in inert weight of 28 lb and an increase in propellant energy.

This phase ended in April 1964 when a 52-lb useful payload was lifted to a height of 93.2 miles. Black Brant III is now in production for NRC (which commenced use of the vehicle with a very successful firing from Churchill on 21 April 1965) and vehicles have been ordered by others after evaluation in competition with all available US vehicles of similar performance.

The Black Brant III development program, including 9 dynamic flights, has taken some 3 1/2 years and an expenditure of $831,000. The vehicle has throughout demonstrated very high reliability and safety, and has proved adequate to meet the particular and frequently unique demands of experimenters. Vehicles with the latest configuration have achieved stable flight to 125 miles with a 50-lb payload.

Black Brant IV

This is a 2-stage rocket utilizing the 17-inch diameter Black Brant IIA engine as a booster for Black Brant III, with an objective of taking 40 lb to an altitude of 530 miles. The development of this vehicle commenced after completion of the Black Brant II basic design in the spring of 1962. Since the 2 basic vehicles were already developed, attention was aimed at solution of problems associated with the new combined vehicle. These involved redesign of the booster tail assembly, the use of drag flaps to avoid inter-stage bumping or premature separation, and the replacement of the Black Brant III tail fins with a conical stabilizer.

Although only 4 vehicles have been flown so far, the last 2 launched from Churchill in January 1965 met all test objectives; 108-lb useful payloads were lifted to altitudes of about 430 miles, or 95% of predicted value. The flights have demonstrated excellent stability, negligible vibration or lateral acceleration, and staging characteristics exactly as predicted. As with Black Brant III, BAL provided all vehicle-diagnostic instrumentation for the measurement of vehicle-component temperatures, motor pressures, vehicle motions, etc. While

the design is now 90% confirmed, the 2 unsuccessful fights are to be repeated, and 2 further flights are to be undertaken to provide the necessary statistical reliability data. These flights will be used also to demonstrate the ability of the vehicle to achieve the nominal performance of 40 lb to 600 miles.

Black Brant V

Black Brant V is a 17-inch diameter single-stage improved version of Black Brant IIA. Black Brant VA uses the same 15KS25000 motor as Black Brant IIA, but has a modified nose cone and fins. It can carry 200 lb of payload to an altitude of 125 miles.

Black Brant VB is similar in appearance to Black Brant IIA, but in fact is a completely new vehicle capable of lifting 200 lb to 260 miles altitude. This is achieved by the use of all new components including an Aerojet propellant now being produced by BAL at Rockwood, Manitoba. Component development was accelerated by flying nose and tail assemblies on otherwise standard Black Brant IIA vehicles (Black Brant VA).

The static motor development was carried out at Winnipeg and Rockwood, with technical assistance from CARDE in the investigation of combustion instability. In this study, 2 of the motors were shipped from Rockwood to CARDE for testing. A pulsing technique developed by CARDE was used to solve the problem of instability.

Motor development has been a combined BAL and Aerojet effort. At BAL, the motor case was designed and proof-pressure tested. Aerojet provided the propellant grain design and the basic configuration of the nozzle, whereas detail design of the latter was completed by BAL. The propellant was then manufactured, and the motors (designated 26KS20000) were filled and statically test-fired at Rockwood. These motors were "pulsed" using the CARDE-developed technique to demonstrate freedom from combustion instability.

The tail assembly uses a sandwich structure of aluminum honeycomb, bonded aluminum skins and Avcoat ablative insulation. The nose structure, comprising an epoxy-fibre-glass ogive, aluminum body and magnesium igniter housing has been successfully flown.

The first development flights of this rocket were made from Churchill in June 1965 and were completely successful, lifting a 306-lb payload to an altitude of over 1,200,000 ft.

Table 1 summarizes the primary performance and physical characteristics of the Black Brant family of rockets.

SUMMARY OF THE BLACK BRANT ROCKETS

TABLE 1

Vehicle	Nominal Payload	Altitude at Nominal Payload (85° Launch)	Payload Volume	Diameter	Total Length	Maximum Longitudinal Acceleration	Number of Flights (to Sept 1966)
	lb	Statute Miles	cu ft	in	ft	g	
Black Brant I..........	140	90	4.0	17.2	24.3	15	17
Black Brant IIA........	200	100	6.0	17.2	27.7	17	55
Black Brant III........	50	100	1.4	10.2	18.1	27	17
Black Brant IV........	40	620	1.4	10.2 & 17.2	37.2	44	4
Black Brant VA........	200	125	8.0	17.2	26.7	19	4
Black Brant VB........	200	260	5.0	17.2	25.3	20	5

All Black Brants have completed design, static test and flight test phases with the exception of some final flights with Black Brants IV and VB, which should be completed by January 1967.

Participating Government agencies have provided direct and indirect support which has been very valuable, and no doubt contributed much to the relatively low cost and short development history experienced by the project. The principal supporting agencies and their major contributions were: CARDE, which was responsible for engine development and provided assistance on rocket propulsion design and range and launch facilities, NRC, which has contributed directly to the development of the telemetry and instrumentation which is now being sold outside Canada, and indirectly by guidance and advice on user requirements, and NAE, which has supplied direct assistance on design problems associated with high-speed flight.

Market Potential

The sounding rocket market, now amounting to approximately $25,000,000 per annum in the US, has historically been difficult to define and predict, due to the widely assorted user groups, the rapidly changing scientific objectives and the individual vulnerability of

the programs for which these vehicles are to be used. The Black Brant rockets are gaining in user acceptance, and as reliability data mounts up over an increasingly larger number of successful flights, the user interest increases. These vehicles represent what is generally acknowledged to be a definite advance in the state-of-the-art. West Germany has purchased Black Brant III and V rockets, and future orders are expected. In addition, of course, the Canadian market will continue.

The estimated current-year market for Black Brant vehicles alone is about $500,000, and it is confidently expected that this will increase to $1,300,000 by 1969. The dollar value of the rocket sales will in most cases be supplemented by additional user requirements for instrumentation, telemetry, engineering and technical services. Current orders result in dollar sales equivalent to 3 times the basic price of the rockets. Sales of Black Brant rockets and services is expected to total $3,000,000 from August 1966 to December 1967.

Because of the Black Brant skills developed at BAL, the US Army has initiated a program to develop 2 small rocket systems. This is to be a joint Canadian-US-financed effort with BAL as prime contractor. Portions of the work will be done by CARDE.

The 2 rockets to be developed cover altitudes up to 250,000 ft, which will meet requirements of the world meteorological network. A cast polybutadiene propellant is required and BAL is now preparing for this production capability (all of its existing products use polyurethane propellants). CARDE will assist in the design and development of the rocket motors.

Chapter 5

PRESENT ORGANIZATION AND ADMINISTRATION

There is no agency or department of Government with overall responsibility for upper-atmosphere and space science in Canada, corresponding, for example, to the missions of the Atomic Energy Control Board (AECB) and AECL, in the atomic energy field, or to DRB in the military research field.

NRC, DRB, DOT, DOI and several others all have areas of responsibility.

NRC supports upper-atmosphere and space research through its University support program. SRFB is responsible for providing rockets for the universities and for operating CRR. There are relevant intramural research programs in REED, Pure Physics, Mechanical Engineering, and NAE.

The Associate Committee on Space Research of NRC has representatives in its membership of most of the Government departments, universities, and industrial organizations with significant space programs. Although it thus constitutes a national forum on space activities its responsibilities are restricted to advising NRC. Its executive committee advises on grants in aid of university research. A sub-committee of rocket users advises on the co-ordination of experiments in rockets flown by NRC. The Associate Committee assembles the annual report to Committee on Space Research (COSPAR) and provides Canadian representation to that body.

DRB has responsibility for ISIS, and carries on an extensive intramural research program on the upper atmosphere and military satellite communications in DRTE. At CARDE, there is a joint program with the US Department of Defence on re-entry physics, and a program on aerology. In addition, DND has a number of programs.

DOT, having responsibility for the administration of the Radio Act, regulates and controls radio transmission and reception in the country, and assigns radio frequencies. DOT represents Canada on

ITU, the international forum for the assignment and management of radio frequencies, including those assigned for purposes such as satellite communications, rocket and satellite telemetry and command, and so on. Through its Meteorological Branch, DOT uses data obtained by weather satellites, and carries on a research program in the atmosphere up to 100 km using in some instances rockets and satellites.

DOI and DDP support a number of space-oriented projects in Canadian industry, including the Black Brant rocket and HARP programs.

There is no central agency with responsibilities that correspond to those of NASA in the US, or to the Centre National des Etudes Spatiales (CNES) in France. There is no central council for space policy, such as the National Space Activities Council of Japan, or the British National Committee on Space Research, which is organized by the Royal Society.

To summarize, responsibilities for space programs have been assumed by various Government departments and agencies under their usual terms of reference, for example, by DND and DRB in defence, by NRC in university support, and so on.

Chapter 6

INTERNATIONAL RELATIONSHIPS

Canada has relationships with other countries through participation in international organizations for which the Government of Canada has the responsibility of providing representation, such as the UN Committee on the Peaceful Uses of Outer Space and COSPAR of the International Council of Scientific Unions.

Canada also has formal agreements with the US on CRR, the Alouette-ISIS research satellite program, the testing of experimental communications satellites, and the operation of a tracking station near St. John's, Newfoundland. The agreements in effect on 31 October 1966 are given in Part II of this report.

The Committee on Space Research

COSPAR has developed into one of the leading international organizations for the exchange of scientific information on space science. By excluding from its terms of reference the technology of space-vehicle boosters, it opens the way for co-operation in the exchange of scientific information in all the scientific aspects of space. National membership in COSPAR is conditional on having some space activity in the country and on having a national committee which holds the membership. There are members representing the interested International Unions and 3 grades of national membership: satellite-launching countries, rocket-launching countries, and countries having tracking facilities or other support observations and a national committee. The membership held by the national committee represents the national academy or research council of a corresponding organization in each country, and as such is considered to be non-political. In Canada, the Associate Committee on Space Research of NRC holds the membership in COSPAR.

The United Nations Committee on the Peaceful Uses of Outer Space

The General Assembly has established a 28-member Committee on the Peaceful Uses of Outer Space, with a special secretariat, the Outer Space Affairs Group, to assist the Committee. A legal sub-committee and scientific and technical sub-committees report regularly to the Outer Space Committee. Canadian membership is organized by the Department of External Affairs.

The Assembly has agreed to hold a conference in Vienna in September 1967, with the objective of examining the practical benefits to be derived from space research and exploration, and the extent to which non-space powers may enjoy these benefits.

Agreement Between DRB and NASA to Undertake a Joint Program of Ionospheric Research by Means of Satellites (Alouette – ISIS Program)

The formal arrangements for the Alouette program were made under letter agreements, dated 25 August 1959 from DRB, 18 November 1959 from NASA, and 16 December 1959 from DRB.

A memorandum of understanding covering the ISIS program dated 23 December 1963 between DRB and NASA was ratified through an intergovernment executive agreement dated 6 May 1964. This agreement extends to 1970, and thereafter until terminated by either government on 6 months' notice. The basic agreement is that Canada will build satellites for a joint ionospheric program, and that the US will launch them, each country paying for costs incurred within its own borders.

Agreement Between Canada and the US Regarding a Tracking Station Near St. John's, Newfoundland.

This agreement was effected by an exchange of notes signed at Ottawa on 24 August 1960. NRC and NASA were designated as the respective co-operating agencies. In essence, this is an agreement whereby NRC operates a station in Canada on behalf of NASA. The capital costs were paid by the US, whereas Canada pays operating costs and has the use of any data it wants.

An agreement between NRC and NASA to establish the procedures under which NRC and NASA could agree to modifications of or extension to the existing facilities was signed on 17 July 1962.

The Agreement remains in effect for 10 years and may be extended, or terminated on 90 days' notice.

Communications Satellites

The first agreement on communications satellites was signed on 25 April 1963 between DOT and NASA. It provided for experimental testing to be carried out using US satellites and a ground station to be built in Canada. This ground station was later built at Mill Village, Nova Scotia.

A second agreement establishing interim arrangements for a global commercial communication satellite system was signed at Washington on 20 August 1964 by the US and 13 other countries including Canada. Under a special agreement signed at the same time, COTC became the operating agency for Canada. These agreements provide for Canadian participation in ICSC, and for the use by COTC of satellites for external telecommunications.

This interim arrangement is to be reviewed prior to 1 January 1969 to determine whether a permanent international organization should be established.

Use, Operation and Maintenance of CRR

By an exchange of notes dated 11 June 1965, Canada and the US agreed that CRR will be operated by Canada for the joint use of the 2 countries, beginning on 1 January 1966, and continuing until 30 June 1970.

CHAPTER 7

OUTLOOK

7.1 GOVERNMENT PROGRAMS

Defence Research Board

The programs of DRB in DRTE and CARDE now employ 99 engineers and scientists and 86 supporting personnel and are expected to be relatively stable over the next 5 years. Seven major programs, on military communications satellites, meteorological rockets, ISIS, upper-atmosphere and aerology research, missile re-entry and PARL account for expenditures of $10,300,000 in the current year, with an expected decrease to $9,800,000 by 1970. Details are given in Appendix D, figures I, II, III and VI.

Defence Research Telecommunications Establishment

The Alouette-ISIS program is a major preoccupation of DRTE, and it is not expected to be completed before 1972 or 1973. It is apparent that this has been an outstandingly successful program, which has earned a great deal of prestige for Canada, and has succeeded in developing technological capability in spacecraft design manufacture in Government laboratories and in industry, and is earning foreign exchange through export of several million dollars worth of industrial products. Because one of the original concepts was to provide technological opportunities for Canadian industry, no provision had been made for financing participation by university groups. Scientific groups in Canadian universities have now matured to the stage where they have worthwhile experiments to be carried in an ionospheric satellite, and financial provision for their participation is now needed. The program demonstrates the entrée that can be earned into US space activities through joint programs. There seems to be agreement in principle that when the ISIS program is completed with the launching of the final spacecraft, the momentum gained should be retained by a follow-on joint program of similar nature, the details of which are not yet known.

The upper-atmosphere research programs of DRTE have been developed over a number of years, and are forecast to continue at about the present level. While these studies obviously have direct defence applications to communications and radar, their significance to Canada extends outside the defence area. The same can be said about the communications satellite program, which is the only broadly-based active research and development program on satellite communications within a Government laboratory.

The future of PARL is clouded, since the DRB program is nearly complete, and sponsorship of the laboratory is being sought from other agencies. The facility is a valuable asset to Canada and could be valuable as a tracking and control station if Canada develops satellite launch facilities.

Canadian Armament Research and Development Establishment

The aerology program of CARDE is new and there are expectations that it will prove of very great significance in establishing the factors which modify the weather, both natural and artificial. It can be argued that this program is not upper-atmosphere or space research. However it does use high-altitude balloons, and the project directors foresee the eventual use of satellites.

The missile re-entry research program, of direct defence interest, and supported by the US Department of Defence, is expected to continue at about the present level of effort.

The Meteorological (metroc) rocket program of CARDE and DDP is being negotiated as a joint development program with the US Army and is expected to be completed by 1970. Production plans have not yet been established.

Department of Transport

After the major effort of organizing Canadian participation in INTELSAT, and setting up the Mill Village ground station, the Telecommunications Branch of DOT is transferring operating responsibilities to COTC. No new activity of comparable size is seen in the immediate future.

The Meteorological Branch, on the other hand, looks for the establishment of a rocket meteorological program to begin soon, which, by 1970 may reach a level of $290,000 with about 10 staff members employed on the program. It expects that up to 4 rocket-launching stations may be established, in addition to CRR. Forecasts are shown in Appendix D, figure IV.

The Meteorological Branch is extending its research study of the uses of satellite photographs of the earth using APT facilities of the Tiros and Nimbus satellites, and expects to set up a network with a few main receiving stations and a substantial number of secondary read-out stations.

Several other research programs, to study upper-atmosphere dynamics and composition by means of noctilucent clouds, meteor trails observed by radar, and night airglow are planned. Cumulative expenditures on these programs could add up to $1,000,000 by 1970.

The Meteorological Branch recognizes that it has a responsibility to act as a unifying force with respect to studies and activities in meteorology and atmospheric sciences in Canada.

National Research Council

The rocket, satellite and laboratory programs on upper-atmosphere and cosmic-ray research, ground-based read-out of satellites, engineering support for rocket programs and operation of SRFB and CRR employ a total staff of 62 and cost $4,500,000 per annum at the present time, and are expected to employ 87 staff members and cost $7,830,000 by 1970. Details are given in Appendix D, figures V and VI.

The major NRC programs are the financial and engineering support of university upper-atmosphere and space research, operation of CRR and engineering support of rocket programs.

The level of operation of CRR can be forecast with some confidence for the duration of the present agreement with the US, that is, until 1970, since the range facilities are considered nearly complete except for problems arising from the pile-up of rockets waiting for launch during the spring and autumn, when the aurora is most frequent. The level of engineering support is much less definite, since it is dependent on the number and kinds of experiments to be proposed from university groups. This uncertainty is reflected in the data shown in Appendix D, figure VI.

University Support Programs

The major part of support of upper-atmosphere and space research in the universities in the form of grants and contracts came from DRB prior to 1965, when the growth of the NRC grants program overtook that of DRB. NRC support in 1966 was about $400,000 and that of DRB was about $230,000.

NRC grant support is expected to rise to about $1,600,000 by 1970, when DRB grants and contracts are expected to reach about

$380,000. This program to develop scientific and engineering skills and professional training in upper-atmosphere and space technology in Canadian universities has been outstandingly successful in a very few years. There are now a broad base of competence in the universities and a flow of trained graduates coming out.

Department of Energy, Mines and Resources

This department does not carry out research on the upper atmosphere and space, as defined in the terms of reference of this study. Nevertheless, several branches are contributing to upper-atmosphere and space research, both directly and indirectly, and other branches are potential users of data gathered in space programs.

7.2 UNIVERSITY PROGRAMS

Introduction

This section reflects a distillation of views from representations made to the Study Group by 40 individuals, departments, or faculties from 18 major Canadian universities. In the opinion of the university community, Canada needs a total approach to research and development in space. Maximum benefit can accrue to the country only if space research is carried out cooperatively and efficiently at all levels in Government, universities and industry, with each sector participating in the role for which it is best fitted.

The primary reason for university participation in a national space program is educational. The benefits of an interdisciplinary approach to university education are well established. Space research is interdisciplinary, involving as it does all branches of pure and applied science. It has already been demonstrated that the depth of knowledge and breadth of outlook induced by space research serve the best interests of graduate training.

Future Programs

The range of interests in Canadian universities in space research is broad. Some groups are engaged in space-oriented laboratory work, such as experiments in chemical aeronomy; others have developed facilities to simulate the conditions of flight in the upper atmosphere. Refinements of the Langmuir probe, electron gun and other similar instruments have opened the way for rocket and satellite experiments.

There has been considerable interest in direct investigation of the physics of the upper atmosphere using ground-based facilities. Examples are measurement of cosmic-ray particles to provide information on interplanetary magnetic fields and determination of the properties of the ionosphere by scattering of radio waves. However, the advent of rocket and satellite techniques, which make possible direct observation of the properties of the upper atmosphere and space, has opened the way for a considerable extension of these studies. University scientists plan to use rockets and satellites for such investigations as direct measurement of the temperature of the upper atmosphere using an electron gun, and the correlation of satellite-measured particle fluxes with radio-auroral intensities. Work on the dynamics of aerospace vehicles now proceeding in university laboratories will undoubtedly be extended to include studies under actual space conditions.

The future outlook for space research in Canadian universities is indicated by the kinds of large facilities available or under development. Shock tubes and light gas guns have been constructed for simulation of re-entry physics, meteor impact phenomena and the dynamics of the magnetosphere. A plasma tunnel has been developed for investigation of "ionospheric aerodynamics". An implosion-driven, hypervelocity launcher and range for reproducing suborbital flight in various planetary atmospheres and an apparatus for the simulation of micrometeors are under investigation. An analytical plotter will be available for the study of earth and lunar topography. Ground-based radar facilities and cosmic-ray detectors will be further developed for more extensive observations.

A program of investigations of the upper atmosphere designed primarily to use the Black Brant series of rockets is now in operation and is well organized to facilitate the participation of Canadian universities. Launching equipment, vehicles and telemetry systems have been made available to universities by SRFB. Grants are also provided to fund the university contribution. This arrangement makes it possible for small university groups to participate effectively in upper-atmosphere studies. Indications are that more universities will become involved in this activity.

In the future rockets will likely be confined primarily to suborbital investigations, for example, for meteorological studies. At higher altitudes satellites are now preferred since a greater return of information is possible for a given instrument package. This form of space research will become a major preoccupation of Canadian universities.

Participation in the Alouette-ISIS series of satellite experiments has shown the way. Other experiments have been suggested such as:

(a) observation of the behavior of gravity-gradient stabilized satellites in synchronous orbits. The resultant technological experience would be a real commercial advantage if Canadian synchronous communications or TV satellites are launched.

(b) measurement of micrometeoroid impact, after development of a gauge that will be calibrated in the laboratory with particles accelerated in shock tubes and a hypervelocity launcher.

(c) measurement of atmospheric density, composition, kinetic temperature, and rotational and vibrational excitation of molecular nitrogen. The methods to be employed are similar to those developed and used at UTIAS.

(d) determination of the surface conditions (type and amount of gas absorbed) of various materials exposed to the atmosphere at orbital velocities. Information of this type will be an indispensable link between surface-accommodation studies in the laboratory and those that may be performed in a satellite. Such information is important for accurate prediction of aerodynamic forces at satellite altitudes.

(e) measurement of the population and spectra of trapped or precipitating energetic particles in the north polar region. The methods are a logical extension of those which have been used in a number of rocket experiments at Churchill.

(f) measurement of auroral emissions, particularly at wavelengths not observable from the ground. The techniques are being developed in a number of university laboratories.

More generally it can be said that university research groups are prepared to co-operate in a wide range of experiments in space physics, communications, meteorology and geodesy from space platforms.

Launch Vehicles

For the further development of an effective program of research in the upper atmosphere and space, the consensus of university opinion is that the present rocket-launching capability must be extended to include an orbital launching facility for moderate-sized satellites. Canadian university views are almost unanimous that the development, construction and management of launching facilities are a responsibility of the Federal Govemment. They conclude that universities do not belong in the launching business. However, the control of the scientific experiment (for which the launching is necessary) should continue to be the prime responsibility of the principal investigator.

There was no significant preference among university research groups for a gun-launch system. With many difficult problems to solve already in the design and construction of an original satellite experiment, the emphasis must be on simplicity and reliability. In most cases high launch accelerations introduced severe difficulties and in others the experimental technique was such that no appreciable acceleration could be accepted. The preference was clearly for a rocket launching system.

Life Science Studies

It should be added that there is some interest in Canadian universities in the subject of the environmental sciences as they apply to space. If the environs of space and the planets are incompatible with human survival, then life-support systems must be devised. The biologist, biomedical specialist and bioengineer must co-operate in the research and development leading to the specification and fulfilment of the requirements for survival.

University Research Institutes

A major role in Canada's space program can be played by the university institutes described in Section 3.1. These centers of excellence have demonstrated their ability to participate effectively and efficiently in space research. In general they are post-graduate, interdisciplinary, mission-oriented and integrated into the university structure in such a way as to ensure a concentrated effort with efficient management. Besides the clearly demonstrated capacity of these institutes to turn out exceptional graduates and produce internationally-recognized research, it has been shown that they can stimulate local industry through their innovations and inventions, the discovery of new techniques and their needs for sophisticated equipment and instrumentation.

Support of Basic Research and Graduate Training

Of the total of about $17,000,000 of Federal funds currently devoted to space research in Canada a little more than half is spent on engineering development and engineering support of the major research programs. The remainder, amounting to about $6,000,000, is spent on direct support of the research programs.

There are about 230 professionally qualified research scientists in Canada active in this area, the number being about equally divided between Government and universities with a small number in industry. If graduate students are added, and some argument may be made that their needs and activities are similar to those of the professional researchers, then the numbers are approximately 200 in universities and 100 in Government laboratories, although the effective numbers in the universities are somewhat reduced by undergraduate teaching responsibilities. Most universities with vigorous graduate programs expect that a staff member who is responsible for graduate work will devote at least half his time to a combination of independent research and direction of graduate student research.

In any case the Federal funds spent in universities directly on space research amount to about one-tenth of those spent in Government laboratories for this purpose. In fact the average research support for each of the 125 professors amounts to about $6,300 per annum whereas a Government researcher can expect about $60,000, though the 2 figures are not strictly comparable because the universities draw heavily on other sources for salaries and overhead.

Nevertheless, there is a large disparity which is reflected in, or may be the cause of the nature of, the research work undertaken. Most of the work in universities is either laboratory work or ground-based observational work and only a small part involves rocket-borne or satellite-borne observations. Clearly, the present level of funding would not permit a significant increase in the proportion of the work done in high altitude vehicles.

There is some indication that universities have been reluctant to permit graduate students to undertake rocket experiments because of the risk of vehicle failure. While a university group is involved in only one or 2 rocket firings a year there seems to be a valid case for emphasizing ground-based measurements in the graduate training program. Several university groups have now reached a size which can support several rocket experiments per year and are finding that in such programs graduate students can partake without undue risk of catastrophic set-backs. Much of the benefit of space research in the universities will be lost unless graduate students are permitted to experience the demanding discipline of rocket and satellite experiments.

The expected growth rate of the universities is well known and the prediction of growth in the numbers of staff members doing space research in the years to 1971 (an increase of 150%) is perhaps not too unrealistic. However, the predicted Government support for this group

is only enough to raise the average annual support per professor by 10%, from $6,300 to just under $7,000. It has been argued that this amount is not sufficient to maintain a meaningful laboratory research program for a professor and his students. If a significant part of the program is to use rockets and satellites the level of support must be increased substantially.

No significant increase in the number of scientists in Government laboratories has been predicted for the next 5 years. We may expect, therefore, that the center of gravity of the space research program at least in terms of people, if not in dollars, will swing more and more to the universities. It follows that the nature of the university program will determine more and more the nature of the total Canadian program. Insofar as university institutes are concerned, the replacement of one-year grants to individual scientists by long-term support and the provision of continuing institutional appropriations to initiate the research of promising new members of the staff, establish permanent positions for engineers, technicians and administrative assistants and provide building space, services and intergroup facilities, illustrate the problems that must be solved before they can play their proper role in a national space program.

The relatively large involvement of the US in support of Canadian university programs leads inevitably to their reflecting US rather than Canadian interests, for example, $410,000 US and $740,000 Canadian in 1966, exclusive of HARP. This also renders Canadian university programs highly vulnerable to changes in US policy.

In summary, the next 5 years will see a burgeoning of our graduate schools in terms of both staff and students. A fraction, probably a growing fraction, of these new people will elect to do space research. It is necessary to provide a level of research support that is sufficient to ensure a balanced program of both ground-based and vehicle-borne experiments. To do otherwise would be to exclude our graduate students from a challenging and economically important field of research. The graduate students trained in the next 5 years will be the research leaders in the 1970's.

Organization For Space Programs

The universities have expressed some interesting opinions on possible guidelines for the content and organization of a national space program. No one feels that Canada should embark on a project to put a man on the moon (although international participation should not be ruled out), but all are convinced that Canadians should have a sound, long-range space program of their own, consistent with their ability to pay for it.

A properly balanced space program can contribute much to reduce the emigration of our brilliant scientists and engineers, improve innovation, invention and production in industry, encourage the decentralization needed to ensure a more equitable distribution of Federal funds for large facilities between the Government laboratories on one hand and university institutes and industrial research centers on the other and in general create an overall effort on a scale large enough to ensure some sense of national purpose.

More specifically the institutes and large departmental groups in Canadian universities realize that some constraints must be accepted if they are to participate effectively in a national, co-ordinated space program. Heavy emphasis on mission-oriented research is expected and properly refereed proposals, on site evaluations and performance studies are inevitable. It is also clear that university space institutes must have interests and research projects that complement one another and form a natural part of national space prorgam.

As regards the organization of a national space program for Canada the need for substantially improved co-ordination of the present effort has been pointed out by all participating universities. Since there is no effective co-ordination of the various Government departments funding existing space research, inequities have arisen in the support of university groups. Universities which have aligned themselves with the policy of individual Government departments have been extensively funded while others have had technically reasonable proposals refused. No satisfactory procedure exists at present for the proper evaluation of all proposals on a competitive basis by one impartial committee which represents the total community, Government, universities and industry. Technical aspects of space research also point to more and more co-ordination on a national scale. For example there are no boundaries in the atmosphere, and organization must be such that the interests of the dynamical meteorologist and those of the ionospheric physicist in circulation dynamics are well served.

Finally, the universities agreed that in addition to the abovementioned national committee concerned with policy only, there should be a single separate agency charged with the responsibility of funding the agreed national program for research in the upper atmosphere and space. This agency should co-ordinate the needs of Government, universities and industry consistent with the national space policy and and the availability of funds.

7.3 INDUSTRIAL PROGRAMS

The future of Industrial upper-atmosphere and space programs is determined by the market outlook, as seen by Canadian industry, in 3 broad areas:

(a) Canadian Government programs
(b) the domestic market
(c) the export market.

There is a very dynamic interplay amongst these 3 areas, but, with few exceptions, an increase in the magnitude and breadth of the first 2 has a very stimulating effect on the third. The existence of any Canadian export market in this area has been almost entirely due to earlier Government programs wherein industry had a significant involvment.

Aside from any new Government program, perhaps the greatest increase in industrial activity over the next few years will be created by the emergence of operational communications satellites, whose economy in long-haul communications make them attractive to meet future domestic needs. Provided international arrangements can be consummated for such applications, there is every reason to believe that Canadian industry is capable of creating the entire system (except for launching into synchronous orbits). Such a broadened base of skill and experience opens future export markets for that portion of Canadian industry involved. Furthermore, future Government programs become more cost-effective as industrial skills and facilities expand and improve.

Canadian Government Programs

There have been only 2 major Government research and development programs that have not in one way or another required the company involved to share in the costs. These are the DRTE Alouette-ISIS, and the DOT Mill Village Ground Station programs. Since the latter was substantially completed in 1966, ISIS remains as the only Government program in Canadian industry that has not intentionally required contractor financial contributions. All other major programs have been sponsored by DOI or DIR in response to export-market surveys which have revealed a potential future foreign market for products resulting from such programs. These will be covered under Export Markets below. Although it is true that NRC is now purchasing Black Brant rockets and payloads, this program was initiated primarily on the basis of export potential with DOI funds, and Government purchases represent a bonus domestic market.

The ISIS program will run to 1971 – 1972 at a rate of $3,000,000 annually, spent primarily in Canadian industry. The current prime contractor is RCA Victor and the associate prime contractor is de Havilland. Other Canadian companies are involved in the program on a sub-contract basis, either to the main contractors or directly to DRTE.

The Domestic Market

The geography and population distribution of Canada are such that domestic communications by satellites can be economically viable. The emergence of operational communications satellite systems has prompted the Canadian communications industry to invest in technology and facilities for exploiting this new medium. The Bell Canada plan to build a nothern ground station at Bouchette, Quebec, as the first of a network of such stations in Canada's north portends major future industrial activity in this area. Northern Electric will build the station at Bouchette.

Perhaps the most spectacular development in this area is the recent proposal by Niagara Broadcasting and the Power Corporation to establish a third national TV network across Canada, based entirely on the use of synchronous satellites. This proposal is based on the use of private capital to fund the entire venture.

Power Corporation had RCA Victor conduct a detailed design study of such a system. Power Corporation proposed the formation of a new company, the Canadian Satellite Corporation (CANSAT), to manage the systems studies associated with the program, manage the implementation phase, conduct liaison with INTELSAT, COMSAT, etc., and own and operate the system. CANSAT would be financed by the private sector, wherein ownership could be shared by Canadians. In order to achieve satellite systems in the early 1970's, Power Corporation considers the CANSAT organization must be formed before the middle of 1967. The proposed system could be put in operation within a period of 5 years. This assumes satellite launch by an Atlas-Agena, or equivalent, and satisfactory international arrangements with INTELSAT and US for a US launching.

A program of this magnitude would certainly involve a heavy industrial activity in Canada over the next 5 years.

A further potential program in satellite ground stations is COTC east-coast facility to be contracted for in the near future. This may involve Canadian industry.

A small domestic market exists for weather-satellite ground stations. The continuing management of the St. John's NASA-NRC minitrack station, and perhaps eventually CRR both represent industrial activities continuing into the future.

The provision of Black Brant sounding rockets for the upper-atmosphere research programs of NRC and the universities represents future industrial business. The provision of the actual payloads for these vehicles is much more uncertain due to the existence of non-industrial Government-subsidized facilities already established for this purpose. No doubt industry will be called upon where very specialized skills or facilities are required that do not exist elsewhere.

The Export Market

The Canadian Government industrial assistance programs have done a great deal to stimulate export business for Canadian industry. These programs have involved company financial participation, usually on a 50/50 basis, although in some instances US agencies have picked up portions of the company's share. The primary export market is the US; only a very small amount of business has so far been done with other countries.

The attraction of the $7,000,000,000 space market of NASA and Department of Defence (DOD) has probably been the greatest impetus for Canadian industrial investment in upper-atmosphere and space activities and facilities. Already a significant export market exists, and it is estimated that Canadian industry has exported about $16,405,000 worth of goods and services in this area to date.

HARP has been the largest space program funded by DOI to date. This program will be fully funded by the US after 30 June 1967. A complete description, including the industrial involvement, is included as Part III of this report.

The Black Brant program is the next largest DOI space project; this is described in Section 4.2 of this report. It is estimated that sales of Black Brant rockets and services will amount to a total of $3,000,000 from August 1966 to December 1967.

The Meteorological Rocket System is the third largest DOI space project. This is expected to get underway at BAL this year, to be completed by 1970. This could lead to a very large market for the needs of US Army and civilian meteorological agencies.

DOI support to CDC has placed this company in a leading position to push the state-of-the-art in light gas guns, high-g telemetry and associated instrumentation, with funding from US sources expected in the future.

RCA Victor has received significant support from DOI on satellite communications, and a continuing Program for Advancement of Industrial Technology (PAIT) program is being planned on ground stations. This company is currently bidding on a number of foreign requirements, which could result in future export business for total systems management of the ground station design, manufacture, installation and check-out. Also, RCA Victor has received DIR support in its space research activities. Most of its current export programs in research terminate during 1967, but it is expected that this activity will continue with a gradual build-up over the next 5 years, with about 50% of the projects funded from the US. Also, RCA Victor has received DIR support in its space research activities. Most of its current export programs in research terminate during 1967, but it is expected that this activity will continue with a gradual build-up over the next 5 years, with about 50% of the projects funded from the US.

Other Government support programs in weather-satellite picture-receiving equipment and HF communications are starting to create export business.

STEM represents a direct benefit from the Alouette program. This product has resulted in over $4,000,000 of export business since 1961. Recently competition has arisen in the US, in spite of patent protection. A DIR program has been initiated to accelerate technological development and maintain the Company's lead. It is expected that STEM will continue to be a source of major export business for some time to come.

Summary

Some industrial programs have ended, but new ones are replacing them, so that the short-term outlook is a continuation of the current intensity of effort, of the order of $16,000,000 per annum. The initiation of any major communications satellite program, either public or private, could create a significant increase in the industrial sector over the next 5 years. No major additional expansion of Canadian industrial upper-atmosphere and space activity can be foreseen without the introduction of a major new Canadian Government program.

There was a general consensus that industrial participation in any new program should be through fully-funded study and research and development contracts, and that the program should favor activities

in Canadian industry. Several briefs suggested that the existing development and production-sharing arrangements with the US be extended to include the NASA space programs. Government departments claimed this would only be possible after Canada established its own unified space program thereby establishing a stronger bargaining position.

7.4 SATELLITE COMMUNICATIONS

Growth and Needs

The communications industry in Canada has grown tenfold in the last quarter century. Capital investment now exceeds $4,000,000,000 and yearly operating revenues exceed $1,000,000,000. Annual expenditures on buildings and equipment exceeded $700,000,000 in 1966. The industry, comprising the telephone, telegraph and broadcasting segments, continues to expand at a rate of 8 to 12% per annum.

The high rate of expansion of the communications industry generates pressures to exploit new technology, such as satellite communications or solid-state electronics, and to provide for this expansion in the most economical way possible, and at the same time provides capital to finance the application of this new technology.

A forecast of communications-satellite requirements for Canada, estimated by one common carrier and typical of several forecasts is as follows:-

Data – Voice (4 kc/s) Channels Available for Satellite Transmission

	1970	1980	1990	2000
Northern Canada	200	300	400	600
Canada E – W	860	2000	4500	11,000

Number of Satellites Required for Data-Voice and Domestic TV
Distribution

Data-voice	1/4	1/2	1	2
TV Dist	1/2	3	4	5

These forecasts were made on the assumptions that 75% of circuits over 900 miles in length continue to go by landline or radio relay, that microwave and cable facilities will continue to be used for TV distribution in densely populated areas, that direct broadcast of TV from satellites will not occur during this period, and that the common carriers would continue to provide distribution services to the broadcasters.

These estimates appear realistic, being confirmed by the Government agencies and the CBC forecast that 12 to 20 TV channels from satellites will be needed for domestic Canadian use by 1980.

The 2 major Canadian networks (CBC and Canadian Television Network) are now paying about $12,500,000 annually for network distribution services, largely via microwave radio relay links. As broadcast services expand and are extended to Northern Canada, the costs of network distribution will surely grow to $20,000,000 or $25,000,000 per annum by 1980. It appears certain that at least part of this increased capacity will be provided by communications satellites.

Ownership of Canadian Satellites

A fundamental question is whether Canada should own its own domestic satellites or rent them from COMSAT. The principal factor in this question is that the space 22,300 miles above the equator along a belt approximately 18,000 miles long (20° either side of 95°W longitude), is available to any country for operation of a synchronous satellite for domestic TV transmission.

Space law at the present time would seem to permit Canada the right to lay claim to a piece of this sky as a location for satellites for Canada's particular needs. Canada's needs are modest in relation to those of INTELSAT, the US and South American countries, for their own domestic satellite requirements and surely can be resolved by negotiation backed by an adequate measure of resolution.

The sky territory for location of Canada's satellites is valuable. If given over to the US, or any other country, this territory could be lost forever. Staked in the near future, it could be used to fulfill Canada's particular and distinctive requirements. Ownership of this property would give Canada due bargaining power in the evolution of an overall domestic satellite TV service for all of North and South America. This territory should be treated as prudently as Canada's water resources. It should be shared, rented or sold only on terms that are good for Canada.

Canadian ownership of national transportation systems (rail and air), electric power services, national telecommunications services and national radio and TV services permits Canada to shape its own destiny. Accordingly, it seems most vital that any extension to Canada's telecommunications system as provided by a domestic satellite system be owned and operated by Canadians.

Any Canadian TV satellite system will of necessity have many aspects of its performance dictated by agreements with the US. The

Canadian satellite would most likely be positioned between 2 US domestic satellites. Each of the active satellites in the proposed satellite belt would receive and transmit in the same frequency band as its neighbor satellites under present frequency assignments. Accordingly, such parameters as satellite positioning accuracy, radiated power, radiation pattern, polarization, frequency stability and many others would have to be established by technical agreement between agencies of the Canadian and US governments, so that Canadian satellites would not interfere with or suffer interference from US satellites.

Such a problem of international co-ordination and co-operation in the field of telecommunications is comparable with that of the assignment of location, frequency, power, and radiation pattern of TV and broadcast stations in Canada and the US. Personnel of DOT and FCC, with support from broadcast associations in each country, have reached harmonious and just decisions in such matters. Aside from telecommunications, there are many programs – water resources, gas and oil lines, electric power grids, etc – in which the US and Canada have established standards and agreements to permit co-ordination of facilities, while giving due protection to the interests of their countries.

The Assigned Radio Frequencies

At the Extraordinary Administrative Radio Conference held at Geneva in 1963, ITU assigned frequencies as follows for communications satellites used in the North and South American sector of the world.

Band	Frequency Mc/s	Communications Satellite Use	Other Uses
A	3400 – 3500	Down	Radio Location, Amateur
	3500 – 3700	Down	Fixed, Mobile, Radio Location
	3700 – 4200	Down	Fixed, Mobile
B	4400 – 4700	Up and Telecommand	Fixed, Mobile
C	5925 – 6425	Up	Fixed, Mobile
D	7250 – 7300	Down	
	7300 – 7750	Down	Fixed, Mobile
E	7900 – 7975	Up	Fixed, Mobile
	7975 – 8025	Up	
	8025 – 8400	Up	Fixed, Mobile

The practice appears to be developing to use 500-Mc/s bands of frequencies in bands A and C for civil communications satellites, and bands D and E for military communications satellites. The only frequencies cleared for exclusive use are in bands D and E, 7250 to 7300 Mc/s and 7975 to 8025 Mc/s. Band A, for example, is widely used in Canada for the 2 transcontinental microwave radio relay systems. These represent a $75,000,000 investment, and carry the bulk of Canadian long-distance TV and telephone traffic.

The sharing of frequency bands for satellite systems with land-based microwave systems is inherently unsound from an engineering viewpoint. This was emphasized to the Study Group in a number of presentations. The present assignments are particularly onerous to Canada, which is one of the world's heaviest users of long-distance radio-relay systems. It was strongly recommended that frequencies above 10,000 Mc/s and below 14,000 Mc/s should be reassigned for communications satellite use on an exclusive world-wide basis. In the view of the industry, additional frequencies will in any event have to be assigned to accommodate the growing needs.

Another issue of major importance is the reservation of frequencies for direct satellite-to-home transmission. At present it would seem most practical to reserve some of the UHF TV bands (470 to 890 Mc/s) which have not yet been assigned in Canada for this purpose. The US has already compromised its future in this application by licensing the UHF band for ground TV broadcast. Canada should not do the same.

Outlook for the Future

A possible plan for the development of communications satellites for domestic Canadian use, would provide for experimental satellite to be in orbit by 1970 or 1971, to give service in Northern Canada, and to be followed by several operating satellites a few years later. There are a number of straightforward technical problems to be solved and a certain amount of experience to be gained that can best be done with an experimental satellite.

The unresolved question concerns the provision of the space segment (the satellites) for this expansion. In the US NASA is doing experimental work in satellite communications, and COMSAT is making available and selling services on a commercial basis. The Canadian common carriers are not in a position to accept the risk or to underwrite the costs of developing communications satellites on their own. Therefore, if satellites to meet Canadian needs are to be designed and built in Canada, it is evident that a Canadian agency will have to be

responsible for this part of the program, that is, a Crown corporation such as COTC, a Government agency, or a private corporation such as the proposed CANSAT.

The provision of satellites for Canadian use is a commercial operation which requires technical and managerial skill and competence, and which includes an element of risk. It would be unfortunate if this package, including substantial profits, were to go to a foreign corporation, since the technical competence and capability to build this family of satellites now exists in Canadian industry.

The outlook for the communications industry clearly will be much brighter if a Government decision were made to assign responsibility for provision of the space segment of future Canadian communications to a Canadian agency and to authorize a Canadian communications satellite program.

In the more distant future, there may be a separation of telecommunications functions in satellites, and a low-altitude multiple-satellite system for telephones may come into use in Canada, with the synchronous satellites being reserved for TV and data uses, where the long round-trip transit time is not a significant factor. This development is foreseen as logical when the growth of domestic communications requires an expansion into a further new system. The low-altitude satellite system, although needing more costly steerable antennas on the ground, has advantages, since simpler, less expensive spacecraft without station-keeping capabilities can be used. Also the transit-time delay is negligible, thereby maintaining the quality of long-distance telephone service. Such satellites could be launched by a modest booster, of the variety mentioned subsequently in Section 10.2.

7.5 LIFE SCIENCES

There does not appear at present to be an identifiable theme for research in the space area in life sciences in Canada. A number of research workers are active in studies of life-support systems in present-day military aircraft and supersonic civil aircraft, at the University of Toronto and McGill University, the RCAF Institute of Aviation Medicine, the Defense Research Medical Laboratory, and the Research Institute of the Hospital for Sick Children in Toronto. Some of these studies are also relevant to life support in spacecraft, and accordingly there has been a significant dialogue with NASA and some financial support from that source. The view has been expressed that the eventual extension of flight techniques may involve Canada and Canadians in manned space flight in the distant future, and that in anticipation of this eventuality modest support and encouragement for research in this area should be provided now.

Chapter 8

THE SCALE OF A CANADIAN PROGRAM

Elsewhere in this report we have discussed details of possible programs. Having in mind that present Government expenditures on space research are approximately $17,000,000 per annum, and growing, it is our intention to establish in this chapter a reasonable upper bound on levels of expenditure.

The space program in the US is being carried on at a level of about $7,000,000,000 per annum, $5,000,000,000 of which is in the NASA program, the remainder in the military program. This represents about 1% of the gross national product of the US.

The Apollo program to place a US national on the moon by 1970 absorbs the major part of NASA funds. The space science and applications program is costing about $660,000,000 or about 0.1% of GNP[1].

France's national space effort, despite pruning, is maintaining its status as the most ambitious of all European space programs and annual expenditures are currently about $56,000,000 (1964) or 0.063% of GNP. The French objective is to establish a measure of independence from the US and to ensure that France will be able to compete in her market area, particularly in providing communications and television services.

In Britain, the non-military space program is costing about $66,000,000 (1964) or 0.083% of GNP. The British objective is to capture for their industry a share of space technology and markets, and in particular to provide communications to the Far East where Britain has areas of military and civil interest.

In comparison, the Canadian program was at a level of about $14,000,000 (1964) annually, or 0.032% of GNP.

Other studies have shown that the total level of Canadian technological activity in research and development is being carried at a

[1]The world market for aerospace products 1965 – 1975, DOI, Ottawa, June 1966.

level much below that of other technologically advanced countries. It appears that in relative terms the same conclusion applies in the space area.

The significance to Canada of developments in space technology is at least comparable to that in Britain and France, for very similar reasons. The risk of domination by the US is clearly greater in the Canadian situation. Other countries have established the challenge, and the level of national resources devoted to this contest, and have shown that expenditures of the order of $50,000,000 to $60,000,000 annually can provide an effective independence in space technology. Stated another way, it would appear that Canada could achieve similar national objectives by devoting about 0.07 to 0.10% of the GNP to space activities.

In terms of technical manpower, it is unrealistic to expect stable growth rates greater than about 30 to 35% per annum. This would establish a limit on the build-up of a Canadian space program, and it is consistent to suggest that a $60,000,000 annual expenditure could not be achieved in a period of less than 4 to 5 years.

Chapter 9

THE CASE FOR A CANADIAN PROGRAM

9.1 SOCIAL IMPLICATIONS

Man has always been confronted by frontiers. In early historical times the desert and the sea were the barriers to his further expansion, but the domestication of the camel and the construction of seaworthy ships enabled him to cross those obstacles, and both the desert and the sea became a means of livelihood and a way of communication, opening up rich lands beyond. In this continent, the vast western plains were the frontiers of civilization until the invention of the steam locomotive opened up the wilderness to hundreds of thousands of settlers and provided a link with the new communities of western coasts. It was "the iron horse", not the mammalian one, which conquered the prairies in fulfilment of a promise of Confederation.

The frontier today is the even greater vastness of outer space, and again it is a series of technological advances which are offering man the opportunity whereby to turn this barrier also into a means of communication, and to have access in the literal sense to new worlds.

The assault upon space is being pioneered by 2 nations, the US and the USSR. To seek a parallel to the engagement of so great a proportion of the national wealth and effort in a non-military enterprise one must go back to the pyramids of Egypt, the great trilithons of Stonehenge or the colossi of Easter Island. There is this difference, however: the technological advances which are the outcome of space research spill over into the more normal activities of western man and have put new power into the hands of men at all levels of society. The computer and the transistor are very ready examples, but the indirect benefits to technology in general are considerable indeed.

Since the costs involved in space research are so great, and since there are many other areas of research still relatively unexplored, it is arguable that Canada, like many another smaller nation, should stay out of this activity and devote her comparatively slender resources to the study of other more immediately rewarding problems. The fact is that our contiguity to the US and our close involvement with the intellectual activity of the North American continent do not allow us to stand wholly aloof from such a major preoccupation of our immense southern neighbor. Our ready access to the research centers of the US armed forces, Government departments, institutes and universities means that intelligent Canadian physicists, astronomers, engineers, mathematicians (to name but a few of the kinds of specialists involved) find themselves inevitably drawn to thinking about the problems upon which their US counterparts are so busily engaged. It is quite unrealistic to think that Canadian scientists will not become active participants in this truly continental activity, seeing that it presents them with many of the greatest opportunities and most challenging problems of their professional disciplines. If Canada does not provide access to these challenges, the more eager and forceful of her scientists and technologists will be drawn away to those places where that access is afforded, and her own mental climate will suffer.

To the research workers themselves, this kind of argument, however acceptable, may seem to border upon rationalization. Their attitude is that of committed research workers in general: research is part of man's search for knowledge and therefore requires no further justification. We may accept this as a basic principle, but nevertheless recognize the need to relate it to the contingencies of the contemporary situation. Given Canada's cultural, political, financial and intellectual resources, the case for her engagement in space research is irrefutable.

The influence of space technology will be felt in every home in Canada. Modern telecommunications in the form of telephone and TV are a vital part of our home life, even to those who live in remote areas. It has come to be regarded as the right of every Canadian whether he lives in Toronto, Churchill or Resolute Bay, Northwest Territories, to be able to speak to any other person in Canada for personal or business reasons, to see the Grey Cup game or the Stanley Cup playoffs in color. As modern technology brings down the cost, and makes these conveniences available in all parts of Canada, society will demand they be made available on the best terms possible.

Space technology, as represented by the ability to measure the weather through instruments placed in orbit around the earth, to survey ice in the shipping lanes and our mineral and forest resources, to detect forest fires, to locate and to provide communications to aircraft

in flight, to connect computers together by data links, will invade industry and business life in Canada. The impact in the next decade may be modest, but there seems no doubt that in the second century of Confereration the fabric of Canadian society will be held together by strands in space just as strongly as the railway and telegraph held together the scattered provinces in the last century.

Since this is so, the crucial issue is the extent to which Canadians will control this vital element of their national fabric. Railways and communications have since 1867 been under the ultimate jurisdiction of the Canadian Parliament, because the means as well as the method were subject to Canadian law. The difference so far as space technology is concerned is that the means are not at present subject to the jurisdiction of Parliament, though the method may be. No matter what Parliament legislates in space technology, the application of Canadian legislation is conditional upon the concurrence of whichever foreign government controls launching vehicles and launching sites.

Ultimately one realizes that, while science is "open", technology is "closed". Science is open in the sense that scientific discoveries are publicized widely, and debated openly among scientists. Technology is closed since it involves "know-how" which cannot be but down on paper in the same way as the results of scientific investigation. Technology includes particular ways of preparing or working materials or of organizing and managing a program. Technology is subject to commercial secrecy, to patents procedures, to control of key materials or devices. It cannot readily be exported, it must be carefully nurtured and developed in a country over a period of years.

Canada, in the interests of survival, must define those technologies which are crucial to Canadian aspirations, independence and social justice.

Space technology is so directly related to the needs of a large, sparsely populated country, that it cannot be ignored. In a free society, it will be used, and the role of the Government is to see that space technology is used in the best interests of Canada. It is therefore an inescapable conclusion that the elements of space technology vital to Canada must be under Canadian control.

Clearly, this argument cannot be carried to the limit to justify complete self-sufficiency in space technology in Canada. For example, the provision of Canadian launch vehicles for launching all Canadian scientific and application satellites, the establishment of world-wide tracking facilities and so on clearly would be excessive. Nevertheless enough of these needs should come from Canadian sources so that there is a measure of choice available to permit the use of Canadian resources where Canada's interests cannot, or will not, be served adequately from elsewhere.

9.2 ECONOMIC IMPLICATIONS

Canadians have already learned that Canada's contiguity to the US implies some involvement in the major pre-occupations of that country. Our relatively easy access to the laboratories of government, universities and industry in the US means that Canadian scientists and engineers are inevitably drawn into some form of participation in the solution of US problems.

Space science in the US has encouraged an educational revolution. Besides providing a means for massive support of educational institutions, the US space program has provided a challenging new approach to graduate training. The MSc or PhD candidate in the space sciences must not only devise instruments to operate in the laboratory but must extend his techniques to include compactness, light weight and reliability to meet the requirements of rockets and satellites. His theoretical investigations must include realistic simulations of upper-atmospheric and space conditions. Add to this the experience he gains from the supervision of technicians of many skills, co-operation with industrial suppliers, participation in exhaustive pre-flight check-outs and programing to meet blast-off deadlines, and one can appreciate how well he has been prepared to enter the modern scientific world.

Unlike such fields as molecular biology and nuclear physics, which are concerned primarily with new basic information, upper-atmosphere and space research is directed more towards the application of man's present knowledge to an understanding of his atmospheric and space environment. A very important feature of a space research program is the fact that it involves a large number of different scientific disciplines, including the physical, biological and social sciences, on a scale never before achieved. The interdisciplinary nature of space research means that a Canadian program in this field will stimulate many aspects of the social and scientific and economic life of the country.

Canada has become a nation with a high standard of living and a rapidly growing industrial capacity. The maintenance and further improvement of this standard of living will become more and more dependent on the continuing growth of industry. The proper conditions for this growth will depend critically on whether Canada attains and maintains a position in the forefront of engineering and scientific

developments. Canada cannot rely heavily on imported technological innovation without running the serious risk of losing out in world competition for markets. A space program represents a continuing challenge to the advanced technological capability of the country.

A special feature of space research and development is its tendency to decentralize its activities. It does not promote the regionalism inherent in some single-facility projects. In particular, observation stations and launching facilities in Canada must be located in accordance with technical requirements which take advantage of differences in the physical environment in different parts of the country. The interdisciplinary nature of space research and the many components forming an efficient program imply a wide diversification of projects to industry.

Very recently it began to be realized that satellite-borne sensors have a great potential for the survey of natural resources over large areas. For example, a photograph taken from an orbiting Gemini vehicle clearly showed an excess of salinity in the soil of Texas cotton fields. This information, so dramatically obtained, was useful to agriculturalists who were studying the reasons for crop failure in the area. In fact the value of the survey satellite has already been demonstrated for military reconnaissance and weather forecasting. Recent assessments show that survey satellites will be useful for the scrutiny of Canada's water, mineral, agricultural and even human resources. Research and development should lead to survey satellites that will locate mineral deposits, assess river and reservoir sedimentation, measure the movement of glaciers, monitor air and water pollution, study ice conditions and so on. Thus the satellite can make a significant contribution to the development of many of Canada's natural resources. Without a clear policy of participating in this program, the spectre of other countries being in possession of vital information on Canadian natural resources without our knowledge or consent is raised.

Private investment in space technology is growing rapidly in Canada. In the next 5 years, investments of private capital may total $50,000,000 to $100,000,000, depending primarily on Government decisions regarding the use of satellites for telephone and television relay. Expenditures of $25,000,000 to $30,000,000 may be expected even if new programs are not begun. A large fraction of this investment, particularly in the private sector, may be made in the US for the purchase of services such as satellite manufacture, operation and launching. As the use of satellite technology grows in Canada, the fraction which is procured in Canada, and the fraction which is imported to contribute to our imbalance of international payments, will depend in large measure on Government policies.

The cost of providing launch vehicles for Canadian scientific satellites, will, we expect, reach $6,000,000 or $7,000,000 per annum by 1975. We foresee launches by 1975 of communications satellites to synchronous orbit, for Canadian domestic use, reaching a frequency of one every 18 months. Each launch will cost $5,000,000 to $10,000,000. The total cost of launch services could be $10,000,000 to $15,000,000 per annum.

Since total self-sufficiency in space technology is unattainable at present, and probably extravagant in the future, Canada must seek a proper balance between technological imports and exports. Such a balance will surely entail development and production-sharing agreements between Canada and those other countries with whom we are trading in space technology, particularly the US.

9.3 INDUSTRIAL IMPLICATIONS

The intensive research and development effort in the military and space fields throughout the world will have a major effect in shaping the structure of the world market for manufactured goods within the next 5 to 10 years. Part of this structure of course is the military and space market itself, which will continue to offer attractions in countries where technology remains advanced. The main point, however, is that the world market demand in sectors other than military and space, will be increasingly structured by new techniques, processes and products arising from military and space research and development, because of the sheer magnitude and thrust of technological momentum already established in these areas.

In recent years Canada has not been a heavy spender in military research and development. In order to offset this, industrial research and development incentives have been established by the Government, first in the military field, and more recently in the civilian sector. Although it is very early to arrive at a conclusion, there is every evidence that this approach will be successful in stimulating innovation and strengthening the export market position of Canada's secondary industries. These measures, however, with very few exceptions, are directed toward individual companies whose size is not sufficiently large to permit the development of large-scale systems and the exploitation of results of fundamental research. Furthermore, the requirement for company financial participation limits the magnitude of such programs to those within the financial resources of the individual firms, and therefore expansion may well be limited.

It is not the purpose of this study to examine the desirable expansion rate of Canadian secondary industry. However, it is evident

that the influx of graduate and postgraduate engineers and scientists into the labor market over the next 5 to 10 years from Canadian universities alone, will establish the growth rates needed in Canadian research and development activities if all of these people are to be absorbed effectively. It is also clear that a large percentage of these graduates will be available to, and should be absorbed by, secondary industry to create the necessary jobs for the rapidly expanding labor force.

The full utilization of this valuable asset is unlikely to be accomplished without major Government programs, at least in the initial period, to provide the expansion and broadened industrial base in advanced technology required for future export markets. Since military research and development activities are unlikely to expand appreciably, in view of Canada's current military role, a space program offers all of the ingredients required to provide the needed expansion. It has been suggested that no other major technological endeavor can be envisaged at this time that fulfils as many of the future needs of Canadian secondary industry as a well-integrated space program.

A well-integrated space program entails activities ranging from fundamental research through applied research to the development of specific hardware and equipment, the operation of service facilities and ranges and the reduction and processing of data. Of all of these activities, by far the most expensive is the development of specific hardware and equipment, but it is just in this area that the major benefit accrues to industry in terms of the employment and improvement of skills, techniques and facilities. The space program must therefore heavily involve developmental and manufacturing activities if it is to be meaningful to Canada's secondary industries. The interdisciplinary, non-regional nature of space activities assures the involvement of a broad base of manufacturing industries across Canada. The technological challenges posed by the requirements of this field assures a continuing demand for the best technical talent this country has to offer, working in an environment of high creativity and innovation.

Experience in the US and other countries has shown that a stable, continuing and imaginative space program attracts much of the best technical talents and resources of the country. This could be expected from the stimulation of imagination, glamor and challenges associated with this field. It could be argued that this would have a deleterious effect on other areas of technology of importance to the country. Whereas this may not be a severe problem for larger countries, it could be an important factor for a country like Canada, with limited resources. The fact is, however, that without a major challenging, stimulating and advanced technological program or objective in the country, many of Canada's technical resources will be attracted elsewhere. Given a space program, then, the problem is to learn how to couple this activity to the other sectors of the economy where there are national needs, and where the civilian sector, both at home and abroad, can benefit.

So far, in the Organization for Economic Co-operation and Development (OECD) countries, the "spin-off" from space activities into other product areas has not been very impressive. This, however, could be misleading because at this time intensive space efforts are only a few years old. The results of space research have had, and will continue to have, a greater influence on civilian innovation by stimulating the general rate of technological advance. For example, the requirements of space research, especially for guidance and control, have led to fundamental and applied research in such fields as semiconductors, micro-circuitry, micro-modules, energy conversion and physical metallurgy, which are bound to have an impact on civilian technology. In addition, techniques of managing and planning, such as operational research, PERT, systems engineering, and value engineering will lead to a general increase in productive efficiency, and to a more rapid identification of opportunities for innovation.

The high standard of performance and reliability required of space programs has led to the development of techniques of measurement, testing and control which will serve to increase the quality and reliability of products and components. This is particularly important for the electronics industry, which is the primary source of automatic production equipment for other industries. Finally, the needs of space programs have in certain fields led to the increased availability of materials and of testing and laboratory equipment, thereby making the field more useful commercially. Such has been the case in the US in the field of cryogenics.

Nevertheless, it follows that a corollary to a Canadian space program is a concurrent program to assure that the maximum benefit accrues to the other sectors of the economy. This should be the subject of a special study to establish how the technology created by a major Government program can be channelled into other areas for maximum benefit to the country. Ingenuity has already been portrayed in the emerging success of the current industrial research and development incentive schemes in Canada; the challenge of effecting a higher degree of "spin-off" from a Canadian space program, thereby improving the cost-effectiveness of the dollars spent, can undoubtedly be solved with equal imagination.

Chapter 10

IMPLEMENTATION

10.1 ORGANIZATION AND ADMINISTRATION

It is apparent that the lack of a central organization for space activities in Canada has been unfortunate. This lack was recognized in the Report of the Royal Commission on Government Organization (Section 23). The need of a centrally responsible agency was specifically pointed out in 37 of the briefs submitted to us, and was a common view from industry, universities and Government agencies. (See Appendix A).

Although the views ranged from suggestions for a central information agency to those for an agency with large laboratory facilities, the majority held that there was a need for a central co-ordinating and contracting agency, operating under the policy direction of an advisory committee which was commonly envisioned as an organ of the Science Council of Canada.

It was held that the central agency should be a civilian branch of the Government but with some responsibility for military programs. It is presumed that the prime responsibility for military space programs would remain with DND, but that the central space agency would be responsive to defence needs and would provide services to DND. In order to achieve this symbiosis, some measure of military participation in the agency might be necessary.

Several reasons were given to support the need for a central responsibility for space activities. In the absence of any central direction or central agency there has been no delineation of Canada's objectives in space, from scientific, technological, social or economic viewpoints. There has been no central responsibility for the development of applications of space technology to communications satellites, resource surveys and other specific Canadian needs. There has been no unified planning for, nor co-ordination of, special facilities such as vibration and thermal vacuum test facilities, central data acquisition or processing facilities, or tracking facilities. Management and technical direction, particularly of non-military rocket development programs, has had to be organized on an interdepartmental basis. There is no agency with responsibility for support of development of space technology in accord with Canadian needs, as opposed to export; nor is there any for the assessment of technical proposals, particularly from industry or universities, which require formal Canadian technical and financial support before they can be accepted for flight on NASA spacecraft; for example, proposals from Barringer Associates for a new form of remote sensor, or from de Havilland for a STEM experiment in the Apollo spacecraft.

The absence of a central agency has been a greater handicap to industry and to the universities than to Government agencies and departments, since the latter are in a position to acquire authority as needed to carry out their specific responsibilities. Nevertheless, problems arise between agencies where there is divided responsibility; as for example the support of university researchers, an NRC role, where the university researcher wishes to place instruments in an ISIS satellite, for which DRB has responsibility. The support of the HARP-McGill program by DOI under a parliamentary vote intended to support export developments was eventually found to be inconsistent with the ultimate objectives of HARP and the US co-operating agency.

Problems of organization and administration will grow as Canadian use of space technology grows without some form of central organization and assignment of responsibility within the Government.

We consider that a central agency with responsibilities for space research and development for operation of major government facilities is necessary, and would recommend its establishment.

In examining the various forms of possible organization, we were impressed by CNES of France. CNES is such a central co-ordinating agency, which reports to a minister for policy and budget purposes, and performs most of its activities by contracting to government, industry and universities. By this arrangement, France was able to superimpose an integrated space program with central direction on already existing civil and military agencies without disrupting their activities or personnel.

Administrative arrangements for the co-ordination of the Japanese space program have evolved in a way which might be a guide for Canada. Space policy for Japan is the responsibility of the National Space Activities Council, an advisory committee that reports directly to the Prime Minister. This council is composed of 30 government

officials and scholars. The action necessary to carry out the approved space policy is the responsibility of the Science and Technology Agency, of which the Aeronautics and Space Section of the Research Co-ordination Bureau is in direct charge of space administration. The National Aerospace Laboratory and the National Space Development Center are the major government research laboratories which come under this agency.

The major university space institute in Japan is the Institute of Space and Aeronautical Science at the University of Tokyo. Many other university divisions are co-operating in an extensive program to explore the upper atmosphere and space using rockets and satellites, for example, for Research Institute of Atmospherics, the Institute of Plasma Physics, the Research Institute of Electrical Communication and the Tokyo Astronomical Observatory.

Japanese industry participates extensively in space research and development as well as manufacture through the Federation of Economic Organizations, a national economic organization consisting of leading industrial, commercial, financial and trade associations. The Federation makes studies of the national economy, including both domestic and international problems, and suggests solutions to the Japanese Government.

10.2 FACILITIES

Satellite Launch Facilities

Canada has all the essential facilities for a co-ordinated space program, with the exception of satellite launch vehicle facilities.

We do not consider that Canada should attempt at this time to provide satellite launch facilities to meet all program needs. These fall into 2 categories, launchers for small (100-lb) scientific spacecraft, and for large (500- to 1000-lb) spacecraft in earth-synchronous orbits. The former requirement might be satisfied with a HARP gun launcher, a vehicle formed of clustered Black Brant rockets, or the NASA Scout 4-stage solid-fuel rocket. A much larger vehicle is needed to place a large spacecraft in synchronous orbit at 22,300-mile altitude — something of the order of the Atlas-Agena, a large liquid-fueled vehicle.

In our view, it will be necessary to purchase launches for communications satellites for at least the next decade. These will have to be obtained from one of the countries having these facilities, presumably either the US, or the European consortium ELDO. These will have to be obtained on the best financial and technical terms possible.

We do consider that a development of Canadian capabilities to put small satellites into orbit, with potential for growth to meet future needs, must be undertaken. The purchase of facilities such as the NASA Scout vehicle and the use of US launch facilities seems inevitable in the first instance. We foresee a program leading to perhaps 4 launches a year by 1975, which level seems to be the break-even point for establishing and maintaining a facility of this nature.

This is the one major decision in development of facilities that we foresee. No detailed design study of vehicle configuration has been performed, though the HARP gun, clustered Black Brant, and Scout types of configuration have been recommended to us. The first step clearly is to perform a design study.

The US, USSR, France and Britain have developed large rocket vehicles first as weapons delivery systems, and more recently as man-carriers. Because of the investment of large sums in development and production of these rockets, these countries have launch vehicles available for incidental civilian scientific programs, communications or weather satellite launchers, space probes and so on. Therefore, the cost, for example, of a US communications satellite is much less than it would have been if there had been no military rocket program. Indirectly, US agencies enjoy the benefits of a very substantial government subsidy in the form of big military boosters.

To put it another way, although the basic research on rockets was done in the 1930's, the investment in engineering technology, capital equipment such as launch pads, and test ranges did not take place until the 1950's, when nuclear weapons gave an incentive for building large rocket delivery systems. Then placing instruments in orbit for scientific experiments or for engineering applications became feasible in the 1960's.

Canada's need for these vehicles could most logically be met by buying rockets from those countries which have them if the numbers needed are small, or by manufacture in Canada, under licence if need be, for larger numbers. Such a course might be financially most reasonable, other things being equal.

Economic and Political Factors

There are however, 2 important considerations to weigh in establishing a policy; availability of rocket vehicles for purchase on favorable terms, and the creation and maintenance of a full kit of technological tools.

Rocket vehicles capable of placing satellites into orbit are not for sale like automobiles. There are restrictions because the basic rockets were made as weapons and remain under military control. The export of whole rockets, or even of sub-systems, may be prohibited on the grounds that such action could be construed as constituting "proliferation of weapons delivery systems".

In fact, the only precedents for the relatively free sale of launch vehicles has been sale by the US for launching scientific satellites, where either the launch vehicles remained under control of the US or the launch vehicle (NASA Scout) was a non-military rocket obviously unsuitable as a weapons carrier. When one realizes that commercial and other interests stand to gain if launch-vehicle technology is not exported, it becomes quite apparent that an assumption that launch vehicles will be freely available is questionable, as long as a monopoly exists.

The second reservation concerns the desirability of completing the technical base for an activity which is of vital importance to the nation. A program to build a launch-vehicle capability, however small, creates in the country a cadre of technical people who understand all aspects of the problem, rocket motors, guidance, command and destruct systems, reliability control, launch environment and so on. The people with this body of knowledge search for ways to apply it, to improve their products, and to compete for export business using their skills. There is created a sense of initiative in the technical community which is absent if we cannot complete the job within our own resources.

Views of the Scientific Community

There appears to be a consensus of opinion leaning towards a

> "modest orbital launch capability for payloads up to approximately 100 lb on the assumption that Canadian requirements for small satellite payloads will be sufficient to justify the capability and that by 1990 this kind of activity will be meaningful in exploiting the Canadian environment. This presupposes international co-operation in the use of tracking and other ground

support facilities. A small-payload Canadian orbital capability should not preclude buying launching time from the US for larger payload requirements. At the same time, it should not be expected to give a normal business return but should be recognized as a pace-setter for a number of Canadian companies, universities and research establishments'',

"It should be emphasized here that the development of a Canadian launcher of the Scout class is not an overly ambitious undertaking for a country which already is producing and launching multi-stage sounding rockets of the Black Brant type. The progression from sounding rockets to satellite launchers is fundamentally one of providing the necessary guidance and control to incline the flight path horizontally and insert a payload into orbit. The basic elements already exist of rocket motor technology, staging design and a launch and tracking complex at Churchill",

"Nous croyons que tôt ou tard le Canada devra lancer ses propres satellites (au moins pour les communications) et que cela doit se préparer de longue date. Ces lancements seront nécessités pour le commerce et l'industrie (sinon pour maintenir l'autonomie canadienne)",

"We emphasize that the development of a launching capability is at this time an entirely reasonable possibility because it has been shown that the basic developmental and manufacturing competence exists within the country",

to quote from 4 briefs received from a Government department, an industrial firm and 2 universities. In 24 briefs received by the Study Group, this topic was mentioned. (See Appendix A). A number of briefs were devoted specifically to the question, presenting different views on how a Canadian orbit capability could best be achieved.

The issue was not completely one-sided, there being some concern whether the costs of a launch facility could be justified.

Cost of a Small-Satellite Launch Facility

The Study Group examined the cost question in as much detail as possible in a short time. Two proposals were put forward from Canadian groups, one to develop a gun-launched system, and the other to cluster and stage rockets of the Black Brant type. Figures for the costs of developing either one of these methods into a reliable tested and proven launch system were of course unavailable, and approximate estimates only could be made.

However, a great deal of valuable information was obtained from NASA on the Scout rocket, which is one of the very few orbital boosters which was not designed initially as a weapon. Development of the vehicle was begun in 1959, and 48 have been launched to date. The total cost of the program has been $119,514,896. The average cost per vehicle, including development and the 3-ground support complexes was $2,480,000. An analysis of the program shows that the cost per vehicle has remained relatively constant during this period, since increasing expenditures to improve reliability and performance have offset the initial development and ground-facility costs.

At the present time the cost per vehicle includes a pro-rated figure to cover fixed yearly costs. The cost to the user at the rate of one per annum is $3,368,000, reducing to $1,578,400 for 5, to $1,379,555 for 9, and to $1,280,133 for 15. Since about 10 Scouts are now being used per annum the unit cost is about $1,400,000.

The Scout system has the capability of launching a 258-lb payload into a 360-nautical-mile polar orbit, or 320 lb into a low-inclination easterly orbit. It is a 4-stage solid rocket vehicle, which can be launched from one of 3 sites in the US.

It is our understanding that Scout boosters can be purchased from NASA for about $1,400,000 each, launched from a range in the US. It would seem appropriate to use this vehicle for small scientific satellites, probably first launched from a range in the US, then from a range to be set up in Canada by 1975, when we except the rate of launches will reach 4 per annum.

The conversion of the Scout booster to a Canadian version could be accomplished over a number of years, through gradual replacement with improved motors, interstage sections, guidance and control systems, using and expanding existing industrial capacity at a reasonable rate. Such a program could develop an industrial capacity for rocket vehicle development which in the latter part of the 1970's might be able to supply the greater part of Canada's needs.

A critical question is the rate at which any such program could be carried out. There is slack at the present time due to the completion of the Black Brant rocket-development program. Growth at a reasonable rate might permit a $10,000,000 per annum program by 1975, a level equivalent to the Scout program at a 4-launch-per-annum rate, for a total cost of about $35,000,000 over that period.

This is as far as the information from the NASA Scout program can be projected in the Canadian context. It should not be construed as an endorsation of the Scout, or of rockets over gun-boosters, but simply the only extrapolation available to the Study Group which is based on experience. The initial step would be a thorough design study, which we estimate would take about 20 engineer-years to accomplish.

Other Facilities

Canada has a sound basis for other aspects of a space program. Canadian industry has a demonstrated capability to provide spacecraft for both scientific uses and telecommunications applications. There exists an excellent sounding rocket range at Churchill which might be extended to include satellite-launch facilities. Industry can provide sounding rockets, and has the installed plant to begin manufacture of larger rockets. There are research and development groups in industry and Government capable of meeting all the foreseen hardware requirements with the necessary technological competence. The universities are training scientists and engineers in what would appear to be adequate numbers to meet the needs of the program, at least with no more shortage than now exists in other fields.

There are some facilities which are inadequate and need expansion. Environmental test facilities for space simulation and vibration are an example. There seems no reason why this lack cannot be met in due course.

If it becomes necessary to augment the global tracking and readout facilities for the Canadian space program, it was suggested that this might be done as part of Canada's foreign aid program, wherein the facilities would be provided by Canada to the universities of underdeveloped countries, thereby assisting the educational institutions of these countries.

In view of the anticipated expansion of the Canadian space program in the 1970's, it clearly is desirable for Canada to assume full responsibility for CRR when the present agreement expires in 1970, rather than being subject to US concurrence in use of the range.

Chapter 11

RECOMMENDATIONS

Program Theme

Application of space technology to specific Canadian needs should be the central theme of the program. Canada needs satellites for TV and telephone services to the north, for augmenting communications east and west, for surveying natural resources, for surveillance of weather, spotting forest fires and ice in shipping lanes and for many other purposes. The prime objective for space technology in Canada is its application to telecommunications and survey problems of a large sparsely settled country.

Secondly, the upper atmosphere over Canada is like that over no other country, with northern lights, ionospheric storms, and a magnetic field which trails away from the sun nearly to the moon's orbit. The weather over much of North America is triggered by events in the denser atmosphere over Canada, but some phenomena occur at heights where only rockets or satellites can make measurements. Research in the laboratory, at rocket ranges, from the ground or from satellites is in our own interest, and a duty to others in the world affected by our atmosphere. The second objective for a Canadian space program is the study of the unique atmosphere high over Canada.

The field of space activities should, in Canada, include all activities directly associated with rockets and other launch vehicles, with spacecraft, and with those ground-based activities which relate directly to upper-atmosphere and space phenomena. The space program is separate and distinct from aeronautics in Canada.

Organization

The absence of a national mission-oriented agency with overall responsibility for upper-atmosphere and space activities in Canada has resulted in fragmented programs, divided responsibility, and serious omissions in planning. These deficiencies are bound to become more serious in the future, and could lead to tragic consequences for Canada in loss of technological opportunity, and in gradual erosion of national control over natural resources and domestic communications.

Therefore we recommend:

(a) the establishment of a national advisory committee on space research and development.

It should be pointed out that this function cannot be filled by the NRC Associate Committee on Space Research, unless the authority of the Committee is radically altered and enlarged.

Therefore we recommend:

(b) the establishment of a central co-ordinating and contracting agency for space research and development.

This agency would assume financial responsibility for some of the existing programs, but would contract authority back to the agencies and departments which now direct these programs, at least for the present. It is not envisaged that the central agency would establish laboratory facilities where these exist or can be established in industry or universities. In due course there might be some consolidation of existing Government laboratories in the space area.

Therefore we recommend:

(c) the establishment of impartial procedures for the selection of rocket and satellite experiments.

These procedures are necessary to provide uniformity of opportunity for scientists in Government, university and industry.

Orbital Launch Vehicles

Canada will, within the next decade, need to launch small scientific satellites at a rate which will justify supply from Canadian sources.

Therefore we recommend:

(a) the initiation of a design and cost study for a small-satellite launch vehicle and related facilities for Canadian use.

Canada will require a continuous series of launches of communications satellites into synchronous orbit, to establish and maintain a telecommunications system for domestic Canadian use.

Therefore we recommend:

(b) the negotiation of purchase of launching services for synchronous orbit communications satellites on terms which will ensure continuing Canadian specification and control of domestic communications.

Space Facilities

All major facilities such as launch ranges, launch vehicles, test facilities, data acquisition and processing facilities must be considered as national investments, neither to be duplicated unnecessarily on the one hand nor to be built inadequately on the other.

Therefore we recommend:

(a) that major investments in space facilities should not be undertaken without reference to the overall space program.

The use by Canada of CRR is expected to grow nearer to parity with the US and the present joint agreement is potentially restrictive on Canadian use of CRR.

Therefore we recommend:

(b) that when the agreement covering CRR expires on 30 June 1970 it should be re-negotiated on the basis of complete Canadian control with specific provision for launching US rockets on a reimbursable basis.

Satellite Communications

The need for use by Canada of communications satellites for domestic communications is clearly established, and there is a risk that ultimate control over the specification, supply, and operation of the space segment of a communications satellite system may not reside in Canada.

Therefore we recommend:

(a) that steps be taken to ensure continuing Canadian control of domestic communications.

(b) that, while it may be necessary to purchase launch services for synchronous satellites, Government policy on use of telecommunications satellites for domestic communications be developed so as to ensure Canadian control and maximum use of Canadian capabilities for the development and manufacture of both space and ground components of the various systems.

The space available for locating synchronous communications satellites is limited, and Canada has a clear claim to a reasonable number of positions for domestic communications satellites.

Therefore we recommend:

(c) that Canadian rights to station satellites in synchronous orbit locations between 75°W and 115°W longitude be established by international agreement and taken up by occupation within a reasonable time.

The present international assignment of radio frequencies is unsatisfactory to Canada on several accounts, and no provision of frequencies has yet been made to anticipate direct broadcast to home receivers from communications satellites.

Therefore we recommend:

(d) that consideration be given to reassignment by ITU of frequencies for communications satellites to increase the bandwidth available, to remove the limitations due to interference with the present radio-relay services in Canada, and to provide frequencies for direct TV broadcast from satellites.

Industrial Development and Production

The domestic need for launch vehicles and space hardware is growing. Developments of this nature in other countries are fully supported by government on military or other grounds.

Therefore we recommend:

(a) that industrially based, study and research and development programs, fully funded, be undertaken on launch-vehicle systems and components to meet Canadian needs.

(b) that systems management and prime contract activities be awarded to Canadian industry for the development and supply of the major hardware portions of the Canadian space program.

Complete self-sufficiency within Canada for the supply of space hardware is not expected within the foreseeable future. Extensive purchases will therefore have to be made from other countries. We need to achieve a balance of payments on this account and to promote export opportunities for Canadian industry, similar to the existing defence production and development-sharing agreements.

Therefore we recommend:

(c) the negotiation with other countries of development- and production-sharing arrangements in the space field.

We anticipate that space programs can initiate innovations in a wide range of technology. One purpose of supporting space research

and development is to generate new processes and products of value primarily to industries outside the space area.

Therefore we recommend:

(d) the initiation of a program to establish and implement the best way to channel the technology derived from the space program into other areas for maximum benefit to the country.

University Institutes and Research Groups

There is an increasing need for university institutes to establish extensive research facilities for research and graduate training by a group of staff and students. The effectiveness of a university research group also increases much more rapidly than the numerical increase in staff once a critical size is reached which permits staff members to assist one another in different phases of their research. Furthermore, a large enough group to provide for several rocket launches a year is needed to reduce the hazard of graduate research on space vehicles, or to handle the experiments in satellites. These institutes and university research groups will represent an increasingly important element of the total national resources in space research and development.

Therefore we recommend:

the integration of the programs of university space institutes and research groups into a national space program, consistent with the role of these institutes and groups as centers of research and advanced education, and that they be properly funded to contribute effectively and efficiently.

Life Sciences

There is no identifiable theme in the present space-research activities of life scientists in Canada, but excellent work is going on in unrelated areas, some of which has direct relevance to manned space flight, studies of life possibilities on other planets, and so on. Canadian life scientists should have an opportunity for direct participation in space experiments, in anticipation of the eventual development of programs requiring Canadian competence.

Therefore we recommend:

that Canadian life scientists be encouraged to participate directly in space programs in Canada or to co-operate in foreign programs.

APPENDIX A

The Body of Opinion

A total of 112 briefs was received; most were in the form of written presentations at hearings held from Halifax to Vancouver.

Three issues were raised repeatedly in these briefs,

(a) the need for a central Canadian organization for space,

(b) the need for Canadian communications satellites,

(c) the need for a Canadian satellite launching capability.

There was a wide measure of agreement in principle on these questions in the industry, university and Government briefs, as shown in the following table.

	Central Organization	Domestic Communications Satellites	Canadian Launching Facility
Industry..........	9	8	4
Government.......	15	14	10
University........	13	6	10
Total............	37	28	24

Opinions expressed in the briefs varied widely in detail, but the weight of opinion was heavily on the positive side of these issues.

Sixteen suggestions for scientific satellite experiments were raised in the briefs, some being well-developed, and others being more speculative, with launch dates suggested from 1968 on. There were 3 potential users of gun-sondes for measurements up to about 100 km.

APPENDIX B

The Study Group is grateful to individuals and organizations who presented briefs or other communications. The principal contributors were as follows:

FROM UNIVERSITIES

Dalhousie	C.K. Hoyt W.C. Lin Department of Chemistry
Nova Scotia Technical College	Department of Mechanical Engineering School of Graduate Studies
New Brunswick	Department of Surveying Engineering
Laval	Department of Physics
McGill	Space Research Institute Faculty of Graduate Studies and Research J.S. Marshall Faculty of Engineering Department of Meteorology
Montreal	G.G. Cloutier
Ottawa	P.M. Thompson
York	Centre for Research in Experimental Space Science
Toronto	Institute for Aerospace Studies D.A. Turner (also Hospital for Sick Children)

Western Ontario	Department of Physics Faculty of Engineering Science Department of Chemistry W.H. Wehlau
Manitoba	Department of Physics W.G. Barker Department of Mechanical Engineering
Saskatchewan	Institute of Space and Atmospheric Studies B.W. Currie Department of Physics Department of Electrical Engineering A. Vallance Jones
Calgary	Department of Physics H.A. Buckmaster J.R. Prescott
Alberta	Department of Electrical Engineering Department of Physics
British Columbia	J.A. Jacobs C.S. Wright
Canadian Services College, Royal Roads	H.J. Duffus G.M. Boyd
Victoria	Department of Physics
Maryland (US)	D.L. Matthews

FROM INDUSTRY

EMI Cossor Electronics Limited	Communications Division
Canadian Industries Limited	Development Division Explosives Division
CAE Industries Limited	Electronics Division
Canadair Limited	Engineering Division

The Telephone Association of Canada	
Bell Telephone Company of Canada	Planning and Research R.A. Cline C.H. McGuire
Northern Electric Company Limited	Research and Development Laboratories E.S. Kelsey G.B. Thompson
Aviation Electric Limited	Research and Development
Canadian Overseas Telecommunication Corporation	
RCA Victor Company Limited	Research Laboratories Space Systems
Computing Devices of Canada Limited	Space Sciences Division
Canadian Westinghouse Company Limited	Electronics Division
de Havilland Aircraft of Canada Limited	SPAR Division
Ferranti Packard Electric Limited	Electronics Division
Barringer Research Limited	A.R. Barringer
Bristol Aerospace Limited	Rocket and Space Division
Canadian National Telecommunications	H.J. Clarke
Sinclair Radio Laboratories Limited	Research and Development Division
Electronic Associates of Canada Limited	E.W. Leaver
Litton Systems (Canada Limited	J.J. Green J.M. Bridgman

FROM GOVERNMENT AGENCIES

Atomic Energy of Canada Limited	Space Physics Group
Board of Broadcast Governors	W.R. Wilson

Canadian Broadcasting Corporation	J.P. Gilmore
Canadian Armament Research and Development Establishment (DRB)	W.N. English J. Hampson D.J.G. McKinnon C. Cumming W.G. Brownlee F. Jackson H.K. Clark
Department of Industry and Department of Defence Production	Industrial Research Adviser Electrical and Electronics Branch Aircraft Branch Machinery Branch S.B. Shaw
Department of Energy, Mines and Resources	Departmental Committee on Satellites Dominion Radio Astrophysical Observatory
Department of National Defence	Chief of Technical Services
Defence Research Board	Chief Scientist (Physics and Engineering) S.A. Brightwell
Defence Research Telecommunications Establishment (DRB)	F.T. Davies J.S. Belrose
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Department of National Health and Welfare	Health Services Branch, Aerospace Medicine and Safety
National Research Council	B.G. Ballard K.F. Tupper D.C. Rose Space Research and Facilities Branch National Aeronautics Establishment I.B. McDiarmid A.G. McNamara Pure Physics Division Radio and Electrical Engineering Division Upper Atmosphere Research Section Division of Mechanical Engineering
Department of Transport	Meteorological Branch Telecommunications and Electronics Branch

and from the:

Canadian Aeronautics and Space Institute	Council of CASI

APPENDIX C

Current Major Research Projects in Canadian Universities

Note: This list is not comprehensive. It supplements information provided in Section 3.1.

The Institute for Aerospace Studies, University of Toronto

I *Mechanics of Suborbital Flight*

1. Free-Molecule Transfer of Mass, Axial Momentum and Energy Through Axially Symmetric Tubes – USAF/AFOSR*
2. Free-Molecule Flux Properties of Conical Sections Over a Wide Range of Speed Ratios – USAF/AFOSR
3. Electron Beam Probe – USAF/AFOSR, DRB
4. Rotational Temperature Measurements in Under expanded Jets and Shock Waves Using an Electron Beam Probe – USAF/AFOSR, DRB
5. Experiments on the Diffusive Separation of Helium-Argon Mixtures in Free Jets and Shock Waves – USAF/AFOSR, DRB
6. Free-Molecule Pressure Probes – USAF/CRC

II *Plasma Dynamics – Upper-Atmospheric Simulations*

1. Low-Density Plasma Tunnel – DRB, USN/ONR
2. Theory of Spherical and Cylindrical Electrostatic Probes in a Collisionless, Fully Maxwellian Plasma at Rest – USAF/AFOSR
3. A Comparison of Microwave and Langmuir-Probe Diagnostics – USAF/AFOSR, DRB
4. The Behavior of Free-Molecule, Cylindrical Langmuir Probes in Supersonic Flows, and Their Application to the Study of the Blunt-Body Stagnation Layer – USAF/CRC, USN/ONR, DRB

* Supporting Agency

5. Shock-Tube Studies of Magnetohydrodynamic Boundary Layers – USAF/AFOSR, DRB
6. Two-Dimensional Magnetohydrodynamic Boundary-Layer Theory – USAF/AFOSR
7. The Finite Expansion of an Inviscid Compressible Plasma with Low Conductivity in the Presence of a Longitudinal Magnetic Field – USAF/AFOSR
8. Calculation of the Transport Coefficients for Non-Equilibrium 2-Temperature Plasmas by the 13-Moment Method – NRC
9. Theoretical Investigation of the Solar Differential Rotation – NRC
10. Investigation of the Ionization Processes Behind a Strong Shock Wave in Hydrogen – DRB, USAF/AFOSR
11. A Study of Hall Current Acceleration – DRB, USAF/AFOSR
12. An Experiment on the Utilization of an Electron Beam to Measure Plasma Properties – DRB, USN/ONR
13. Theoretical Studies of the Structure of Shock Waves in a Weakly Ionized Plasma – USN/ONR

III *Hypersonic Gasdynamics and Re-entry Physics*

1. Nonequilibrium Expansion Flows of Dissociated Oxygen and Ionized Argon Around a Corner – USAF/AFOSR, NRC, DRB
2. Integral Methods in Compressible Laminar Boundary Layers and Their Application to Hypersonic Pressure Interactions – NASA, NRC, DRB
3. A Theoretical Analysis of the Driver – Reservoir Method of Driving Hypersonic Shock Tunnels – USAF/ARL, DRB
4. A Self-Calibrating Probe for Measuring Free-Stream Atom Concentration in a Hypersonic Flow – NASA, NRC, DRB
5. Shock and Combustion-Wave Dynamics in an Implosion-Driven Hypervelocity Launcher – USAF/ARL, DRB
6. Sonic Line in Nonequilibrium Flows – NASA, NRC, DRB
7. Analogue Networks for High Heat Transfer Rate Measurements – USAF/AFOSR, NRC, DRB
8. Instrumentation and Calibration of the 11-inch x 15-inch Hypersonic Shock Tunnel – NASA, USAF/AFOSR, NRC, DRB

9. Determination of Diaphragm Opening Time and Use of Diaphragm Particle Traps – USAF/AFOSR, NASA, NRC, DRB
10. A Preliminary One-Dimensional Study of the Initiation of Secondary Solid Explosives by Hydrogen-Oxygen Detonation Waves – USAF/ARL, DRB
11. Development Study of the UTIAS Implosion-Driven Hypervelocity Launcher – USAF/ARL, DRB
12. A Critical Review of Hypervelocity Launchers – USAF/ARL, DRB
13. Multipoint-Detonation-Generated Implosions from Hemispherical Shells of Sheet Explosive – USAF/ARL, DRB
14. An Experimental Determination of the Gladstone-Dale Constants (Refractive Indices) of Dissociated Oxygen and Ionizing Argon – NASA, USAF/AFOSR, NRC, DRB
15. Experimental Investigations of Nonequilibirum Corner Expansion Flows of Dissociated and Ionized Gases – USAF/AFOSR, NASA, NRC, DRB
16. Nozzle Flows with Coupled Vibrational and Dissociation Non-Equilibrium – NASA, USAF/AFOSR, NRC, DRB
17. Laboratory Calibration of a Meteoroid Impact Gauge – NASA, NRC, DRB
18. Temperature and Concentration Measurements in Non-equilibrium Corner Expansion Flows – NASA, USAF/AFOSR, NRC, DRB
19. The Shock-Tube and Shock-Wave Phenomena on Earth and in Space – USAF/AFOSR, USAF/ARL, NASA, DRB, NRC

IV *Plasma Propulsion and Energy Conversion*

1. Inert Gas Heater for Propulsion-Energy Conversion Tunnel – DRB
2. Power-Generation Channels for Magnetogasdynamic Studies – DRB
3. Development of Electromagnet Facility – DRB
4. Development of Heat Exchanger for Magnetogasdynamic Facility – DRB

V *Aerodynamic Noise-Jet Investigations*

1. Response of a Flexible Panel to Turbulent Flow: Running Wave Versus Modal Density Analysis – USAF/AFOSR
2. Turbulence Measurements Relevant to Jet Noise – NRC, USAF/AFOSR
3. An Aerofoil Probe for Measuring Transverse Velocity in Unsteady Flow – NRC, USAF/AFOSR
4. Refraction of Sound by Jet Flow and Jet Temperature – NRC, USAF/AFOSR, NASA
5. Distortion of a Shock Wave Traversed by a Vortex – NRC, USAF/AFOSR
6. State-of-the-Art Review of Jet Noise – USAF/AFOSR

VI *Aerospace Flight Dynamic*

1. Development of a Circular Track for Testing Airborne Vehicles Flying Near the Ground – DRB, NRC, USAF/RTD
2. Studies of the Re-entry Flight Paths of Lifting Vehicles – USAF/AFOSR
3. Minor Circle Flight for a Hypersonic Vehicle – USAF/AFOSR
4. Passive Attitude Stabilization of Earth Satellites – USAF/AFOSR
5. Spin Decay of Satellites – DRB, USAF/AFOSR
6. Lateral Instability of Aircraft due to Aerodynamic Cross-Coupling – USAF/AFOSR, de Havilland
7. Dynamics of Human Pilots – DRB, NRC

VII *Materials Science and Structures*

1. Failure Mechanisms and Statistical Aspects of Metal Fatigue – NRC, NASA
2. Effect of Humidity on the Failure Mechanisms of Metal Fatigue – NRC, NASA
3. Effect of Grain Size on Fatigue Life and Failure Mechanisms in Metal Fatigue – NRC
4. Buckling of Circular Cylindrical Photoelastic Shells in Axial Compression – NRC, NASA

VIII *Upper Atmospheric Research*

1. Rocket Measurements at High Altitudes with a Specially Developed Electron Gun – NRC

IX *Molecular Beams – Surface Interactions – Simulation of Space Flight*

1. Development of a High-Energy Molecular-Beam Facility – NASA, DRB
2. Electron Beam Studies of Skimmer Interaction in a Free Jet – NASA, DRB
3. Optical Lever Force and Energy Transducer – NASA, DRB
4. Scattering of High-Energy Molecules from Surfaces – DRB, NRC
5. Interaction of Low-Energy Ions with Controlled Surfaces – USN/ONR, NRC
6. Pulsed Electron Beam Velocity Analyser – USN/ONR, DRB
7. Selective Gettering of Gases by Vacuum-Deposited Nickel Films – DRB

Note: Divisions F (Subsonic Aerodynamics) and K (Industrial Aerodynamics) of the UTIAS research program have been excluded from the above list.

Institute for Space and Atmospheric Studies, University of Saskatchewan

I *Investigations Using Radio Techniques*

1. Measurements of Winds and Electron Densities in the Mesosphere
2. Polarization of VHF Auroral Echoes
3. Polarization of Auroral Radar Echoes
4. UHF Scattering in the Lower Ionosphere
5. Auroral Motions and the Auroral Electro-Jet

II *Investigations Using Optical Techniques*

1. Hydrogen Emissions During Aurora
2. Twilight and Airglow Studies
3. Atmospheric Motions from Photometric Observations
4. Dayglow and Daytime Auroral Emissions

5. Measurements of Auroral and Nightglow Temperatures with a Wide-Angle Michelson Interferometer

III *Investigations Involving the Use of Rockets and Balloons*

1. Twilight and Day Airglow Infrared Oxygen Emissions
2. Dayglow Studies from Balloons and Rockets Using a Fabry-Perot Spectrometer
3. Photometer for Observations from A Rocket
4. X-ray and Acoustical Measurements from a Balloon

IV *Space Engineering*

1. Stabilization of Ejectable Rocket-Borne Probes
2. Procedures for Measurement of Particle Density at High Altitudes
3. Upper-Atmospheric Electric Fields Using Artificial Micrometeoroids
4. Generation of Artificial Micrometeoroids for Electric Field Studies.

V *Other Investigations*

1. Ionospheric Tides
2. Fine-Scale Structure of Auroral Brightness Fluctuations
3. Large-Scale Structure of Auroral Brightness Fluctuations
4. Auroral Morphology
5. Heights of Noctilucent Clouds

Space Research Institute of McGill University

1. Impact Physics – NASA
2. Cloud Expansion in Free Space – USAF
3. Pyrophoric Effects in Hypervelocity Impacts – USAF
4. Underwater Towing Characteristics of Bodies – DRB
5. Exobiological Studies – NRC
6. Wind-Shear – Drift Measurements – HARP
7. Composition and Thermodynamic Studies – HARP
8. Meteor Shower – HARP
9. Nose-Cone Re-Entry Heating

Department of Physics, University of Western Ontario.

1. Radio Wave Scattering in the Disturbed Ionosphere
2. Radio Wave Scattering from Meteors
3. Meteor Wind and Wind-Shear Measurements
4. Satellite Scintillation Studies of Ionospheric Structures
5. Rocket Scintillation Studies of Ionospheric Structures
6. Satellite Studies of Ionospheric Electron Content (Faraday and Doppler Methods)
7. Ionospheric Absorption Studies Using Riometer, Meteor Scatter Systems and Rockets
8. Correlation of Satellite-Measured Particle Fluxes with Radio-Auroral Intensities
9. Studies of Solar Radio Phenomena Related to Geophysical Phenomena
10. Meteor Ablation and Ionization Studies
11. Studies of Waves in Auroral Structures Using Radio/Radar Methods
12. Theoretical Studies Related to Electron Scattering in the Ionosphere and Radio-Auroral Scattering

Université Laval

1. Development of the Inflexion Mass Spectrometer (1947)
2. Development of an Electrometer with Vibrating Reed (1951)
3. Improvement of an Electron Multiplier (1952)
4. Production of Monoenergetic Electron (1956)
5. Study of Ion Sources (1956-57)
6. Improvement of the Electron Selector (1959)
7. Charge Exchange Measurements (1961)
8. Study of the Effective Section of Excited Ions (1963)
9. Investigation of a Magnetic Ionic Optical System (computer program) (1964)
10. Improvement of a Quadripolar Mass Filter (1964)
11. Ambipolar Recombination (1965)
12. Electron Multiplier with High Effectiveness for a Quadripole (1966)

13. Electron Spectroscopy
14. Crossed-Pencil Ion Source for Ionic Structure Studies

University of Calgary

I *Cosmic Radiation*

1. Neutron Monitors, Sulphur Mountain and Calgary
2. Extensive Air Showers
3. Primary Cosmic Rays
4. Balloon Measurements of Solar Neutrons
5. Rocket Measurements of Fast Neutrons above the Atmosphere

II *Cosmic Electromagnetic Emissions*

1. X-ray Astronomy by Rockets
2. Gamma-ray Astronomy

III *Auroral Research*

1. Satellite-Borne Detectors
2. Rocket and Balloon Measurements of Auroral X-rays and Optical Emissions
3. Ground-Based Observation of Optical Aurora
4. Magnetic-Field and Cosmic Noise Studies

IV *Solar Terrestrial Relationships*

APPENDIX D

TABLE I

CURRENT GOVERNMENT PROGRAMS (1966)

Program	Responsible Agencies	Expenditures (1966) $ Thousands	US Expenditures in Canada (If Applicable) $ Thousands
1. Alouette/ISIS	DRB	4,222	
2. Churchill Research Range	NRC	2,170	2,170
3. Missile Re-entry	DRB	2,000	600
4. Engineering Support, Rockets	NRC	1,750	
5. HARP-McGill	DOI	1,500	1,150
6. Upper Atmosphere Research	DRB	1,237	
7. Rocket Development	DOI/DRB	970	
8. Aerology	DRB	818	
9. University Support	DRB/NRC	740	410
10. Satellite Communications	DRB/DOT	731	
11. NRC Space Research	NRC	612	
12. PARL	DRB	518	
13. Industrial Research Support	DRB	225	
14. St. John's Tracking Station	NRC	200	
15. Cosmic Ray Research	AECL	80	
		17,773	4,330

TABLE II

SPACE BUSINESS IN CANADIAN INDUSTRY

	$ Thousands
Total Sales in Canada	15,166
Total Sales to US	15,571
Total Sales to Europe	834
Company-Funded Activities	5,750
Total for 1961 to 1966	37,321
Total for last complete year (1965-66)	17,068
Capital Investment in Plant and Facilities	17,362

Source: Data provided in response to questionnaire sent to all Canadian Corporations active in the field

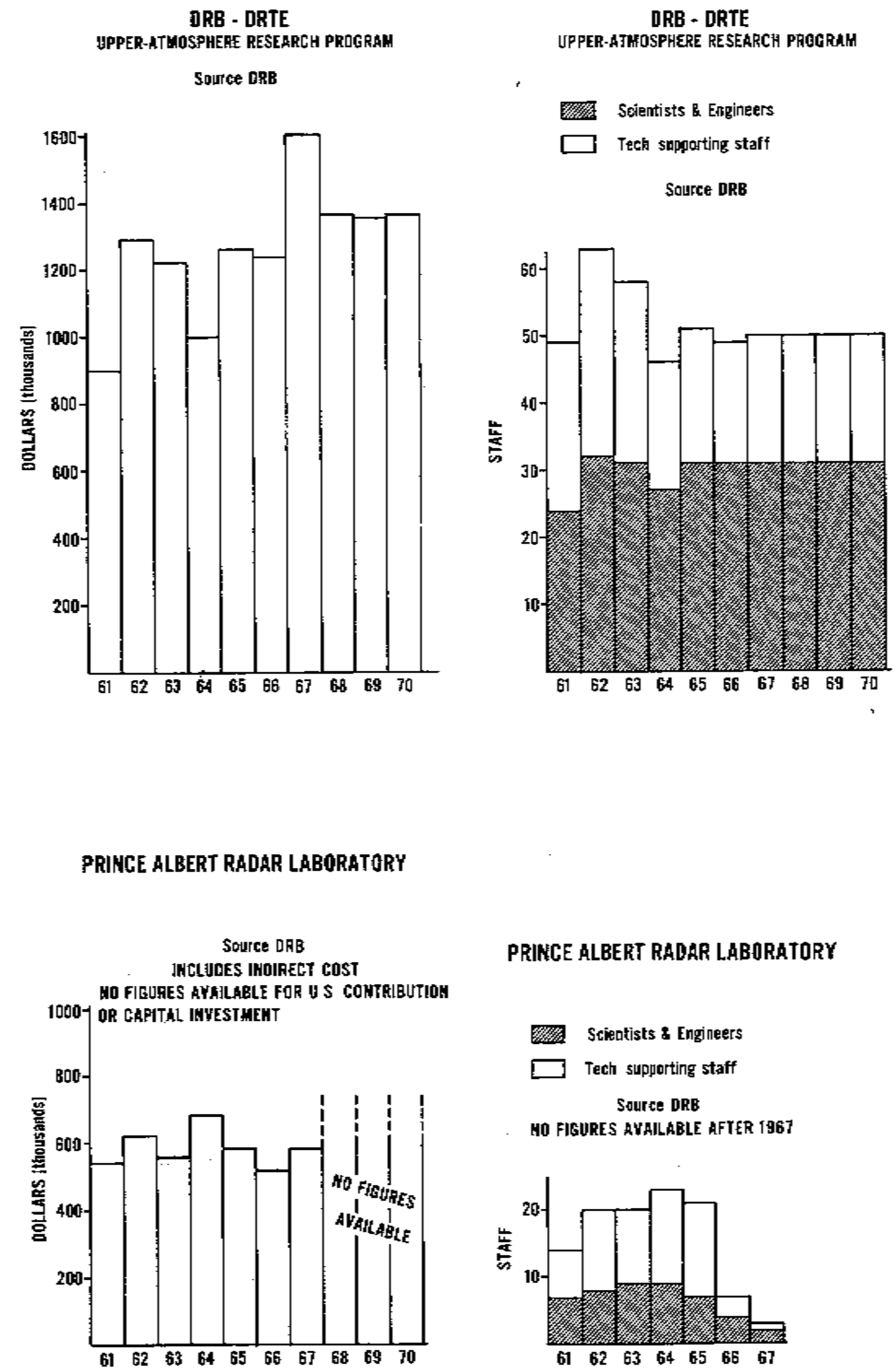

Fig I DRTE UPPER ATMOSPHERIC RESEARCH AND THF PRINCE ALBERT RADAR LABORATORY

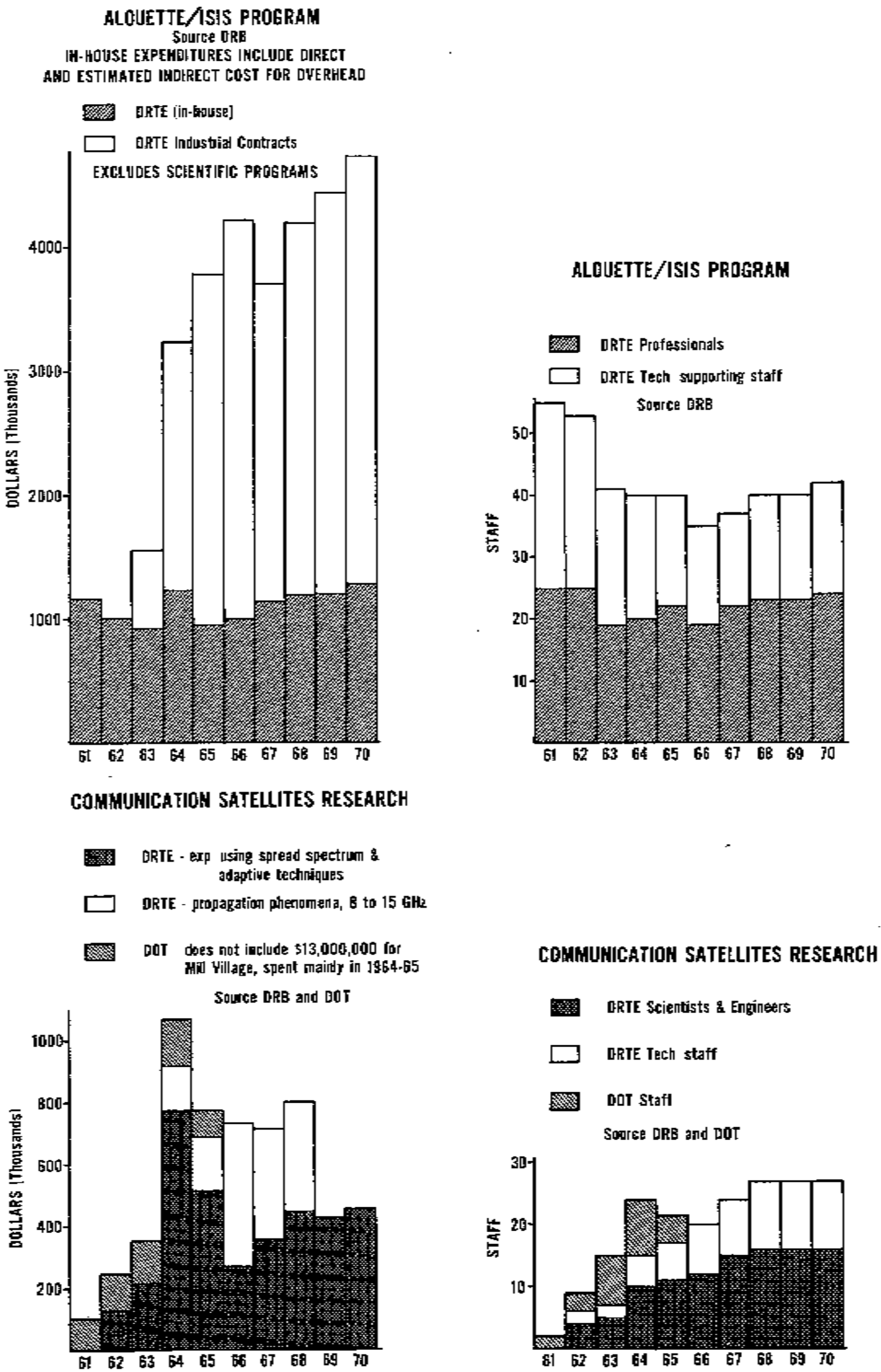

Fig II SATELLITE PROGRAMS; ALOUETTE/ISIS AND COMMUNICATIONS SATELLITES

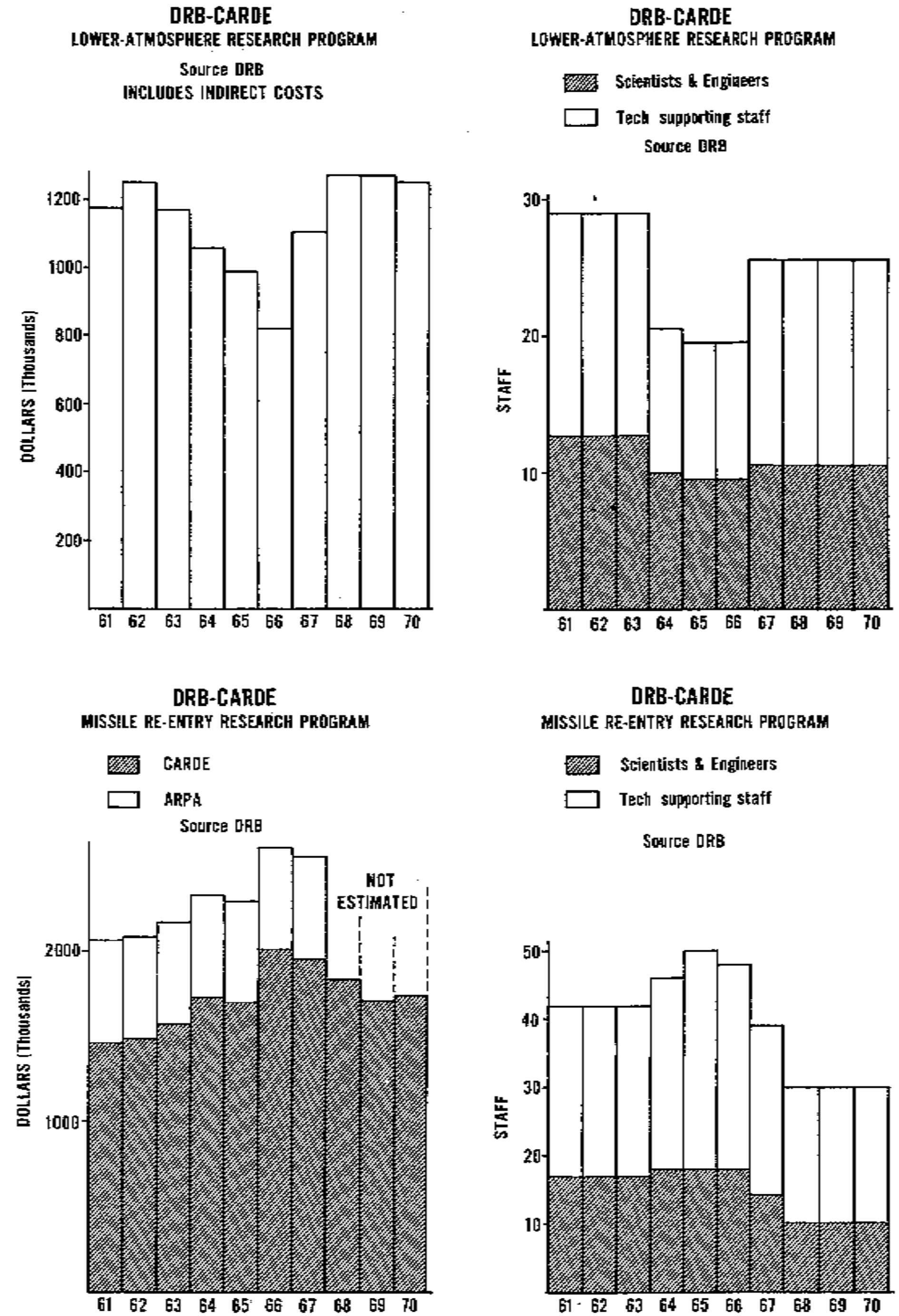

Fig III CARDE PROGRAMS IN AEROLOGY AND MISSILE RE-ENTRY RESEARCH

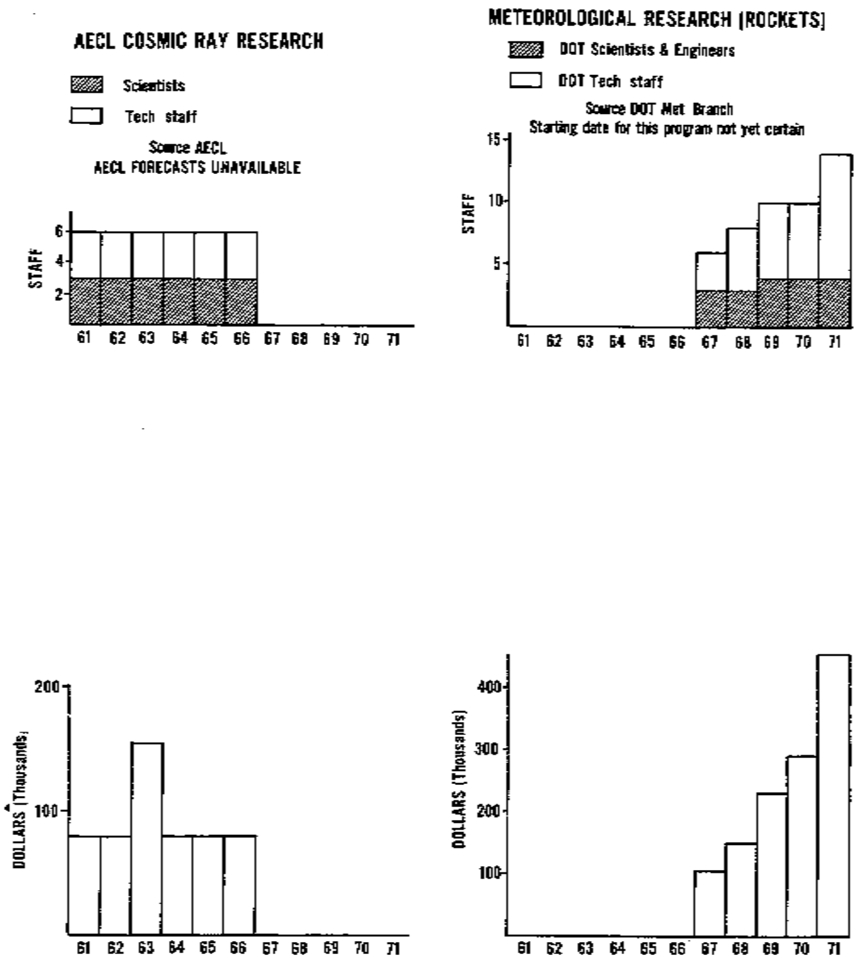

Fig IV AECL COSMIC RAY PROGRAM AND DOT METEOROLOGICAL ROCKET PROGRAM

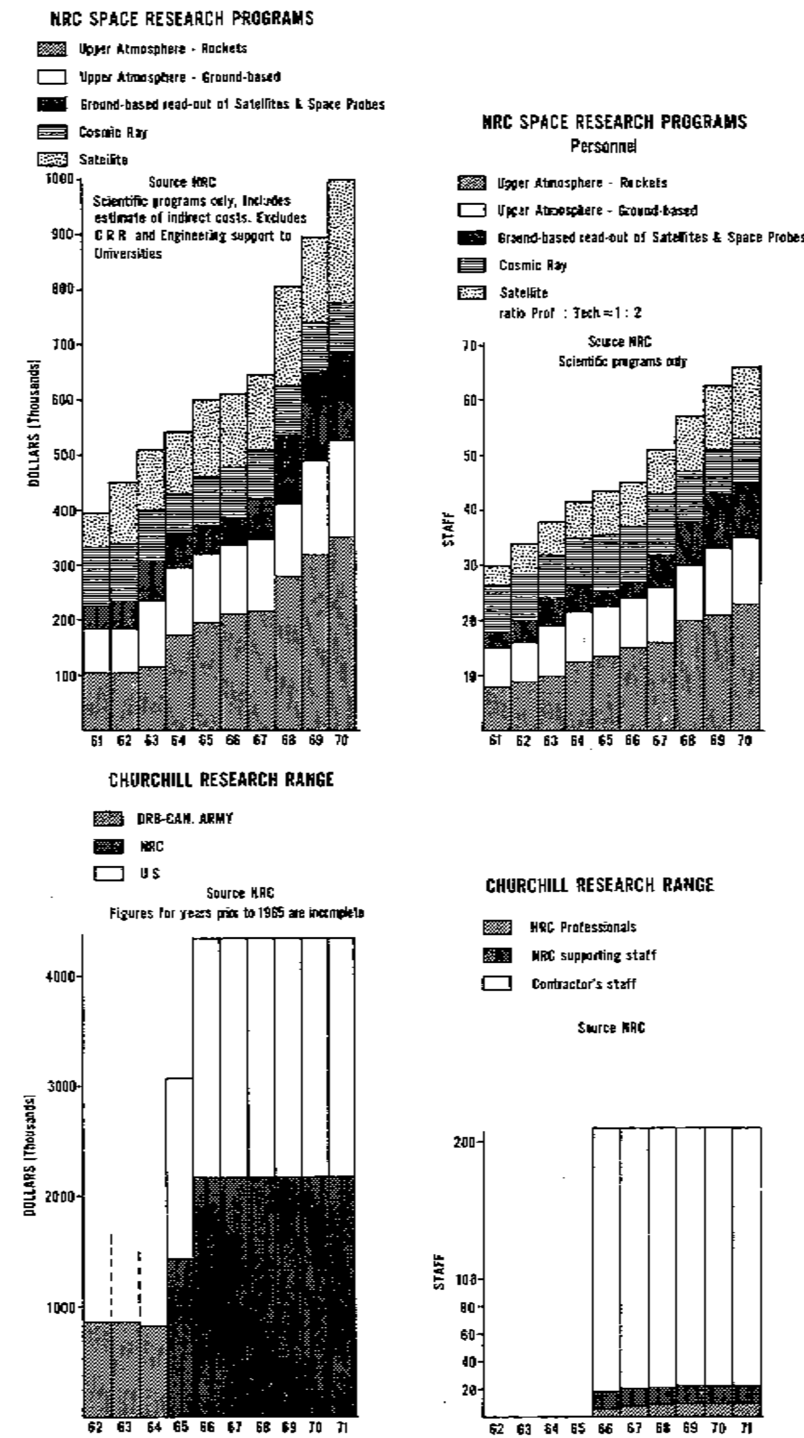

Fig V NRC LABORATORY SPACE RESEARCH PROGRAM AND THE CHURCHILL RESEARCH RANGE OPERATION

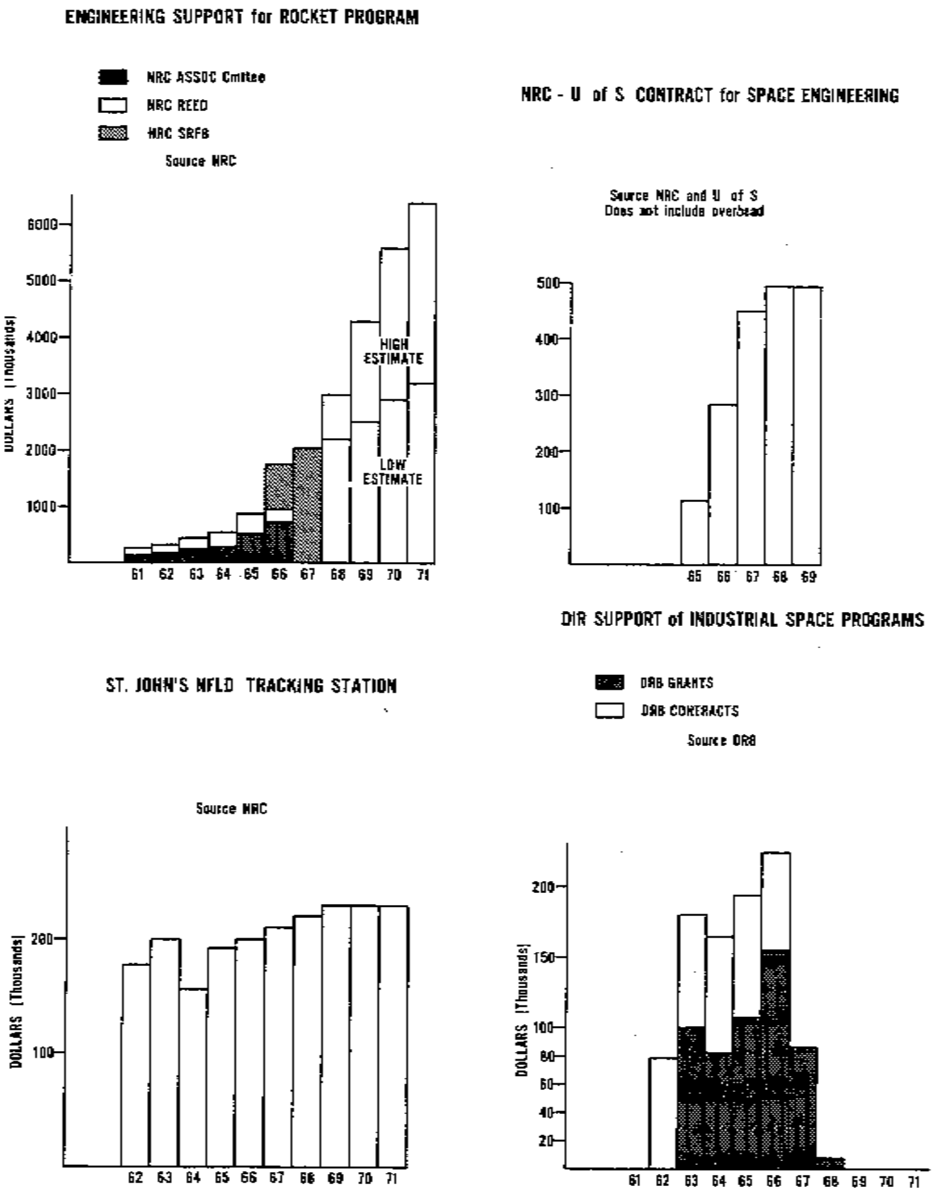

Fig VI NRC SUPPORT PROGRAM; ROCKET ENGINEERING; SPACE ENGINEERING DIVISION, UNIVERSITY OF SASKATCHEWAN; ST. JOHN'S NFLD TRACKING STATION; AND DRB INDUSTRIAL RESEARCH PROGRAM

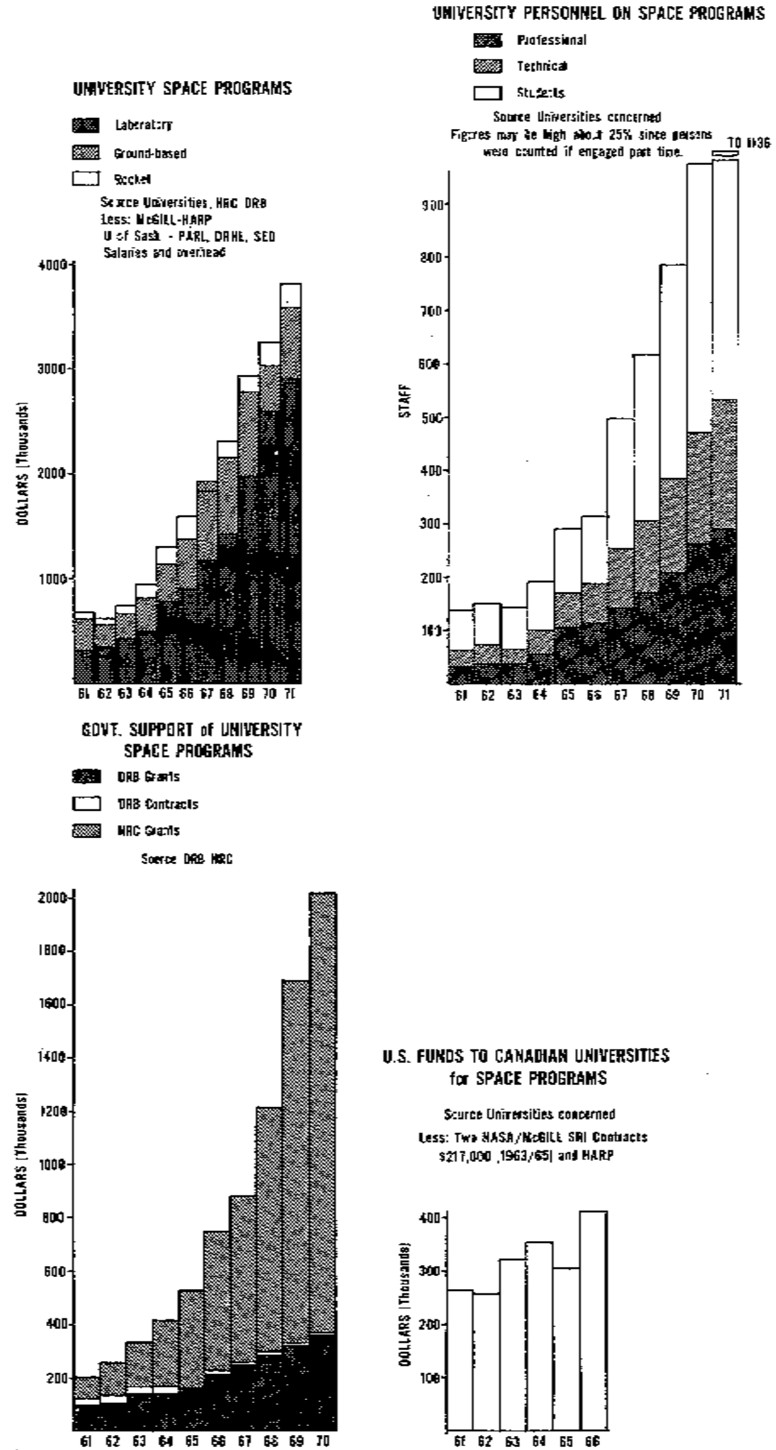

Fig VII UNIVERSITY SPACE PROGRAMS AND GOVERNMENT SUPPORT OF UNIVERSITY RESEARCH

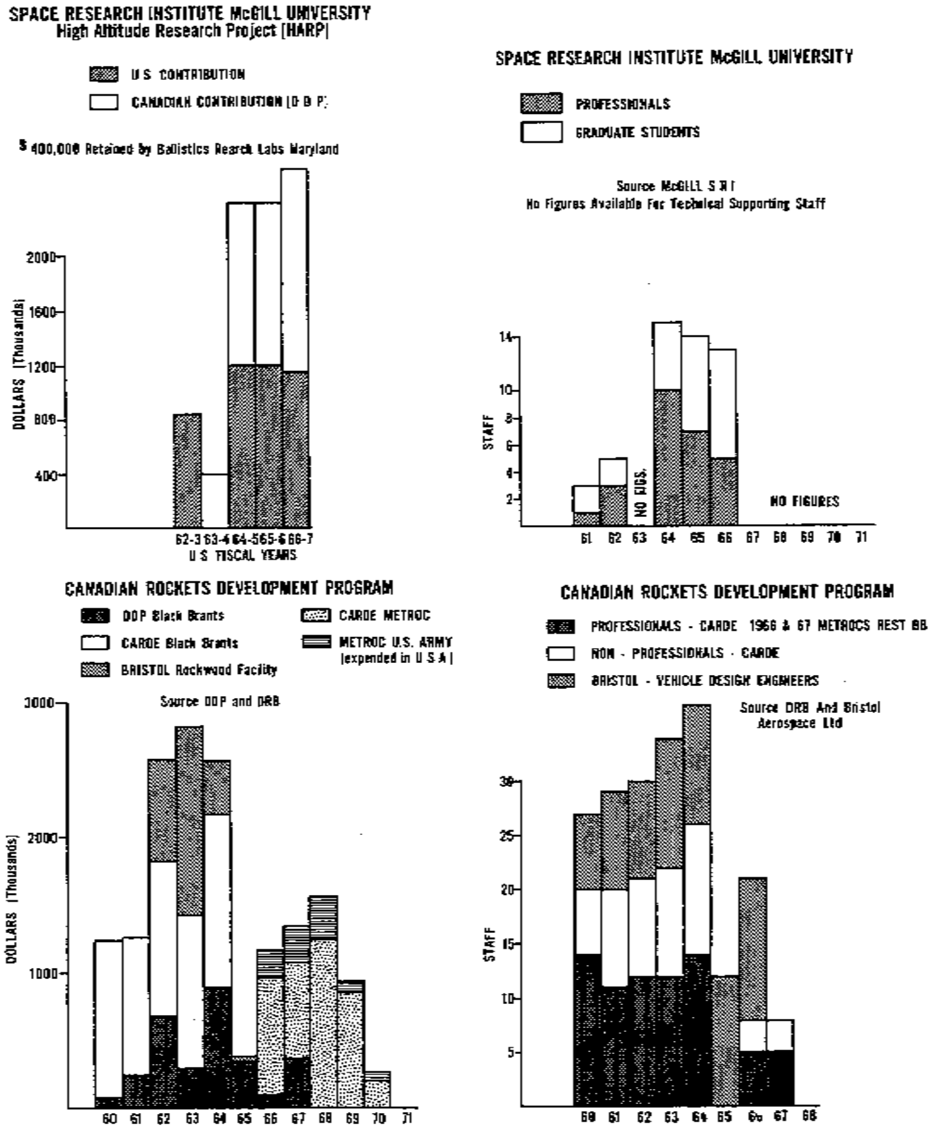

Fig VIII LAUNCHER DEVELOPMENT PROGRAMS; HARP-McGILL AND ROCKET PROGRAMS

Part II

CANADIAN INTERNATIONAL SPACE PROGRAMS.
TEXTS OF AGREEMENTS, MEMORANDA OF UNDERSTANDINGS, AND OTHER INTERNATIONAL ARRANGEMENTS IN FORCE 31 OCTOBER, 1966

Section 1

THE ALOUETTE-ISIS PROGRAM

1.1 LETTER AGREEMENT DRB-NASA 25 AUGUST 1959

Dr. T. Keith Glennan,
Administrator, National Aeronautics and Space Administration,
Washington, D.C.

Dear Dr. Glennan: I wish to refer to discussions between personnel of NASA, the Defense Research Telecommunications Establishment (DRTE), and the Office of the Defence Research Member in Washington concerning the cooperative undertaking between NASA and DRTE in a topside sounder satellite project.

By letter dated 31 December, 1958, the office of the Defence Research Member in Washington passed to NASA a proposal concerning the topside sounding experiment. Receipt of this proposal was acknowledged by letter of 11 March, 1959, which outlined procedures concerning the proposed cooperative undertaking. The Canadian contribution is to consist of the following:

(a) to develop an ionospheric sounder for installation in a satellite;
(b) to construct three engineered models, one for installation in a satellite, one as a spare and one for testing to destruction;
(c) to provide in Canada ground-based telemetry and recording apparatus for recording satellite sounding signals;
(d) to operate the recording equipment for at least one year at each of four stations: Resolute Bay, Churchill, Ottawa and St. John's;
(e) to exchange copies of all ionograms with cooperating agencies as they are produced.

It is my understanding that NASA is prepared to provide the necessary rockets and launching services to test the proposed Canadian instrumentation and, if the construction of the instrumentation is successful, NASA will provide a satellite vehicle for launching during 1961.

It is agreed that certain procedures set up by NASA which apply to all satellite experiments must be observed in this cooperative undertaking.

Yours sincerely,

A. H. Zimmerman, *Chairman.*

1.2 LETTER AGREEMENT NASA-DRB 18 NOVEMBER 1959

Dr. A. Hartley Zimmerman,
Chairman, Defence Research Board
Ottawa, Ontario, Canada.

Dear Dr. Zimmerman: Since 13 November, 1958, discussions have been underway between personnel of DRTE, DRB, the Office of the Canadian Defence Research Member in Washington, and NASA, concerning the cooperative NASA/DRTE ionospheric topside sounder satellite project. By letter dated 31 December, 1958, NASA received a DRTE proposal on this subject from the Office of the Defence Research Member in Washington. In answer, on 11 March, 1959, I indicated approval of this cooperative project in general terms.

This project has now reached the stage at which the roles of each participant can be delineated more precisely. I concur in your statement of the Canadian contributions contained in your letter of 25 August, 1959. It is my further understanding that the DRTE sounder will utilize the continuous frequency sweep principle, and that DRTE will provide the necessary prototype satellite instrumentation for the preliminary sounding rocket test flights.

The NASA will provide the following:

1. High altitude sounding rockets and launching services, probably in the United States, to test the Canadian satellite prototype instrumentation.
2. A topside sounder satellite vehicle, including its launching in the United States and tracking, scheduled late in 1961.
3. Ground-based telemetry and recording apparatus outside of Canada, to recover the satellite ionograms for at least one year.
4. Copies of the satellite ionograms recorded outside of Canada for exchange with Canada.

This agency is also supporting the development of a more elementary topside sounder which utilizes several fixed frequencies, to be launched in a satellite as soon after its successful rocket tests as space becomes available. Its capability for providing ionospheric data over the complete frequency range of interest is much less than that of the Canadian instrument. Consequently, the scheduled 1961 topside sounder satellite is reserved for the DRTE sounder.

Should completion of the Canadian instrument be delayed so that it is unable to meet the 1961 satellite launching schedule, the fixed-frequency sounder would be considered for substitution. In this event, the Canadian sounder would be rescheduled in a later satellite vehicle, if feasible.

Consequently, it is essential that the ground-based recording stations be instrumented so as to be compatible with both types of satellite sounder. Any additional apparatus at the Canadian stations required by this policy will be provided by NASA. Ionograms from the fixed-frequency sounder will be available to Canada for analysis on the same basis as those from the Canadian swept-frequency sounder.

In the near future the NASA Topside Sounder Working Group will be organized. This group, which will include Canadian representation from its inception, will assist in coordinating the detailed technical arrangements.

I propose that each of our agencies undertake to arrange advance, blanket clearances for laboratory visits, brief or extended, which may be required in the course of this cooperative program.

I shall look forward to hearing whether these arrangements are satisfactory to you.

Sincerely yours.

T. Keith Glennan, *Administrator.*

1.3 LETTER AGREEMENT DRB-NASA 16 DECEMBER 1959

Dear Dr. Glennan: In reply to your letter DS of 18 November, 1959, I am in agreement with the detailed proposals contained therein. However, there is one slight modification that has become necessary since this project was first discussed, namely, due to the special antennae required for the Canadian topside sounder, discussions at the working level have indicated that the body of the satellite should be fabricated in Canada; this we are prepared to do. We are also prepared to instrument the Canadian ground-based recording stations in a manner to be compatible with both the Canadian and the U.S. type of satellite sounder, it being understood that any additional apparatus at the Canadian stations required by this policy will be provided by NASA.

I feel that the formation of the NASA Topside Sounder Working Group, which you mentioned, will result in the necessary co-ordination of the detailed technical arrangements.

Action is being taken to arrange advance blanket clearances for laboratory visits on the part of DRB personnel. We will welcome similar arrangements on your part.

I am very pleased that DRB and NASA are able to undertake this important project on a co-operative basis.

Sincerely yours,

A. H. Zimmerman, *Chairman.*

1.4 MEMORANDUM OF UNDERSTANDING–ISIS 23 MAY 1963

ANNEX

MEMORANDUM OF UNDERSTANDING BETWEEN THE CANADIAN DEFENCE RESEARCH BOARD AND THE UNITED STATES NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

1. The Canadian Defence Research Board (DRB) and the United States National Aeronautics and Space Administration (NASA) affirm a mutual desire to undertake a joint program of ionospheric research by means of satellites. The objectives are to conduct comprehensive studies of the ionosphere from the approaching minimum through the next maximum of the present solar cycle and to make the resulting scientific data freely available.

2. This joint ionospheric monitoring program is planned to consist of a series of four satellites to be launched at appropriate intervals between 1965 and 1970.

(a) The first of these, to be known as ALOUETTE II, will consist of the spare ALOUETTE flight unit with such agreed modifications to the sounder, telemetry, and electronics as engineering feasibility and schedule permit. In order to perform coordinated direct measurements, NASA will launch a satellite of its Explorer series in conjunction with ALLOUETTE II.

(b) The remaining three satellites will bear the name ISIS (International Satellite for Ionospheric Studies). It is expected that two of the ISIS series will carry as the principal experiment a topside sounder of the swept frequency type (or a combination of swept and fixed frequency sounders) and such supporting experiments as may be determined in the manner described in paragraph 3 (c) of this memorandum. It is understood that these two spacecraft and ALOUETTE II will be launched into orbits with apogees of at least 2000 kilometers and with inclinations high enough to obtain auroral zone data. A decision on the character and orbit of the third ISIS will be made during the course of the program. Sounding rocket flights may be necessary to test components and experiments and to conduct correlated experiments.

3. It is intended that this project proceed by mutual agreement between DRB and NASA.

(a) The body responsible for implementing the agreed program will be a Joint (DRB/NASA) Working Group. The Chairman of the Working Group will be appointed by NASA and will have overall responsibility for the success of the project. It is intended that other parties sharing in data acquisition and reduction or participating as supporting experimenters may, as appropriate, attend meetings of the Joint Working Group.

(b) DRB and NASA will name project managers to serve as contacts for technical coordination.

(c) It is the desire of DRB and NASA to give other investigators the opportunity to compete for the space assigned to supporting experiments. Accordingly, DRB will solicit proposals in Canada, and NASA will solicit them in the United States and other countries in conformance with its current practices. When the proposals have been received, DRB and NASA will exchange them so that each agency can review and evaluate all proposals. A Joint DRB/NASA panel will make the final selections. In case of disagreement, the issues in question will be resolved by the Chief Scientist, DRB, and the Associate Administrator for Space Science and Applications, NASA, or their delegated representatives. In general, responsibility for seeing that the supporting experiments are fabricated, tested, and followed through to countdown will rest with the national agency sponsoring the experiment.

4. DRB will have specific responsibility for the following:

(a) Designing, constructing, and testing the several spacecraft, their subsystems, and the topside sounders, except as noted in paragraph 5 (d) and 5 (e), and integrating supporting experiments into the spacecraft. The spacecraft will be designed to be compatible with the Delta vehicle.

(b) Providing payloads for such sounding rocket tests of spacecraft components, sounders, new experiments, and agreed correlated rocket experiments as are recommended by the Joint Working Group and are approved by DRB and NASA.

(c) Controlling the satellites in accord with schedules approved by the Joint Working Group.

(d) Operating at least one telemetry station in Canada capable of supplying information on spacecraft operation.

5. NASA will have specific responsibility for the following:

(a) Providing four launch vehicles with at least the capability of the Delta, payload support hardware and separation mechanisms, and integration of payloads and launch vehicles.

(b) Launching the spacecraft into the agreed orbits.

(c) Providing and launching up to five sounding rockets no larger than the Javelin/Journeyman class for such tests of spacecraft components, sounders, new experiments, and agreed correlated experiments, as are recommended by the Joint Working Group and are approved by DRB and NASA.

(d) Providing spacecraft power, command, and telemetry subsystems which DRB and NASA agree cannot feasibly be manufactured in or procured by Canada.

(e) Establishing specifications and providing facilities for final spacecraft environmental and flight acceptance tests.

(f) Providing tracking and data acquisition which can be accomplished by existing NASA facilities.

6. Data processing and reduction will be a joint responsibility of the agencies participating in the program and will be shared among them by mutual agreement.

7. DRB and NASA intend that processed data be distributed expeditiously among the participating investigators, who will define their current areas of interest, meet regularly to keep each other informed of their progress and problems, make recommendations for the conduct of the program, and publish results. DRB and NASA may invite other interested parties to their meetings and authorize the distribution of reduced data to other investigators who can make useful contributions. No longer than one year after the data has been obtained, it will be made available to the scientific community through the World Data Centers. Specifically, a complete set of world ionograms and a tabulation of data from supporting experiments will be placed in the World Data Center at Boulder, Colorado; other World Data Centers will receive a catalogue of all available data.

8. DRB and NASA agree to grant each other royalty free licenses to use inventions which are necessary to carry out their respective responsibilities under this program to the extent that their respective Governments own or have the right to grant such licenses.

9. DRB and NASA will use their best efforts to arrange with their respective authorities for free entry of equipment into each country as required by the program.

10. DRB and NASA will each bear the cost of discharging its respective responsibilities including the cost of travel by its personnel and transportation charges on all equipment for which it is responsible.

11. It is understood that the ability of both DRB and NASA to carry their obligations into effect is subject to the availability of appropriated funds.

12. This Memorandum of Understanding may only be terminated prior to 1970 by mutual agreement.

13. This Memorandum of Understanding will be subject to the approval of the Governments of the United States and Canada to be expressed by an exchange of notes between them.

A. Hartley Zimmerman
For the Defence Research Board

Hugh L. Dryden
For the National Aeronautics
and Space Administration

Dec. 23, 1963.

1.5 EXCHANGE OF NOTES US–CANADA 6 MAY 1964

EXCHANGE OF NOTES (May 6, 1964) BETWEEN THE GOVERNMENT OF CANADA AND THE GOVERNMENT OF THE UNITED STATES OF AMERICA CONSTITUTING AN AGREEMENT ON INTERNATIONAL SATELLITES FOR IONOSPHERIC STUDIES (ISIS) (WITH A MEMORANDUM OF UNDERSTANDING).

The Ambassador of the United States of America to Canada to the Secretary of State for External Affairs

EMBASSY OF THE UNITED STATES OF AMERICA

Ottawa, May 6, 1964.

No. 324

SIR:

I have the honor to refer to discussions between representatives of the United States National Aeronautics and Space Administration and the Canadian Defence Research Board regarding proposals for cooperation in a joint program of ionospheric research by means of satellites. The objectives of the proposed joint program are the conduct of comprehensive studies of the ionosphere from the approaching minimum through the next maximum of the present solar cycle and to make the resulting scientific data freely available to the world scientific community.

The program agreed upon and the details for its proposed implementation have been incorporated in the attached Memorandum of Understanding between the United States National Aeronautics and Space Administration and the Canadian Defence Research Board which was signed on December 23, 1963. The Memorandum of Understanding has been approved by the Government of the United States of America. It is understood that implementation and direction of the United States participation in the proposed program shall be the responsibility of the United States National Aeronautics and Space Administration and that implementation and direction of Canadian participation shall be the responsibility of the Canadian Defence Research Board.

If the foregoing meets with the approval of the Canadian Government, I have the honor to propose that this Note together with the attached Memorandum of Understanding and your reply, shall constitute an Agreement between our two Governments for cooperation in a joint program of ionospheric research by means of satellites to be effective from the date of your reply. This agreement may be terminated by agreement between the two governments prior to 1970 and thereafter, by either government upon six months notice.

Accept, Sir, the renewed assurances of my highest consideration.

W.W. Butterworth

Enclosure:
Memorandum of Understanding

The Honorable
Paul Martin,
Secretary of State for External Affairs,
Ottawa.

The Secretary of State for External Affairs to the Ambassador of the United States of America to Canada.

DEPARTMENT OF EXTERNAL AFFAIRS

Ottawa, May 6, 1964.

No. 72

EXCELLENCY:

I have the honour to refer to your Note No. 324 of May 6, 1964, with its attached Memorandum of Understanding between the Canadian Defence Research Board and the United States National Aeronautics

and Space Administration, regarding co-operation in a joint programme of ionospheric research by means of satellites.

The Canadian Government approves the Memorandum of Understanding and it therefore concurs in your proposal that your Note and the attached Memorandum of Understanding together with this reply, shall constitute an Agreement between the Government of Canada and the Government of the United States for co-operation in a joint programme of ionospheric research by means of satellites, to be effective from the date of this reply. This Agreement may be terminated by Agreement between the two governments prior to 1970, and thereafter by either party upon six months notice.

Accept, Excellency, the renewed assurances of my highest consideration.

Paul Martin
Secretary of State for External Affairs.

His Excellency W. Walton Butterworth,
Ambassador of the United States of America,
100 Wellington Street,
OTTAWA.

Section 2

TRACKING STATIONS, ST. JOHN'S, NEWFOUNDLAND

2.1 EXCHANGE OF NOTES WITH ANNEX AGREEMENT US–CANADA 24 AUGUST 1960

EXCHANGE OF NOTES (August 24, 1960) BETWEEN CANADA AND THE UNITED STATES OF AMERICA CONCERNING THE ESTABLISHMENT OF A SATELLITE TRACKING STATION NEAR ST. JOHN'S, NEWFOUNDLAND

The Ambassador of the United States of America to Canada to the Secretary of State for External Affairs

THE FOREIGN SERVICE OF THE UNITED STATES OF AMERICA

Ottawa, August 24, 1960

No. 367

SIR:

I have the honor to refer to recent discussions between representatives of our two Governments concerning our common interests in the advancement of science, particularly in the increase of man's knowledge of his spatial environment and its effects. In view of the mutual benefits that could result from the extension of such knowledge and from its peaceful applications, the Government of the United States proposes that the Government of Canada join with it in a co-operative effort for tracking and receiving radio signals from space vehicles to be carried out in accordance with the terms annexed to this Note.

It is understood that to the extent this agreement will depend on funds appropriated by the Congress of the United States it is subject to the availability of such funds.

If the Canadian Government concurs, I propose that this Note and your reply shall constitute an agreement effective from the date of your reply.

Accept, Excellency, the renewed assurances of my highest consideration.

R. B. Wigglesworth

The Honorable
Howard C. Green,
Secretary of State for External Affairs,
Ottawa.

The Secretary of State for External Affairs to the Ambassador of the United States of America to Canada

DEPARTMENT OF EXTERNAL AFFAIRS

Ottawa, August 24, 1960

No. 161

EXCELLENCY:

I have the honour to refer to your Note No. 367 of August 24, 1960 in which you propose that the Government of the United States should join with the Government of Canada in a co-operative effort for tracking and receiving radio signals from space vehicles to be carried out in accordance with the terms annexed to your Note, through the establishment of a satellite tracking station near St. John's, Newfoundland.

I have the honour to state that the Government of Canada is prepared to enter into an agreement to establish such a station on the conditions set out in the annex to your Note, and therefore accepts your proposal that your Note and this reply should constitute an agreement for this purpose.

It is understood that to the extent that this agreement will depend on funds appropriated by the Canadian Parliament, it is subject to the availability of such funds.

Accept, Excellency, the renewed assurances of my highest consideration.

Howard Green,
Secretary of State for External Affairs.

His Excellency Richard B. Wigglesworth,
Ambassador of the United States of America,
Ottawa.

ANNEX

CONDITIONS TO GOVERN THE ESTABLISHMENT AND OPERATION OF A MINITRACK STATION IN THE VICINITY OF SAINT JOHN'S, NEWFOUNDLAND

(This effort is to be conducted through a co-operating agency from each Government, which on the part of the United States Government will be the National Aeronautics and Space Administration and

on the part of the Canadian Government will be the National Research Council.)

1. *Sites*

The location and size of the station site required in Canada shall be a matter for mutual agreement by the co-operating agencies of the two Governments. Canada shall acquire and retain title to all lands required for the station.

2. *Liaison Arrangements*

The co-operating agencies of both Governments shall consult fully at all stages of station site selection, construction and operation.

3. *Provision of Electronic Equipment*

(a) The Canadian Government reaffirms the principle that electronic equipment at installations on Canadian territory should, as far as practicable, be manufactured in Canada. The question of practicability must, in each case, be a matter for consultation between the co-operating agencies of both Governments to determine the application of the principle. The factors to be taken into account shall include availability at the time required, cost and performance.

(b) Because of the delivery problems and the relatively small quantities involved, it is agreed that the technical component will, in all probability, be provided from a U.S. source. The question of installation, however, should be decided in consultation between the co-operating agencies of both governments.

4. *Construction*

(a) Procedures for accomplishing construction of the station and for the procurement of construction equipment, construction supplies and related technical services shall be determined by agreement between the co-operating agencies of the two Governments.

(b) Rates of pay and working conditions will be set after consultation with the Canadian Department of Labour, in accordance with the Canadian Fair Wages and Hours of Labour Act.

5. *Canadian Law*

Nothing in this Agreement shall derogate from the application of Canadian law in Canada, provided that, if in unusual circumstances its application may lead to unreasonable delay or difficulty in construction or operation, the United States authorities concerned may request the assistance of Canadian authorities in seeking appropriate alleviation. In order to facilitate the rapid and efficient construction of the station, Canadian authorities will give sympathetic consideration to any such request submitted by the United States Government authorities.

6. *Financing*

The cost of construction of the station, of the provision and replacement of specialized equipment and of necessary specialized training of operational personnel shall be the responsibility of the U.S. Canada shall provide the land for the station site at no cost to the United States. Following construction of the station, the maintenance and other costs associated with the operation of the station except those pertaining to additional equipment and new construction shall be borne by Canada. The costs connected with the pay and upkeep of United States personnel posted to the station for scientific or other purposes will be borne by the United States Government. The two Governments shall co-operate fully to ensure that the station is established, maintained and operated with all possible economy.

7. *Manning*

The manning of the station will be carried out by Canadian personnel; the United States co-operating agency may by agreement with the Canadian co-operating agency station personnel at the site if it is deemed technically desirable to do so.

8. *Period of Operation of the Station*

This Agreement will remain in effect for a period of ten years and for such additional periods as may be subsequently agreed upon by the two Governments. Either Government, however, may terminate the Agreement at any time by giving the other Government ninety days written notice of intent to terminate, in which event the Agreement will terminate at the end of the ninety day period.

9. *Ownership of Removable Property*

The United States shall retain ownership of any removable property (including readily demountable structures) it provides. The United States shall have the right of removing or disposing of all such property on termination of this agreement, provided that removal or disposal shall not be delayed beyond a reasonable time after the date upon which the operation of the station has been discontinued. The disposal of United States excess property in Canada shall be carried out in accordance with the provisions of the Exchange of Notes of April 11 and 18, 1951,* between the Secretary of State for External Affairs and the United States Ambassador in Ottawa concerning the disposal of excess property.

10. *Telecommunications*

Established commercial communication systems will be used where practical for communication between the station and appropriate

* Canada Treaty Series 1951, No. 9.

United States bases. The cost of this or any special installations that may be necessary will be borne by the United States co-operating agency. Operation and maintenance of all communication equipment will be the responsibility of the Canadian co-operating agency. The Canadian co-operating agency will also be responsible for appropriate approvals and the assignment of frequencies.

11. *Scientific Information*

All scientific data obtained in the course of operation of this station shall be made available to both Governments. The station can be used for independent scientific activity of the Canadian Government, it being understood that

(a) such activities will be conducted so as not to conflict with the agreed schedule of operation; and

(b) any additional operating costs resulting from such independent activity will be borne by the appropriate Canadian authorities.

12. *Canadian Immigration and Customs Regulations*

(a) Except as otherwise agreed, the direct entry of United States personnel from outside Canada shall be in accordance with Canadian customs and immigration procedures which will be administered by local Canadian officials designated by Canada.

(b) Canada will take the necessary steps to facilitate the admission into the territory of Canada of such United States co-operating agency personnel as may be assigned to visit or participate in the operation of the station.

13. *Taxes*

The Canadian Government shall grant remission of customs duties and excise taxes on goods imported and of federal sales and excise taxes on goods purchased in Canada which are or are to become the property of the United States Government and are to be used in the construction and/or operation of the installations, as well as refunds by way of drawback of the customs duty paid on goods imported by Canadian manufacturers and used in the manufacture or production of goods purchased by or on behalf of the United States Government and to become the property of the United States Government for the construction or operation of the installations.

14. *Supplementary Arrangements and Administrative Agreements*

Supplementary arrangements or administrative agreements between the co-operating agencies of the two Governments may be made from time to time for purposes of carrying out the intent of this Agreement.

2.2 AGREEMENT NRC-NASA 17 JULY 1962

AGREEMENT BETWEEN THE NATIONAL RESEARCH COUNCIL OF CANADA AND THE U.S. NATIONAL AERONAUTICS AND SPACE ADMINISTRATION IN CONNECTION WITH THE ESTABLISHMENT AND OPERATION OF A MINITRACK STATION NEAR ST. JOHN'S, NEWFOUNDLAND

This Agreement is entered into between the National Research Council of Canada (NRC) and the National Aeronautics and Space Administration of the United States of America (NASA) pursuant to the Agreement between the two Governments effected by an exchange of notes on August 24, 1960, concerning the establishment and operation of a minitrack station near St. John's, Newfoundland.

The purpose of the present Agreement is to establish the procedures under which NRC and NASA may agree from time to time on the modification of the existing facilities of, and the installation of new equipment at, the minitrack station, and under which NASA will reimburse NRC for the costs incurred by NRC in connection with such work. It is understood that this Agreement is made in implementation of the aforementioned Inter-governmental Agreement of August 24, 1960 and is not intended to supersede or vary the provisions of that Agreement.

ARTICLE I. PROCEDURES FOR INITIATING REQUIREMENTS

(a) Work Requirements Initiated by NASA

From time to time NASA may initiate requirements for installation of new equipment, or for modification of the existing facilities. In each case, the Officer responsible for administering this Agreement on behalf of NASA (hereafter called the Authorized Officer) will forward a statement of such requirements to NRC for concurrence before further action may be taken. If NRC agrees to undertake the work involved, NRC will so inform the Authorized Officer in writing and advise him of the estimated length of time required for accomplishment of the work and the estimated cost of such work. The Authorized Officer may thereafter request that such work be undertaken by NRC, and will do so by issuing a work order under this Agreement,

which order will contain a description of the work NRC has agreed to undertake, the completion date, and the total estimated cost.

(b) Work Requirements Initiated by NRC

From time to time NRC may initiate requirements for modification of the existing facilities. In each case, NRC will forward a statement of such requirements to NASA Goddard Space Flight Center, Greenbelt, Maryland, Attention: Operations and Support Division, with an information copy to NASA Headquarters, Washington 25, D.C., Attention: BRA. The statement of requirements should include the estimated length of time required for accomplishment of the work and the estimated cost of such work. If NASA agrees to accomplishment of the proposed requirement with NASA funds, the Authorized Officer will request that such work be undertaken by NRC, which he shall do by issuing a work order under this Agreement, which order will contain a description of the work NRC has agreed to undertake, the completion date, and total estimated cost.

(c) In the event that the Authorized Officers of NASA and NRC should fail to reach agreement on details under either paragraph (a), or paragraph (b), above, the points in question may be referred respectively to the President of NRC and the Administrator of NASA or their authorized representatives, for resolution.

(d) The Authorized Officer for NRC under this Agreement is Dr. Richard S. Rettie. The Authorized Officer for NASA under this Agreement is Mr. E.W. Quintrell (Procurement and Supply Division). A change in the designation of its Authorized Officer may be made by either agency by notification in writing to the other.

ARTICLE II. REIMBURSEMENT OF NRC'S COSTS

(a) NASA will reimburse NRC for cost incurred by NRC in connection with work undertaken pursuant to Article I hereof, which are determined to be allowable costs, as provided herein. Costs incurred by NRC in performance of and in conformity with the provisions of this Agreement shall be determined to be allowable costs if allocable to this Agreement in accordance with accounting principles and practices generally followed by the Canadian Government.

(b) Short distance transportation or storage of electronic equipment, supplies, or materials essential to antenna or building construction will be allowable items of cost under this Agreement insofar as they relate to work undertaken by NRC pursuant to Article I hereof.

(c) Once each month, or at more frequent intervals as mutually agreed upon, NRC may submit to NASA, in such form and reasonable detail as agreed upon, a voucher supported by a statement of costs incurred by NRC in performing this Agreement. Such statements will be certified by an official of NRC authorized to certify such statements.

(d) Vouchers and supporting statements of costs may be addressed to the NASA Headquarters, 400 Maryland Avenue S.W., Washington 25, D.C., Attention: Code BRA. They should be submitted in triplicate, and for identification purposes bear the number "NASw–402" on each copy.

(e) Upon receipt of each such voucher, NASA will make payment thereon in accordance with provisions of this Article. Payment will be made in United States dollars, at the rate of exchange current on the date of payment.

(f) It is agreed that annually, and in connection with the final payment under this Agreement, the appropriate Agency of the Canadian Government will conduct an audit of the expenditures made by NRC and charged to this Agreement, and will submit a report of such audit to NASA Headquarters, Attn: Code BRA, which report will indicate the amounts which are properly chargeable to this Agreement under accounting principles and practices generally followed by the Canadian Government.

ARTICLE III. PERIOD OF AGREEMENT

This Agreement will take effect upon signature by both parties and shall remain in effect until June 30, 1963. Thereafter, it shall be extended automatically for additional periods of one year, unless sixty days written notice is given by either party of its intention not to extend the Agreement.

ARTICLE IV. AVAILABILITY OF FUNDS

(a) As of the effective date of this Agreement, and to cover the period ending June 30, 1963, NASA has allotted the total sum of

$25,000 to cover reimbursement to NRC for costs incurred by NRC in connection with work undertaken by NRC during such period pursuant to Article I hereof, and billed to NASA in accordance with Article II hereof. At any time during such period that NRC foresees this funding limit may be exceeded within a subsequent 60-day period, it will promptly notify the NASA Authorized Officer in writing. As a result of such notification, or on its own initiative, NASA may increase the amount of funds available hereunder.

(b) Additional funds to cover subsequent annual periods during which this Agreement remains in effect will be allotted by NASA for the purposes of this Agreement.

ARTICLE V. PROGRAM REPORTS AND ESTIMATES OF COST

(a) Once each month, or at such other frequency as may be mutually agreed upon, NRC will submit a report on the progress of all work undertaken by NRC pursuant to Article I of this Agreement until such work is completed. Such report will include a statement of the estimated costs incurred during the month reported and a forecast of the costs to be incurred during the next succeeding three months. The report will be in sufficient detail to permit analysis for purposes of proper fund programming, and be broken down by individual projects.

(b) In submitting the reports called for under paragraph (a) above, one copy is to be forwarded to NASA Goddard Space Flight Center, Greenbelt, Maryland, Attention: Operations and Support Division, and two copies to NASA Headquarters, Attention: BRA.

ARTICLE VI. U.S. OFFICIALS NOT TO BENEFIT

No member of or delegate to the Congress of the United States, or resident commissioner of the United States, shall be admitted to any share or part of this Agreement, or to any benefit that may arise therefrom; but this provision shall not be construed to extend to this Agreement if made with a corporation for its general benefit.

ARTICLE VII. COVENANT AGAINST CONTINGENT FEES

NRC agrees that no person or selling agency has been employed or retained to solicit or secure this Agreement upon an agreement or understanding for a commission, percentage, brokerage, or contingent fee, excepting bona fide employees or bona fide established commercial or selling agencies of NRC for the purpose of securing business. For breach or violation of this warranty, the United States Government shall have the right to annul this Agreement without liability, or in its discretion, to deduct from amounts due NRC the full amount of such commission, percentage, brokerage, or contingent fee.

ARTICLE VIII. RECORDS

NRC agrees to maintain books, records, documents, and other evidence pertaining to the costs and expenses of this Agreement to the extent necessary to properly reflect all net costs for which reimbursement is claimed under the provisions of this Agreement.

For the National Aeronautics and Space Administration:

Hugh L. Dryden,
Deputy Administrator.

Washington, D.C., July 11, 1962.
For the National Research Council:

F.L. Rosser,
Vice president (Administration).

Ottawa, July 17, 1962.

Section 3

COMMUNICATIONS SATELLITES

3.1 EXCHANGE OF NOTES CANADA–US 13 AUGUST 1963

EXCHANGE OF NOTES (August 13 and 23, 1963) BETWEEN CANADA AND THE UNITED STATES OF AMERICA CONCERNING THE TESTING OF EXPERIMENTAL COMMUNICATIONS SATELLITES (WITH A MEMORANDUM OF UNDERSTANDING).

The Chargé d'Affaires a.i. of the Canadian Embassy in the United States of America to the Secretary of State of the United States of America

CANADIAN EMBASSY

Washington, D.C.
August 13, 1963

No. 439

SIR,

I have the honour to refer to a Memorandum of Understanding concerning the testing of experimental communications satellites, signed by representatives of the National Aeronautics and Space Administration and the Department of Transport on April 25, 1963 and April 4, 1963, respectively.

On the instructions of my Government, I have the honour to express the concurrence of the Canadian Government in this Memorandum, a copy of which is attached, and to propose that this Note and the Memorandum attached thereto, together with your reply, shall constitute an Agreement between our two Governments on this subject with effect from the date of your reply.

Accept, Sir, the renewed assurances of my highest consideration.

H. B. Robinson
Chargé d'affaires a.i.

The Honourable Dean Rusk,
Secretary of State,
Washington, D.C.

3.2 MEMORANDUM OF UNDERSTANDING DOT–NASA 25 APRIL 1963

The Department of Transport of the Government of Canada and the United States National Aeronautics and Space Administration (NASA), as cooperating agencies, intend to participate jointly in the testing of experimental communications satellites launched by NASA to the extent that such testing is technically feasible.

To facilitate such experimental testing, each cooperating agency agrees to provide a ground station to receive and/or transmit television and multichannel telephonic or telegraphic signals between the two stations and over other paths in the course of these tests. No exchange of funds between the two agencies is contemplated.

Each cooperating agency agrees:

(i) to obtain the necessary radio frequencies;

(ii) to make available to the other such operating schedules as are necessary for the communications tests;

(iii) to facilitate demonstration tests involving, as necessary, temporary connection to its telecommunication networks.

Since there are additional experimenters participating in the testing, NASA will undertake to determine suitable schedules in the interests of all experimenters.

NASA agrees to provide satellite radiation characteristics and orbital parameters as required for the design, construction and operation of the Department of Transport ground station. In this connection, the exchange of such information as is covered by proprietary rights shall be arranged in such a manner as fully to respect those rights.

Data, including information relating to the space environment, obtained in the communications tests shall be exchanged and made freely available to the scientific community. Signals transmitted over the satellite links in this cooperative program are to be used for test purposes only and are not for commercial exploitation.

Each cooperating agency shall designate a point of contact for technical liaison purposes in the conduct of this program and shall provide suitable and periodic progress reports to the other.

This understanding between the cooperating agencies shall not preclude the use of ground stations for tests outside the cooperative projects covered by this understanding.

This Memorandum is conditional upon the concurrence of the respective Governments and shall be confirmed by an exchange of notes;

For the Department of Transport	For the National Aeronautics and Space Administration
SIGNED	SIGNED
J. R. BALDWIN	HUGH L. DRYDEN
Ottawa, Ontario.	Washington, D.C.
April 4, 1963 (Date)	April 25, 1963. (Date)

3.3 EXCHANGE OF NOTES US–CANADA 23 AUGUST 1963

The Secretary of State of the United States of America to the Chargé d'Affaires a.i. of the Canadian Embassy in the United States of America.

Department of State

Washington, August 23, 1963.

SIR:

I have received your Note dated August 13, 1963 concerning a Memorandum of Understanding on the testing of experimental communications satellites, signed by representatives of the Department of Transport and the National Aeronautics and Space Administration on April 4, 1963 and April 25, 1963, respectively.

The Government of the United States concurs in this Memorandum, and agrees to your proposal that your Note and the Memorandum attached thereto, together with this reply, shall constitute an Agreement between our two Governments on this subject with effect from this date.

Accept, Sir, the renewed assurances of my high consideration.

WILLIAM C. BURDETT
For the Secretary of State

The Honorable
H. Basil Robinson,
Chargé d'Affaires ad interim of Canada.

3.4 AGREEMENT, COMMUNICATIONS SATELLITE SYSTEM 20 AUGUST 1964

AGREEMENT ESTABLISHING INTERIM ARRANGEMENTS FOR A GLOBAL COMMERCIAL COMMUNICATIONS SATELLITE SYSTEM

The Governments signatory to this Agreement,

Recalling the principle set forth in Resolution No. 1721 (XVI) of the General Assembly of the United Nations that communications by means of satellites should be available to the Nations of the world as soon as practicable on a global and non-discriminatory basis;

Desiring to establish a single global commercial communications satellite system as part of an improved global communications network which will provide expanded telecommunications services to all areas of the world and which will contribute to world peace and understanding;

Determined, to this end, to provide, through the most advanced technology available, for the benefit of all nations of the world, the most efficient and economical service possible consistent with the best and most equitable use of the radio spectrum;

Believing that satellite communications should be organized in such a way as to permit all States to have access to the global system and those States so wishing to invest in the system with consequent participation in the design, development, construction (including the provision of equipment), establishment, maintenance, operation and ownership of the system;

Believing that it is desirable to conclude interim arrangements providing for the establishment of a single global commercial communications satellite system at the earliest practicable date, pending the working out of definitive arrangements for the organization of such a system;

Agree as follows:

ARTICLE I

(a) The Parties to this Agreement shall co-operate to provide, in accordance with the principles set forth in the Preamble to this Agreement, for the design, development, construction, establishment, maintenance and operation of the space segment of the global commercial communications satellite system, to include

(i) an experimental and operational phase in which it is proposed to use one or more satellites to be placed in synchronous orbit in 1965;

(ii) succeeding phases employing satellites of types to be determined, with the objective of achieving basic global coverage in the latter part of 1967; and

(iii) such improvements and extensions thereof as the Committee established by Article IV of this Agreement may decide subject to the provisions of Article VI of this Agreement.

(b) In this Agreement,

(i) the term "space segment" comprises the communications satellites and the tracking, control, command and related facilities and equipment required to support the operation of the communications satellites;

(ii) the terms "design" and "development" include research.

ARTICLE II

(a) Each Party either shall sign or shall designate a communications entity, public or private, to sign the Special Agreement which is to be concluded further to this Agreement and which is to be opened for signature at the same time as this Agreement. Relations between any such designated entity and the Party which has designated it shall be governed by the applicable domestic law.

(b) The Parties to this Agreement contemplate that administrations and communications carriers will, subject to the requirements of their applicable domestic law, negotiate and enter directly into such traffic agreements as may be appropriate with respect to their use of channels of communication provided by the system to be established under this Agreement, services to be furnished to the public, facilities, divisions of revenues and related business arrangements.

ARTICLE III

The space segment shall be owned in undivided shares by the signatories to the Special Agreement in proportion to their respective contributions to the costs of the design, development, construction and establishment of the space segment.

ARTICLE IV

(a) An Interim Communications Satellite Committee, hereinafter referred to as "the Committee", is hereby established to give effect to the co-operation provided for by Article I of this Agreement. The Committee shall have responsibility for the design, development, construction, establishment, maintenance and operation of the space segment of the system and, in particular, shall exercise the functions and have the powers set forth in this Agreement and in the Special Agreement.

(b) The Committee shall be composed as follows: one representative from each of the signatories to the Special Agreement whose quota is not less than 1.5%, and one representative from any two or more signatories to the Special Agreement whose combined quotas total not less than 1.5% and which have agreed to be so represented.

(c) In the performance of its financial functions under this Agreement and under the Special Agreement the Committee shall be assisted by an advisory sub-committee on finance. This sub-committee shall be established by the Committee as soon as the Committee becomes operative.

(d) The Committee may establish such other advisory sub-committees as it thinks fit.

(e) No signatory or group of signatories to the Special Agreement shall be deprived of representation on the Committee because of any reduction pursuant to Article XII (c) of this Agreement.

(f) In this Agreement, the term "quota", in relation to a signatory to the Special Agreement, means the percentage set forth opposite its name in the Annex to the Special Agreement as modified pursuant to this Agreement and the Special Agreement.

ARTICLE V

(a) Each signatory to the Special Agreement or group of signatories to the Special Agreement represented on the Committee shall have a number of votes equal to its quota, or to their combined quotas, as the case may be.

(b) A quorum for any meeting of the Committee shall consist of representatives having, in total, a number of votes exceeding the vote of the representative with the largest vote by not less than 8.5.

(c) The Committee shall endeavor to act unanimously; however, if it fails to reach agreement it shall take decisions by a majority of the votes cast, except that, with respect to the following matters, and subject to paragraphs (d) and (e) of this Article, any decision must have the concurrence of representatives whose total votes exceed the vote of the representative with the largest vote by not less than 12.5:

(i) choice of type or types of space segment to be established;
(ii) establishment of general standards for approval of earth stations for access to the space segment;
(iii) approval of budgets by major categories;
(iv) adjustment of accounts pursuant to Article 4 (c) of the Special Agreement;
(v) establishment of the rate of charge per unit of satellite utilization pursuant to Article 9 (a) of the Special Agreement;
(vi) decisions on additional contributions pursuant to Article VI (b) of this Agreement;
(vii) approval of the placing of contracts pursuant to Article 10 (c) of the Special Agreement;
(viii) approval of matters relating to satellite launchings pursuant to Article 10 (d) of the Special Agreement;
(ix) approval of quotas pursuant to Article XII (a) (ii) of this Agreement;
(x) determination of financial conditions of accession pursuant to Article XII (b) of this Agreement;
(xi) decisions relating to withdrawal pursuant to Article XI (a) and (b) of this Agreement and Article 4 (d) of the Special Agreement;
(xii) recommendation of amendments pursuant to Article 15 of the Special Agreement;
(xiii) adoption of the rules of procedure of the Committee and the advisory sub-committees;
(xiv) approval of appropriate compensation to the Corporation for its performance of services as manager pursuant to Articles 5 (c) and 9 (b) of the Special Agreement.

(d) If the committee, upon the expiration of sixty days following the date when such matter has been proposed for decision, shall not have taken a decision pursuant to paragraph (c) (i) of this Article on the type of space segment to be established to achieve the objective stated in paragraph (a) (ii) of Article I of this Agreement, a decision on such matter may thereafter be taken by the concurring votes of representatives whose total votes exceed the vote of the representative with the largest vote by not less than 8.5.

(e) If the Committee, upon the expiration of sixty days following the date when such matter has been proposed for decision, shall not have approved

(i) any particular budget category pursuant to paragraph (c) (iii) of this Article,

(ii) the placing of any particular contract, pursuant to paragraph (c) (vii) of this Article, or

(iii) any particular matter relating to satellite launchings, pursuant to paragraph (c) (viii) of this Article,

relating to achievement of the objectives stated in paragraphs (a) (i) and (a) (ii) of Article I of this Agreement, a decision on such matter may thereafter be taken by the concurring votes of representatives whose total votes exceed the vote of the representative with the largest vote by not less than 8.5.

ARTICLE VI

(a) The contributions of the signatories to the Special Agreement towards the costs of the design, development, construction and establishment of the space segment during the interim arrangements shall be based upon an estimate of U.S. $200,000,000 for such costs. Each signatory to the Special Agreement shall pay its quota of such costs in accordance with the provisions of the Special Agreement.

(b) The Committee shall determine whether contributions are required during the interim arrangements in excess of the U.S. $200,000,000 estimate and, if so, in what amounts. If the additional contributions required during the interim arrangements were to result in total contributions exceeding U.S. $300,000,000, a special conference of the signatories of the Special Agreement shall be convened to consider the matter and recommend appropriate action before decisions are taken by the Committee. The conference shall determine its own procedure.

(c) Each signatory to the Special Agreement may assume the obligation to pay all or part of its quota of any such additional contributions, but no signatory to the Special Agreement shall be required to do so. To the extent that such obligation is not assumed by any signatory to the Special Agreement, it may be assumed by the remaining signatories to the Special Agreement in the proportion that their

respective quotas bear to each other or as they may otherwise agree. However, if a signatory to the Special Agreement, which is a member of a group of signatories formed in order to appoint jointly a representative on the Committee pursuant to Article IV (b) of this Agreement, does not assume the obligation to pay such additional contributions, the remaining signatories of that group may assume that obligation in whole or in part to the extent that these remaining signatories may agree. The quotas of the signatories to the Special Agreement shall be adjusted accordingly.

ARTICLE VII

In order to ensure the most effective utilization of the space segment in accordance with the principles set forth in the Preamble to this Agreement, no earth station shall be permitted to utilize the space segment unless it has been approved by the Committee pursuant to Article 7 of the Special Agreement.

ARTICLE VIII

The Communications Satellite Corporation, incorporated under the laws of the District of Columbia, herein referred to as "the Corporation", shall, pursuant to general policies of the Committee and in accordance with specific determinations which may be made by the Committee, act as the manager in the design, development, construction, establishment, operation and maintenance of the space segment.

ARTICLE IX

(a) Having regard to the program outlined in Article I of this Agreement, within one year after the initial global system becomes operational and in any case not later than 1st January 1969, the Committee shall render a report to each Party to this Agreement containing the Committee's recommendations concerning the definitive arrangements for an international global system which shall supersede the interim arrangements established by this Agreement. This report, which shall be fully representative of all shades of opinion, shall consider, among other things, whether the interim arrangements should be continued on a permanent basis or whether a permanent international organization with a General Conference and an international administrative and technical staff should be established.

(b) Regardless of the form of the definitive arrangements;

(i) their aims shall be consonant with the principles set forth in the Preamble to this Agreement;

(ii) they shall, like this Agreement, be open to all States members of the International Telecommunication Union or their designated entities;

(iii) they shall safeguard the investment made by signatories to the Special Agreement; and

(iv) they shall be such that all parties to the definitive arrangements may have an opportunity of contributing to the determination of general policy.

(c) The report of the Committee shall be considered at an international conference, at which duly designated communications entities may also participate, to be convened by the Government of the United States of America for that purpose within three months following submission of the report. The Parties to this Agreement shall seek to ensure that the definitive arrangements will be established at the earliest practicable date, with a view to their entry into force by 1st January 1970.

ARTICLE X

In considering contracts and in exercising their other responsibilities, the Committee and the Corporation as manager shall be guided by the need to design, develop and procure the best equipment and services at the best price for the most efficient conduct and operation of the space segment. When proposals or tenders are determined to be comparable in terms of quality, c.i.f. price and timely performance, the Committee and the Corporation as manager shall also seek to ensure that contracts are so distributed that equipment is designed, developed and procured in the States whose Governments are Parties to this Agreement in approximate proportion to the respective quotas of their corresponding signatories to the Special Agreement; provided that such design, development and procurement are not contrary to the joint interests of the Parties to this Agreement and the signatories to the Special Agreement. The Committee and the Corporation as manager shall also seek to ensure that the foregoing principles are applied with respect to major sub-contracts to the extent that this can be accomplished without impairing the responsibility of the prime contractor for the performance of work under the contract.

ARTICLE XI

(a) Any Party may withdraw from this Agreement, and this Agreement shall cease to be in force for that Party three months after that Party shall have notified the Government of the United States of America of its intention to withdraw and the latter shall inform the other Parties accordingly. In the event of such withdrawal, the corresponding signatory to the Special Agreement shall pay all sums already due under the Special Agreement, together with a sum which shall be agreed between that signatory and the Committee in respect of costs which will result in the future from contracts concluded prior to notification of withdrawal. If agreement has not been reached within three months after notification of withdrawal, the Committee shall make a final determination of the sums which shall be paid by that signatory.

(b) Not less than three months after the rights of a signatory to the Special Agreement have been suspended pursuant to Article 4 (d) of the Special Agreement, and if that signatory has not meanwhile paid all sums due, the Committee, having taken into account any statement by that signatory or the corresponding Party, may decide that the Party in question is deemed to have withdrawn from this Agreement; this Agreement shall thereupon cease to be in force for that Party.

(c) Withdrawal by a Party from this Agreement shall automatically effect withdrawal from the Special Agreement by the corresponding signatory to the Special Agreement, but the obligation to make payments under paragraph (a) of this Article or under Article 4 (d) of the Special Agreement shall not be affected by such withdrawal.

(d) Upon any withdrawal under paragraph (a) or (b) of this Article, the Committee, to the extent required to account for the quota of the withdrawing signatory to the Special Agreement, shall increase the quotas of the remaining signatories to the Special Agreement in proportion to their respective quotas or as they may otherwise agree. However, if the signatory to the Special Agreement corresponding to the withdrawing Party was at the time of withdrawal a member of a group of signatories formed in order to appoint jointly a representative on the Committee pursuant to Article IV (b) of this Agreement, the quota of the signatory in question shall be distributed by increasing the quotas of the remaining signatories of that group to the extent that those remaining signatories may agree.

(e) Withdrawal by any Party may also take place if, at the request of the Party concerned, the Committee approves the transfer of the rights and obligations of that Party and the corresponding signatory to the Special Agreement under this Agreement and the Special Agreement to another Party and its corresponding signatory to the Special Agreement. Such transferee or transferees need not have been Parties to the Agreement or signatories to the Special Agreement prior to the time of such transfer.

ARTICLE XII

(a) This Agreement shall be open at Washington for six months from 20th August 1964 for signature:

(i) by the Government of any State which is listed by name in the Annex to the Special Agreement when it is first opened for signature, and

(ii) by the Government of any other State which is a member of the International Telecommunication Union, subject to approval by the Committee of the quota of that Government or its designated communications entity, public or private. On such approval and entry into force or provisional application, the name of that State and the name of its corresponding signatory to the Special Agreement, and its quota are deemed to be inserted in the Annex to the Special Agreement.

(b) The Government of any State which is a member of the International Telecommunication Union may accede to this Agreement after it is closed for signature upon such financial conditions as the Committee shall determine. On such accession, the name of that State and the name of its corresponding signatory to the Special Agreement, and its quota are deemed to be inserted in the Annex to the Special Agreement.

(c) The quotas of the signatories to the Special Agreement shall be reduced pro rata as necessary to accommodate additional signatories to the Special Agreement, provided that the combined original quotas of all signatories to the Special Agreement other than the signatories listed in the Annex to the Special Agreement when this Agreement is first opened for signature shall not exceed 17%.

(d) This Agreement shall enter into force on the date upon which it has been signed without reservation as to approval, or has been approved after such reservation, by two or more Governments. Subsequently it shall enter into force in respect of each signatory Government on signature or, if it signs subject to a reservation as to approval, on approval by it.

(e) Any Government which signs this Agreement subject to a reservation as to approval may, so long as this Agreement is open for signature, declare that it applies this Agreement provisionally and shall thereupon be considered a Party to this Agreement. Such provisional application shall terminate

(i) upon approval of this Agreement by that Government, or

(ii) upon withdrawal by that Government in accordance with Article XI of this Agreement.

(f) Notwithstanding anything contained in this Article, this Agreement shall not enter into force for any Government nor be applied provisionally by any Government until that Government or its corresponding signatory shall have signed the Special Agreement.

(g) If at the expiration of a period of nine months from the date when it is first opened for signature this Agreement has not entered into force for or has not been provisionally applied by the Government of a State which has signed it in accordance with paragraph (a) (i) of this Article, the signature shall be considered of no effect and the name of that State and of its corresponding signatory to the Special Agreement, and its quota shall be deemed to be deleted from the Annex to the Special Agreement; the quotas of the signatories to the Special Agreement shall accordingly be increased pro rata. If this Agreement has not entered into force for or has not been provisionally applied by the Government of a State which has signed it in accordance with paragraph (a) (ii) of this Article within a period of nine months from the date when it is first opened for signature, the signature shall be considered of no effect.

(h) The corresponding signatory to the Special Agreement of any Government which has signed this Agreement subject to a reservation as to approval, and which has not provisionally applied it, may appoint an observer to the Committee in the same manner as that signatory could have been represented in accordance with Article IV (b) of this Agreement if that Government had approved this Agreement. Any such observer, who shall have the right to speak but not to vote, may attend the Committee only during a period of nine months from the date when this Agreement is first opened for signature.

(i) No reservation may be made to this Agreement except as provided in this Article.

ARTICLE XIII

(a) Notifications of approval or of provisional application and instruments of accession shall be deposited with the Government of the United States of America.

(b) The Government of the United States of America shall notify all signatory and acceding States of signatures, reservations of approval, deposits of notifications of approval or of provisional application, deposits of instruments of accession and notifications of withdrawals from this Agreement.

ARTICLE XIV

Upon entry into force of this Agreement, the Government of the United States of America shall register it with the Secretary-General of the United Nations in accordance with Article 102 of the Charter of the United Nations.

ARTICLE XV

This Agreement shall remain in effect until the entry into force of the definitive arrangements referred to in Article IX of this Agreement.

IN WITNESS WHEREOF the undersigned duly authorized thereto have signed this Agreement.

DONE at Washington this twentieth day of August, 1964, in the English and French languages, both texts being equally authoritative, in a single original, which shall be deposited in the archives of the Government of the United States of America, which shall transmit a certified copy to each signatory or acceding Government and to the Government of each State which is a member of the International Telecommunication Union.

3.5 Special Agreement and Annex 20 August 1964

Whereas certain Governments have become Parties to an Agreement Establishing Interim Arrangements for a Global Commercial Communications Satellite System; and

Whereas those Governments have undertaken therein to sign or to designate a communications entity to sign this Special Agreement;

The signatories to this Special Agreement hereby agree as follows:

ARTICLE 1

In this Special Agreement:

(a) "The Agreement" means the Agreement Establishing Interim Arrangements for a Global Commercial Communications Satellite System opened for signature on August 20, 1964, at Washington;

(b) "The Committee" means the Interim Communications Satellite Committee established by Article IV of the Agreement;

(c) "The Corporation" means the Communications Satellite Corporation incorporated under the laws of the District of Columbia pursuant to the Communications Satellite Act of 1962 of the United States of America;

(d) "Design" and "development" include research;

(e) "Quota", in relation to a signatory, means the percentage set forth opposite its name in the Annex to this Special Agreement as modified pursuant to the Agreement and this Special Agreement;

(f) "Signatory" means a Government or a communications entity which has signed this Special Agreement and in respect of which it is in force;

(g) "The space segment" means the space segment defined in Article I (b) (i) of the Agreement.

ARTICLE 2

Each signatory undertakes to fulfill the obligations placed upon it by the Agreement and thereby obtains the rights provided therein.

ARTICLE 3

Each signatory undertakes to contribute a percentage of the costs of the design, development, construction and establishment of the space segment equal to its quota.

ARTICLE 4

(a) During a period of nine months from the date when the Agreement is first opened for signature, each signatory shall, within four weeks from the date of entry into force of this Special Agreement for that signatory, make a payment on account to the Corporation, in

United States dollars, or in currency freely convertible into United States dollars, of a percentage equal to its quota of the expenditure which the Corporation has incurred for the design, development, construction and establishment of the space segment prior to the date when the Agreement is first opened for signature, and, according to estimates established by the Corporation at that date, is to incur for those purposes within six months after that date, together with its proportionate share of any additional contribution required pursuant to paragraph (b) of this Article, and appropriate interest on all such amounts. Each signatory shall pay the remainder of its contribution pursuant to Article 3 of this Special Agreement in accordance with paragraph (b) of this Article.

(b) The Corporation shall submit to the Committee estimates of the time phasing of payments required pursuant to Article 3 of this Special Agreement. The Committee shall call on the signatories to make their respective proportionate payments in order to enable obligations to be met as they become due. Payments shall be made to the Corporation by each signatory in United States dollars, or in currency freely convertible into United States dollars, and in such amounts that, accounting on a cumulative basis, the sums paid by the signatories are in proportion to their respective quotas. Where a signatory other than the Corporation incurs obligations pursuant to authorization by the Committee, the Committee shall cause payments to be made to that signatory.

(c) Accounts for expenditure referred to in paragraphs (a) and (b) of this Article shall be subject to review by the Committee and shall be subject to such adjustment as the Committee may decide.

(d) Each signatory shall pay the amount due from it under paragraph (b) of this Article on the date designated by the Committee. Interest at the rate of six per cent per annum shall be added to any amount unpaid after that date. If the signatory has not made a payment within three months of its becoming due, the rights of the signatory under the Agreement and this Special Agreement shall be suspended. If, after such suspension, the Committee decides, pursuant to Article XI (b) of the Agreement, that the defaulting signatory is deemed to have withdrawn from this Special Agreement, the Committee shall then make a binding determination of the sums already due together with a sum to be paid in respect of the costs which will result in the future from contracts concluded while that signatory was a party. Such withdrawal shall not, however, affect the obligation of the signatory concerned to pay sums due under this Special Agreement, whether falling due before it ceased to be a party or payable in accordance with the aforesaid determination of the Committee.

ARTICLE 5

The following shall be included as part of the costs of the design, development, construction and establishment of the space segment to be shared by the signatories in proportion to their respective quotas:

(a) The direct and indirect costs for the design, development, construction and establishment of the space segment incurred by the Corporation prior to the date when the Agreement is first opened for signature;

(b) All direct and indirect costs for the design, development, construction and establishment of the space segment incurred by the Corporation or pursuant to authorization by the Committee by any other signatory on behalf of the signatories to this Special Agreement subsequent to the date when the Agreement is first opened for signature;

(c) All direct and indirect costs incurred by the Corporation which are allocable to its performance of services as manager in the design, development, construction and establishment of the space segment and appropriate compensation to the Corporation, as may be agreed between the Corporation and the Committee, for such services.

ARTICLE 6

The following shall not form part of the costs to be shared by the signatories:

(a) Taxes on the net income of any of the signatories;

(b) Design and development expenditure on launchers and launching facilities except expenditure incurred for the adaptation of launchers and launching facilities in connection with the design, development, construction and establishment of the space segment;

(c) The costs of the representatives of the signatories on the Committee and on its advisory sub-committees and the staffs of those representatives except insofar as the Committee may otherwise determine.

ARTICLE 7

(a) In considering whether an earth station should be permitted to utilize the space segment, the Committee shall take into account the technical characteristics of the station, the technical limitations on multiple access to satellites due to the existing state of the art, the effect of geographical distribution of earth stations on the efficiency of the services to be provided by the system, the recommended standards of the International Telegraph and Telephone Consultative Committee and the International Radio Consultative Committee of the International Telecommunication Union, and such general standards as the Committee may establish. Failure by the Committee to establish general standards shall not of itself preclude the Committee from considering or acting upon any application for approval of an earth station to utilize the space segment.

(b) Any application for approval of an earth station to utilize the space segment shall be submitted to the Committee by the signatory to this Special Agreement in whose area the earth station is or will be located or, with respect to other areas, by a duly authorized communications entity. Each such application shall be submitted either individually or jointly on behalf of all signatories and duly authorized communications entities intending to utilize the space segment by means of the earth station which is the subject of the application.

(c) Any application for approval of an earth station located in the territory of a State whose Government is party to the Agreement which is to be owned or operated by an organization or organizations other than the corresponding signatory shall be made by that signatory.

ARTICLE 8

(a) Each applicant for approval of an earth station pursuant to Article 7 of this Special Agreement shall be responsible for making equitable and non-discriminatory arrangements for the use of the earth station by all signatories or duly authorized communications entities intended to be served by the earth station individually or jointly with other earth stations.

(b) To the extent feasible the Committee shall allot to the respective signatory or duly autorized communications entity, for use by each earth station which has been approved pursuant to Article 7 of this Special Agreement, an amount of satellite utilization appropriate to satisfy the total communications capability requested on behalf of all signatories and duly authorized communications entities to be served by such earth station.

(c) In making allotments of satellite utilization the Committee shall give due consideration to the quotas of the signatories to be served by each earth station.

ARTICLE 9

(a) The Committee shall specify the unit of satellite utilization and from time to time shall establish the rate of charge per unit at a level which, as a general rule, shall be sufficient, on the basis of the estimated total use of the space segment, to cover amortization of the capital cost of the space segment, an adequate compensation for use of capital, and the estimated operating, maintenance and administration costs of the space segment.

(b) In establishing the unit rate of charge pursuant to paragraph (a) of this Article, the Committee shall include in the estimated operating, maintenance and administration costs of the space segment the estimated direct and indirect costs of the Corporation which are allocable to its performance of services as manager in the operation and maintenance of the space segment and appropriate compensation to the Corporation, as may be agreed between the Corporation and the Committee, for such services.

(c) The Committee shall arrange for the payment of charges for allotments of satellite utilization to be made quarterly to the Corporation. The charges shall be computed in United States dollars and paid in United States dollars or in currency freely convertible into United States dollars.

(d) The components of the unit rate of charge representing amortization and compensation for the use of capital shall be credited to the signatories in proportion to their respective quotas. In the interests of avoiding unnecessary transfers of funds between signatories, and of keeping to a minimum the funds held by the Corporation on behalf of the signatories, the Committee shall make suitable arrangements for funds representing these components to be retained by signatories where appropriate or, if collected, to be distributed among the signatories in such a way that the credits established for signatories are discharged.

(e) The other components of the unit rate of charge shall be applied to meet all operating, maintenance, and administration costs, and to establish such reserves as the Committee may determine to be necessary. After providing for such costs and reserves, any balance remaining shall be distributed by the Corporation, in United States dollars, or in currency freely convertible into United States dollars, among the signatories in proportion to their respective quotas; but if insufficient funds remain to meet the operating, maintenance and administration costs, the signatories shall pay to the Corporation, in proportion to their respective quotas, such amounts as may be determined by the Committee to be required to meet the deficiency.

(f) The Committee shall institute appropriate sanctions in cases where payments pursuant to this Article shall have been in default for three months or longer.

ARTICLE 10

(a) All contracts placed by the Corporation or by any other signatory pursuant to authorization by the Committee relating to design, development and procurement of equipment for the space segment shall, except as otherwise provided by the Committee, be based on responses to appropriate requests for quotations or invitations to tender from among persons and organizations qualified to perform the work under the proposed contract whose names are furnished to the Committee by the signatories.

(b) For contracts which exceed U.S. $125,000 the issue by the Corporation of requests for quotations or invitations to tender shall be in accordance with such conditions as the Committee may determine. The Corporation shall keep the Committee fully informed of decisions taken relating to such contracts.

(c) The Corporation shall consult the Committee before issuing requests for proposals and invitations to tender for contracts for design, development and procurement of equipment for the space segment which are expected to exceed U.S. $500,000. If, as a result of its evaluation of responses to such requests or invitations, the Corporation desires that a contract be placed which exceeds U.S. $500,000, it shall submit its evaluation and recommendations to the Committee. The approval of the Committee shall be required before each such contract is placed either by the Corporation as manager or by any other signatory pursuant to authorization by the Committee.

(d) The Committee shall approve the program for the launching of satellites and for associated services, the launch source and the contracting arrangements.

(e) Except as otherwise directed by the Committee, and subject to paragraphs (c) and (d) of this Article, all contractors shall be selected by the Corporation and all contracts shall be in the name of and be executed and administered by the Corporation as manager.

(f) Except as otherwise determined by the Committee, all contracts and sub-contracts placed for design, development and procurement of equipment for the space segment shall contain appropriate provisions to the effect that all inventions, technical data and information arising directly from any work performed under such contracts (except inventions, technical data and information pertaining to launchers and launchings) shall be disclosed to the Committee and may be used only in the design, development, manufacture and use of equipment and components for the space segment established under the present interim arrangements or under any definitive arrangements which may succeed these interim arrangements, without payment of royalties, by each signatory or any person in the jurisdiction of a signatory or the Government which has designated that signatory.

(g) Except as it may otherwise determine, the Committee shall endeavor to have included in all contracts placed for design and development appropriate provisions which will ensure that inventions, technical data and information owned by the contractor and its subcontractors which are directly incorporated in work performed under such contracts, may be used on fair and reasonable terms by each signatory or any person in the jurisdiction of a signatory or the Government which has designated that signatory, provided that such use is necessary, and to the extent that it is necessary to use such inventions, technical data and information for the exercise of the right to use under paragraph (f) of this Article.

(h) The provisions of this Article shall not be held to apply to contracts for design, development, construction and establishment of the space segment to which the Corporation is a party on the date when the Agreement is first opened for signature. Subject to the provisions of Article 4 (c) of this Agreement, all such contracts shall be recognized by the Committee as continuing obligations for budgetary purposes.

ARTICLE 11

Each signatory shall keep such books, records, vouchers and accounts of all costs for which it is authorized to be reimbursed under this Special Agreement with respect to the design, development, construction, establishment, maintenance and operation of the space segment as may be appropriate and shall at all reasonable times make them available for inspection by members of the Committee.

ARTICLE 12

In addition to functions stated elsewhere in this Special Agreement, the Corporation, as manager pursuant to Article VIII of the Agreement, shall:

(a) prepare and submit to the Committee the annual programs and budgets;

(b) recommend to the Committee the type or types of space segment to be established;

(c) plan, conduct, arrange for and co-operate in studies, design work and development for improvement of the space segment;

(d) operate and maintain the space segment;

(e) furnish to the committee such information as may be required by any representative on the Committee to enable him to discharge his responsibilities as a representative;

(f) arrange for technicians, selected by the Committee with the concurrence of the Corporation from among persons nominated by signatories, to participate in the assessment of designs and of specifications for equipment for the space segment;

(g) use its best efforts to arrange for inventions, technical data and information arising directly from any jointly financed work performed under contracts placed before the date on which the Agreement is opened for signature to be disclosed to each signatory and to be made available for use free of charge in the design, development, manufacture and use of equipment and components for the space segment by each signatory or any person in the jurisdiction of the signatory or the Government which has designated that signatory.

ARTICLE 13

Neither the Corporation as signatory or manager, nor any other signatory as such, shall be liable to any other signatory for loss or damage sustained by reason of a failure or breakdown of a satellite at or after launching or a failure or breakdown of any other portion of the space segment.

ARTICLE 14

Arrangements shall be made whereby all legal disputes arising in connection with this Special Agreement or in connection with the rights and obligations of signatories can, if not otherwise settled, be

submitted to the decision of an impartial tribunal, to be established in accordance with such arrangements, which would decide such questions in accordance with general principles of law. To this end, a group of legal experts appointed by the signatories and by the prospective signatories listed in the Annex to this Agreement when it is first opened for signature shall recommend a draft of a Supplementary Agreement containing such arrangements; the signatories shall, after considering that draft, conclude a Supplementary Agreement for such arrangements within a period of three months from the date when the Agreement is first opened for signature. The Supplementary Agreement shall be binding on all those who subsequently become signatories to this Special Agreement.

ARTICLE 15

Any proposed amendment to this Special Agreement shall first be submitted to the Committee. If recommended by the Committee for adoption, it shall enter into force for all signatories when notifications of approval have been deposited with the Government of the United States of America by two-thirds of the signatories, provided that no amendment may impose upon any signatory any additional financial obligation without its consent.

ARTICLE 16

This Special Agreement shall enter into force for each signatory on the day of signature, provided that the Agreement shall have entered into force for or shall have been provisionally applied by the Government which is or has designated the signatory in question; it shall continue in force for as long as the Agreement continues in force.

IN WITNESS WHEREOF the undersigned duly authorized thereto have signed this Special Agreement.

DONE at Washington this twentieth day of August, 1964, in the English and French languages, both texts being equally authoritative, in a single original, which shall be deposited in the archives of the Government of the United States of America, which shall transmit a certified copy to each signatory or acceding Government and to the Government of each State which is a member of the International Telecommunication Union.

ANNEX

LIST OF PROSPECTIVE SIGNATURES TO THE SPECIAL AGREEMENT

Country	*Name of Signatory*	*Quota*
Australia	Overseas Telecommunications Commission (Australia)	2.75
Austria	Bundesministerium für Verkehr und Elektrizitätswirtschaft, Generaldirektion für die Postund Telegraphenverwaltung	0.2
Belgium	Régie des Télégraphes et Téléphones	1.1
Canada	Canadian Overseas Telecommunication Corporation	3.75
Denmark	Generaldirektoratet for Post og Telegrafvesenet	0.4
France	Government of the French Republic	6.1
Germany	Deutsche Bundespost	6.1
Ireland	An Roinn Poist Agus Telegrafa	0.35
Italy	to be designated	2.2
Japan	Kokusai Denshin Denwa Company Ltd.	2.0
Netherlands	Government of the Kingdom of the Netherlands	1.0
Norway	Telegrafstyret	0.4
Portugal	Administração Geral dos Correios, Telégrafos e Telefones	0.4
Spain	Government of the State of Spain	1.1
Sweden	Kungl. Telestyrelsen	0.7
Switzerland	Direction Générale des PTT	2.0
United Kingdom of Great Britain and Northern Ireland	Her Britannic Majesty's Postmaster General	8.4
United States of America	Communications Satellite Corporation	61.0
Vatican City	Government of the Vatican City State	0.05

3.6 ACCORD, SYSTÈME DE TÉLÉCOMMUNICATIONS PAR SATELLITES 20 AOÛT 1964

ACCORD ÉTABLISSANT UN RÉGIME PROVISOIRE APPLICABLE À UN SYSTÈME COMMERCIAL MONDIAL DE TÉLÉCOMMUNICATIONS PAR SATELLITES

Les Gouvernements signataires du présent accord,

Rappelant le principe énoncé dans la Résolution n° 1721 (XVI) de l'Assemblée Générale des Nations Unies d'après lequel il importe de mettre dès que possible à la disposition de toutes les nations sans discrimination des moyens de télécommunications par satellites sur une base mondiale;

Souhaitant créer un système commercial mondial unique de télécommunications par satellites, pour servir à l'amélioration du réseau universel de télécommunications, étendre les services de télécommunications à toutes les régions du monde et contribuer ainsi à l'entente et à la paix mondiales;

Décidés à cet effet à assurer, pour le bien de toutes les nations et grâce aux meilleures techniques, le service le plus efficace et le plus économique possible, compatible avec une utilisation rationnelle et équitable des gammes de fréquences radioélectriques;

Estimant que les télécommunications par satellites doivent être organisées de telle façon que tous les États puissent avoir accès au système mondial et, que ceux qui le souhaitent puissent y investir des capitaux et participer ainsi à la conception, à la mise au point, à la construction (y compris la fourniture de matériel), à la mise en place, à l'entretien, à l'exploitation et à la propriété du système;

Estimant qu'il est souhaitable d'établir un régime provisoire prévoyant la création d'un système commercial mondial unique de télécommunications par satellites dans les plus brefs délais possibles, en attendant l'élaboration du régime définitif relatif à l'organisation d'un système de ce genre;

Sont convenus de ce qui suit:

ARTICLE I

(a) Les Parties au présent Accord coopèrent, conformément aux principes énoncés au Préambule du présent Accord, en vue de pourvoir à la conception, à la mise au point, à la construction, à la mise en place, à l'entretien et à l'exploitation du secteur spatial du système commercial mondial de télécommunications par satellites selon le programme suivant:

(i) une phase expérimentale et d'exploitation au cours de laquelle est prévue l'utilisation d'un ou plusieurs satellites qui doivent être placés sur orbitre synchrone en 1965;

(ii) des phases successives au cours desquelles seront utilisés des satellites dont le type reste à préciser, en vue d'assurer les éléments de base d'un service mondial au cours de la deuxième moitié de 1967;

(iii) telles améliorations et extensions du système que le Comité créé par l'Article IV du présent Accord décidera sous réserve des dispositions de l'Article VI du présent Accord.

(b) Au sens du présent Accord,

(i) le terme «secteur spatial» désigne des satellites de télécommunications ainsi que l'équipement et les installations de repérage, de contrôle, de commande et autres, nécessaires au fonctionnement des satellites de télécommunications;

(ii) les termes «conception» et «mise au point» visent également la recherche.

ARTICLE II

(a) Chaque Partie signe l'Accord Spécial qui est ouvert à la signature en même temps que le présent Accord ou désigne l'organisme de télécommunications public ou privé habilité à le signer. Les rapports entre l'organisme de télécommunications ainsi désigné et la Partie qui l'a désigné sont régis par la législation intérieure du pays intéressé.

(b) Les Parties au présent Accord prévoient que, sous réserve des dispositions de leur législation interne, les administrations et les compagnies de télécommunications négocieront et concluront directement les accords de traffic appropriés concernant l'utilisation qu'ils feront des circuits de télécommunications prévus par le système à établir selon les dispositions du présent Accord ainsi que les services destinés au public, les installations, la répartition de bénéfices et les dispositions commerciales qui s'y rapportent.

ARTICLE III

Le secteur spatial est la propriété indivise des signataires de l'Accord Spécial proportionnellement à leur contribution respective aux dépenses de conception, de mise au point, de construction et de mise en place de ce secteur spatial.

ARTICLE IV

(a) Un Comité intérimaire des télécommunications par satellites, ci-après dénommé «le Comité» est créé par le présent Accord pour mettre en oeuvre la coopération prévue à l'Article I. Il est chargé de la conception, de la mise au point, de la construction, de la mise en place, de l'entretien et de l'exploitation du secteur spatial du système; en particulier, il exerce les fonctions et est investi des pouvoirs énoncés dans le présent Accord ainsi que dans l'Accord Spécial.

(b) Le Comité est constitué de la manière suivante: un représentant pour chaque signataire de l'Accord Spécial dont la quote-part n'est pas inférieure à 1,5% et un représentant pour deux ou plusieurs signataires de l'Accord Spécial dont la somme des quotes-parts n'est pas inférieure à 1,5% et qui sont convenus d'être ainsi représentés.

(c) Dans l'exercice des attributions de caractère financier qui lui sont dévolues par le présent Accord et par l'Accord Spécial, le Comité est assisté d'un sous-comité financier consultatif; celui-ci sera créé par le Comité dès l'entrée en fonctions de ce dernier.

(d) Le Comité a la faculté de créer tous autres sous-comités consultatifs qu'il jugera utiles.

(e) Aucun signataire ou groupe de signataires de l'Accord Spécial ne pourra être privé de sa représentation au Comité en raison des réductions effectuées conformément à l'Article XII (c) du présent Accord.

(f) Au sens du présent Accord le mot «quote-part» lorsqu'il s'agit d'un signataire de l'Accord Spécial signifie le pourcentage mentionné à l'Annexe à l'Accord Spécial en regard de son nom ou tel qu'il a été modifié conformément au présent Accord et à l'Accord Spécial.

ARTICLE V

(a) Chaque signataire ou groupe de signataires de l'Accord Spécial représenté au Comité dispose d'un nombre de voix égal au chiffre de sa quote-part ou de la somme de leurs quotes-parts selon le cas.

(b) Le quorum nécessaire pour chaque réunion du Comité est constitué de représentants disposant au total d'un nombre de voix supérieur d'au moins 8,5 voix au nombre de voix dont dispose le représentant qui a le droit de vote le plus élevé.

(c) Le Comité s'efforce d'agir à l'unanimité; toutefois, s'il ne le peut il prend ses décisions à la majorité des voix exprimées, sauf que pour les questions suivantes, et sous réserve des paragraphes (d) et (e) du présent Article, toute décision est prise par le vote de représentants dont le nombre total de voix est supérieur d'au moins 12,5 voix à celui dont dispose le représentant qui a le nombre de voix le plus élevé:

(i) choix du ou des types de secteur spatial à établir;
(ii) définition des normes générales pour l'approbation des stations terriennes devant avoir accès au secteur spatial;
(iii) approbation des budgets par catégories principales;
(iv) révision des comptes conformément à l'Article 4 (c) de l'Accord Spécial;
(v) établissement du taux unitaire de la redevance d'utilisation du système de satellites conformément à l'Article 9 (a) de l'Accord Spécial;
(vi) décisions relatives aux contributions supplémentaires conformément à l'Article VI (b) du présent Accord;
(vii) approbation du placement des contrats conformément à l'Article 10 (c) de l'Accord Spécial;
(viii) approbation des questions relatives au lancement des satellites conformément à l'Article 10 (d) de l'Accord Spécial;
(ix) approbation des quotes-parts conformément à l'Article XII (a) (ii) du présent Accord;
(x) établissement des conditions financières d'adhésion conformément à l'Article XII (b) du présent Accord;
(xi) décisions relatives à la dénonciation conformément à l'Article XI (a) et (b) du présent Accord et à l'Article 4 (d) de l'Accord Spécial;
(xii) proposition d'amendements conformément à l'Article 15 de l'Accord Spécial;
(xiii) adoption du règlement intérieur du Comité et des sous-comités consultatifs;
(xiv) approbation d'une rémunération appropriée à payer à la Société pour l'exécution des services en tant que

gérant, conformément aux Articles 5 (c) et 9 (b) de l'Accord Spécial.

(d) Si le Comité, à qui a été proposée, en vue d'une décision, une question au sujet du type de secteur spatial à créer afin de réaliser l'objectif prévu au paragraphe (a) (ii) de l'Article I du présent Accord, n'a pas pris celle-ci à l'expiration du soixantième jour suivant la date à laquelle cette question a été posée, une décision sur cette question peut être prise après ce délai par votes favorables de représentants dont le nombre total de voix est supérieur de 8,5 voix à celui dont dispose le représentant qui a le droit de vote le plus élevé.

(e) Si le Comité, à l'expiration du soixantième jour suivant la date à laquelle lui a été proposée pour décision une des questions suivantes en rapport avec l'achèvement des objectifs prévus dans les paragraphes (a) (i) et (a) (ii) de l'Article I du présent Accord et ne l'a pas approuvée:

(i) toute catégorie particulière de budget conformément au paragraphe (c) (iii) du présent Article;
(ii) le placement de tout contrat particulier conformément au paragraphe (c) (vii) du présent Article ou
(iii) toute question particulière relative aux lancements de satellites conformément au paragraphe (c) (viii) du présent Article,

une décision sur cette question peut être prise après ce délai par votes favorables de représentants dont le nombre total de voix est supérieur de 8,5 voix à celui dont dispose le représentant qui a le droit de vote le plus élevé.

ARTICLE VI

(a) Les contributions des signataires de l'Accord Spécial aux dépenses de conception, de mise au point, de construction et de mise en place du secteur spatial pendant la durée du régime provisoire sont établies sur la base d'un montant total évalué à deux cents millions de dollars des États-Unis. Les signataires de l'Accord Spécial versent leurs quotes-parts de ces dépenses conformément aux dispositions de l'Accord Spécial.

(b) Le Comité décide s'il convient, pendant la durée du régime provisoire, d'appeler des contributions complémentaires au-delà du montant de deux cents millions de dollars des États-Unis; il détermine le montant de ces contributions. Si l'appel de contributions complémentaires pendant la durée du régime provisoire tend à établir le montant total des contributions à plus de trois cents millions de dollars des États-Unis, une conférence spéciale des signataires de l'Accord Spécial sera réunie à l'effet d'examiner la situation et de recommander les mesures qu'elle jugera appropriées avant toute décision du Comité. La conférence arrêtera son règlement intérieur.

(c) Chaque signataire de l'Accord Spécial a la faculté d'assumer l'obligation de verser la totalité ou une partie de sa quote-part des contributions complémentaires; aucun signataire de l'Accord Spécial n'est tenu d'assumer cette obligation. Dans la mesure où l'un quelconque de ces signataires n'assume pas cette obligation, celle-ci peut être assumée par les autres signataires dans la proportion de leurs quotes-parts respectives ou d'une autre manière dont ils pourraient convenir. Toutefois, si un signataire de l'Accord Spécial, qui fait partie d'un groupe de signataires formé pour nommer conjointement un représentant au Comité suivant les dispositions de l'Article IV (b) du présent Accord n'assume pas l'obligation de verser de telles contributions supplémentaires, les autres signataires de ce groupe peuvent assumer cette obligation, en tout ou en partie, dans la proportion dont ils auront convenu. Les quotes-parts des signataires de l'Accord Spécial sont ajustées en conséquence.

ARTICLE VII

Conformément aux principes énoncés au Préambule du présent Accord et pour assurer l'utilisation la plus efficace possible du secteur spatial, aucune station terrienne ne peut être autorisée à utiliser celui-ci sans l'approbation du Comité, donnée suivant les dispositions de l'Article 7 de l'Accord Spécial.

ARTICLE VIII

En ce qui concerne sa conception, sa mise au point, sa construction, sa mise en place, son exploitation et son entretien le secteur spatial est géré, conformément aux directives générales et éventuellement aux instructions particulières du Comité, par la «Communications Satellite Corporation» appelée la Société dans le texte du présent Accord, et constituée conformément à la législation du District de Columbia.

ARTICLE IX

(a) Tenant compte du programme établi à l'Article I du présent Accord, le Comité soumettra aux diverses Parties au présent Accord, dans l'année qui suivra la mise en exploitation du système mondial initial et, au plus tard le 1^er^ janvier 1969, un rapport présentant ses recommandations sur les dispositions définitives concernant le système international mondial destiné à remplacer le régime provisoire établi par le présent Accord. Ce rapport, qui devra refléter pleinement toutes les nuances d'opinion, étudiera en particulier si le régime provisoire devra devenir définitif, ou si une organisation internationale permanente, constituée notamment d'une Conférence Générale et de services administratifs et techniques internationaux, devra être créée.

(b) Quelle que soit la forme du régime définitif,
- (i) les buts de celui-ci devront être conformes aux principes énoncés au Préambule du présent Accord,
- (ii) comme au présent Accord tous les États membres de l'Union Internationale des Télécommunications ou leurs organismes désignés à cet effet pourront y adhérer,
- (iii) les investissements faits par les signataires de l'Accord Spécial seront sauvegardés,
- (iv) toutes les Parties au régime définitif auront la possibilité de contribuer à la définition de la politique générale.

(c) Le rapport du Comité sera examiné au cours d'une conférence internationale à laquelle peuvent participer également les organismes de télécommunications dûment désignés et qui sera réunie à cet effet par le Gouvernement des États-Unis d'Amérique dans les trois mois suivant le dépôt du rapport. Les Parties au présent Accord s'efforceront d'obtenir que le régime définitif soit créé à la date la plus proche possible afin qu'il puisse entrer en vigueur au plus tard le 1^er^ janvier 1970.

ARTICLE X

Dans l'examen des contrats et dans l'exercice de leurs autres responsabilités, le Comité et la Société en tant que gérant tiennent compte de la nécessité de concevoir, mettre au point et acquérir le matériel et obtenir les services les plus appropriés et au meilleur prix pour le fonctionnement et l'exploitation les plus efficaces du secteur spatial. Lorsque les réponses aux demandes de propositions ou aux appels d'offre sont jugées comparables quant à la qualité, au prix c.i.f. et aux délais, le Comité et la Société en tant que gérant veillent également à ce que les contrats soient répartis autant que possible de telle façon que le matériel soit conçu, mis au point et acquis dans les pays qui sont Parties au présent Accord en proportion approximative des quotes-parts respectives des signataires correspondants de l'Accord Spécial; à condition que dans la conception, la mise au point et la fourniture de ce matériel, les intérêts communs des Parties au présent Accord et des signataires de l'Accord Spécial ne soient pas desservis. Dans la mesure où cela peut être accompli sans diminuer la responsabilité assumée par l'entrepreneur principal concernant l'exécution des travaux aux termes du contrat, le Comité et la Société en tant que gérant veillent également à ce que les principes énoncés ci-dessus soient mis en pratique en ce qui concerne les principaux sous-traitants.

ARTICLE XI

(a) Le présent Accord peut être dénoncé par toute Partie; il cesse d'être en vigueur, en ce qui la concerne, trois mois après que celle-ci a notifié sa dénonciation au Gouvernement des États-Unis d'Amérique, lequel en avise les autres Parties. Dans ce cas, le signataire correspondant de l'Accord Spécial, paie la totalité des sommes déjà dues aux termes de l'Accord Spécial, auxquelles s'ajoute une somme convenue entre ce signataire et le Comité pour couvrir les dépenses résultant ultérieurement de contrats passés avant la notification de la dénonciation. Si un Accord n'a pas été conclu dans les trois mois qui suivront la notification de la dénonciation, le Comité déterminera de façon définitive les montants qui seront payés par ce signataire.

(b) Trois mois au moins après la date où l'exercice des droits d'un signataire de l'Accord Spécial est déclaré suspendu conformément au paragraphe (d) de l'Article 4 de l'Accord Spécial et si ce signataire n'a pas payé entre-temps toutes les sommes dues, le Comité, tenant compte des déclarations de la Partie ou du signataire correspondant de l'Accord Spécial, peut décider que cette Partie doit être considérée comme ayant dénoncé le présent Accord, lequel cessera, en conséquence, de lui être applicable.

(c) La dénonciation du présent Accord par une Partie vaut dénonciation de l'Accord Spécial par le signataire correspondant, mais l'obligation d'effectuer des paiements aux termes du paragraphe (a) du présent Article ou aux termes du paragraphe (d) de l'Article 4 de l'Accord Spécial n'est pas affectée par cette dénonciation.

(d) En cas de dénonciation effectuée aux termes des alinéas (a) ou (b) ci-dessus, le Comité procédera, dans la limite de la quote-part du signataire correspondant de l'Accord Spécial, à l'augmentation des quotes-parts des autres signataires de l'Accord Spécial en proportion de leurs quotes-parts respectives ou selon une autre méthode dont ces signataires conviendront. Toutefois, si un signataire de l'Accord Spécial correspondant à la Partie qui dénonce est, à ce moment, membre d'un groupe de signataires formé pour nommer conjointement un représentant au Comité, suivant les dispositions de l'Article IV (b) du présent Accord, la quote-part de ce signataire sera répartie entre les autres signataires du groupe, dans la proportion dont ils auront convenu.

(e) La dénonciation par toute Partie peut également intervenir dans le cas où, à la demande de la Partie intéressée, le Comité approuve le transfert à une autre Partie et à son signataire de l'Accord Spécial, des droits et obligations accordés à la Partie demandante et à son signataire correspondant de l'Accord Spécial par les dispositions du présent Accord et de l'Accord Spécial. Il ne sera pas nécessaire que ces derniers aient été Parties à l'Accord ou signataires de l'Accord Spécial avant la date de ce transfert.

ARTICLE XII

(a) Pendant une période de six mois à compter du 20 août 1964 le présent Accord est ouvert, à Washington, à la signature:

(i) du gouvernement de chaque État dont le nom figure, à la date ci-dessus, à l'Annexe à l'Accord Spécial, et

(ii) du gouvernement de tout autre État membre de l'Union Internationale des Télécommunications, sous réserve toutefois de l'approbation par le Comité de la quote-part revenant à ce gouvernement ou à l'organisme de télécommunications public ou privé désigné par lui. Après approbation et entrée en vigueur ou en application provisoire, le nom de l'État et celui du signataire correspondant de l'Accord Spécial, ainsi que le chiffre de sa quote-part sont considérés comme inscrits à l'Annexe de l'Accord Spécial.

(b) Le gouvernement de tout État membre de l'Union Internationale des Télécommunications peut adhérer au présent Accord après qu'il aura cessé d'être ouvert à la signature; l'adhésion se fera aux conditions financières que déterminera le Comité. Une fois l'adhésion effectuée, le nom de l'État et celui du signataire correspondant de l'Accord Spécial, ainsi que le chiffre de sa quote-part, seront considérés comme inscrits à l'Annexe de l'Accord Spécial.

(c) Pour permettre l'adhésion à l'Accord Spécial de nouveaux signataires, les quotes-parts des autres signataires de l'Accord Spécial sont réduites en proportion. Toutefois, la somme des quotes-parts attribuées à l'origine à tous les signataires de l'Accord Spécial, autres que ceux qui figuraient à l'Annexe de celui-ci lorsqu'il a été ouvert à la signature, ne devra pas dépasser 17%.

(d) L'Accord prend effet à la date à laquelle il a été signé sans réserve d'approbation ou a été approuvé après une telle réserve par deux ou plusieurs gouvernements. Par la suite, il prend effet à l'égard de chacun des gouvernements signataires, à la date où il l'a signé, ou, s'il signe sous réserve d'approbation, à la date de levée de la réserve.

(e) Tout Gouvernement qui signe le présent Accord sous réserve d'approbation peut, aussi longtemps que celui-ci reste ouvert à la signature, déclarer qu'il l'applique à titre provisoire; il est dès lors considéré comme Partie à l'Accord. Cette application provisoire prend fin:

(i) par l'approbation du présent Accord par ce Gouvernement, ou bien
(ii) par la dénonciation qu'il en fait en vertu de l'Article XI du présent Accord.

(f) Nonobstant toute disposition contraire du présent Article, le présent Accord n'entrera en vigueur à l'égard de l'un quelconque des gouvernements ni ne sera appliqué par lui de façon provisoire avant que ce Gouvernement ou son signataire correspondant n'ait signé l'Accord Spécial.

(g) Si à l'expiration d'une période de neuf mois suivant la date où il est ouvert à la signature, le présent Accord n'est pas entré en vigueur pour le Gouvernement d'un État qui l'a signé conformément au paragraphe (a) (i) du présent Article ou n'a pas été appliqué à titre provisoire par celui-ci, la signature de celui-ci est considérée comme nulle et le nom de l'État et celui du signataire correspondant de l'Accord Spécial, ainsi que la quote-part de celui-ci, sont considérés comme rayés de l'Annexe à l'Accord Spécial; les quotes-parts des signataires de l'Accord Spécial seront en conséquence augmentées proportionnellement. Si le présent Accord n'est pas entré en vigueur à l'égard du Gouvernement d'un État qui l'a signé conformément à l'alinéa (a) (ii) dans les neuf mois suivant la date à laquelle il est

ouvert à la signature ou n'a pas fait l'objet d'une application provisoire de sa part, la signature de ce Gouvernement est considérée comme nulle.

(h) Le signataire de l'Accord Spécial correspondant à un Gouvernement ayant signé cet Accord sous réserve d'approbation et qui ne l'a pas mis en application provisoire peut nommer un observateur au Comité, de la même façon qu'il aurait pu désigner un représentant conformément à l'Article IV (b) du présent Accord s'il avait approuvé celui-ci. Cet observateur aura le droit de prendre la parole, mais non de voter; il peut assister aux réunions du Comité pendant une période de neuf mois au plus après la date où le présent Accord est ouvert à la signature.

(i) Aucune réserve ne peut être apportée au présent Accord sauf celles qui sont prévues au présent Article.

ARTICLE XIII

(a) Les notifications d'approbation ou d'application provisoire ainsi que les instruments d'adhésion seront déposés auprès du Gouvernement des États-Unis d'Amérique.

(b) Le Gouvernement des États-Unis d'Amérique avisera tous les signataires et les États ayant adhéré à l'Accord des signatures, des réserves d'approbation, du dépôt des notifications d'approbation ou d'application provisoire, du dépôt des instruments d'adhésion et des notifications de dénonciation du présent Accord.

ARTICLE XIV

Lors de l'entrée en vigueur du présent Accord, le Gouvernement des États-Unis d'Amérique le fera enregistrer auprès du Secrétaire Général des Nations Unies conformément à l'Article 102 de la Charte des Nations Unies.

ARTICLE XV

Le présent Accord restera applicable jusqu'à l'entrée en vigueur du régime définitif mentionné à l'Article IX du présent Accord.

EN FOI DE QUOI les soussignés dûment autorisés ont apposé leur signature au présent Accord.

FAIT à Washington le vingt août 1964, en langues anglaise et française, les deux textes faisant également foi, en un seul original qui sera déposé dans les archives du Gouvernement des États-Unis d'Amérique, lequel en transmettra une copie certifiée conforme à chaque signataire ou gouvernement adhérent et au gouvernement de chaque État membre de l'Union Internationale des Télécommunications.

3.7 ACCORD SPÉCIAL ET ANNEXE 20 AOÛT 1964

ATTENDU que certains Gouvernements sont devenus Parties à un Accord établissant un régime provisoire applicable à un système commercial mondial de télécommunications par satellites;

ATTENDU également que ces Gouvernements se sont engagés par cet Accord à signer le présent Accord Spécial ou à désigner un organisme de télécommunications habilité à le signer;

Les signataires du présent Accord Spécial sont convenus de ce qui suit:

ARTICLE 1

Au sens du présent Accord Spécial:

(a) «L'Accord» désigne l'Accord concernant le régime provisoire applicable à un système commercial mondial de télécommunications par satellites, ouvert à la signature le 20 août 1964 à Washington.

(b) «Le Comité» désigne le comité provisoire des télécommunications par satellites créé par l'Article IV de l'Accord.

(c) «La Société» désigne la «Communications Satellite Corporation» constituée conformément à la législation du District de Columbia, en application du «Communications Satellite Act» de 1962 des États-Unis d'Amérique.

(d) Les termes «conception» et «mise au point» visent également la recherche.

(e) Le mot «quote-part» se rapportant à un signataire correspond au pourcentage indiqué en regard de son nom à l'Annexe au présent Accord Spécial modifié conformément à l'Accord et au présent Accord Spécial.

(f) Le mot «signataire» désigne tout gouvernement ou organisme de télécommunications ayant signé le présent Accord Spécial qui est en vigueur à son égard.

(g) L'expression «secteur spatial» désigne le secteur spatial défini à l'Article I (b) (i) de l'Accord.

ARTICLE 2

Tout signataire s'engage à s'acquitter des obligations prévues à l'Accord et acquiert ainsi les droits qui en découlent.

ARTICLE 3

Tout signataire s'engage à contribuer, pour un pourcentage égal à sa quote-part, aux dépenses de conception, de mise au point, de construction et de mise en place du secteur spatial.

ARTICLE 4

(a) Les signataires versent à la Société, dans les neuf mois suivant l'ouverture de l'Accord à la signature et dans les quatre semaines suivant la date à laquelle l'Accord Spécial entre en vigueur à leur égard, un acompte, en dollars des États-Unis ou en devises pouvant être librement converties en dollars des États-Unis, proportionnel à leurs quotes-parts, des dépenses que la Société a effectuées pour la conception, la mise au point, la construction et la mise en place du secteur spatial antérieurement à la date d'ouverture de l'Accord à la signature et de celles qu'elle effectuera aux mêmes fins pendant les six mois suivant la date susvisée, selon les prévisions établies par la Société à cette date; les signataires effectuent en même temps le versement de leurs quotes-parts des contributions complémentaires éventuellement appelées en application des dispositions du paragraphe (b) du présent Article; à ces versements s'ajoutent les intérêts normaux sur les sommes exigibles. Les signataires versent le solde de leurs contributions, telles que définies à l'Article 3 du présent Accord Spécial, suivant les modalités prévues au paragraphe (b) du présent Article.

(b) La Société présente au Comité un échéancier prévisionnel des versements ultérieurs que l'application des dispositions de l'Article 3 du présent Accord Spécial rendra nécessaires et le Comité invite les signataires à effectuer leurs versements proportionnels de façon que les dépenses soient couvertes au fur et à mesure de leurs échéances. Les signataires effectuent leurs versements auprès de la Société en dollars des États-Unis ou en devises pouvant être librement converties en dollars des États-Unis de telle façon que les versements cumulés soient en permanence proportionnels à leurs quotes-parts. Lorsqu'un signataire autre que la Société expose des dépenses, en vertu d'une autorisation du Comité, le Comité lui en fait obtenir le règlement.

(c) Les comptes relatifs aux dépenses visées aux paragraphes (a) et (b) ci-dessus sont examinés par le Comité et le cas échéant révisés par celui-ci.

(d) Les signataires effectuent à la date fixée par le Comité les paiements leur incombant en application des dispositions du paragraphe (b) de cet Article. Toute somme restant due après la date fixée est grevée d'un intérêt annuel de six pour cent. Lorsqu'un signataire n'a pas effectué de paiement dans les trois mois qui suivent l'échéance, l'exercice de ses droits aux termes de l'Accord et du présent Accord Spécial est suspendu. Si, à la suite de cette suspension, le Comité, conformément à l'Article XI (b) de l'Accord décide que le signataire défaillant est considéré comme ayant dénoncé l'Accord Spécial, le Comité arrête sans appel le montant des sommes déjà dues auxquelles s'ajoute une somme à payer pour les dépenses qui résulteraient ultérieurement de contrats conclus lorsque ce signataire était Partie au présent Accord Spécial. Pareille dénonciation n'affecte toutefois pas l'obligation, pour le signataire en cause, de payer les sommes dues aux termes du présent Accord, que leurs échéances se produisent avant qu'il ait cessé d'être Partie ou qu'elles soient payables conformément à la décision ci-dessus du Comité.

ARTICLE 5

Sont comprises dans les dépenses de conception, de mise au point, de construction et de mise en place du secteur spatial, pour être réparties entre les signataires proportionnellement à leur quote-part respective:

(a) les dépenses directes et indirectes effectuées à ces fins par la Société avant la date à laquelle l'Accord est ouvert à la signature;

(b) toutes les dépenses directes et indirectes effectuées à ces mêmes fins par la Société ou, en vertu d'une autorisation du Comité, par tout autre signataire, au nom des signataires du présent Accord Spécial, après la date à laquelle l'Accord est ouvert à la signature;

(c) toutes les dépenses directes et indirectes effectuées à ces mêmes fins par la Société dans sa gestion, ainsi que la juste rémunération des fonctions exercées par la Société dans les conditions convenues entre celle-ci et le Comité.

ARTICLE 6

Ne font pas partie des dépenses à répartir entre les signataires:

(a) les impôts sur le revenu net de l'un quelconque des signataires;

(b) les dépenses nécessaires à la conception et la mise au point des lanceurs et des installations de lancement, à l'exception toutefois des dépenses effectuées pour l'adaptation de ces lanceurs et de ces installations de lancement à la conception, la mise au point, la construction et la mise en place du secteur spatial;

(c) les dépenses relatives aux représentants des signataires au Comité et aux sous-comités consultatifs, ainsi qu'au personnel attaché à ces représentants, sauf si le Comité en décide autrement.

ARTICLE 7

(a) Lorsqu'il examine s'il faut autoriser une station terrienne à utiliser le secteur spatial, le Comité tient compte des caractéristiques techniques de cette station, des limitations qu'impose l'état actuel de la technologie aux possibilités d'accès multiples aux satellites, des conséquences de la distribution géographique des stations terriennes pour l'efficacité des services qui doivent être rendus par le système. Il tient compte également des avis du Comité Consultatif International Télégraphique et Téléphonique et du Comité Consultatif International des Radio-communications de l'Union Internationale des Télécommunications et des normes générales que le Comité peut établir. Même si le Comité n'a pu établir de normes générales, cela ne doit pas l'empêcher d'examiner et de donner suite à une demande d'approbation relative à l'utilisation du secteur spatial par une station terrienne.

(b) Les demandes visant à autoriser une station terrienne à utiliser le secteur spatial sont soumises au Comité par le signataire du présent Accord Spécial dans la région duquel est ou sera située cette station terrienne ou, s'il s'agit d'autres régions, par un organisme de télécommunications dûment autorisé. Chaque demande de ce genre est présentée soit individuellement, soit au nom de tous les signataires et organismes de télécommunications dûment autorisés qui désirent utiliser le secteur spatial au moyen de la station terrienne faisant l'objet de la demande.

(c) La demande d'approbation d'une station terrienne située sur le territoire d'un État dont le Gouvernement est Partie à l'Accord mais dont la propriété ou l'exploitation relèvent d'une organisation ou d'organisations autres que le signataire correspondant, est présentée par ce dernier.

ARTICLE 8

(a) Chaque organisme présentant une demande d'approbation de station terrienne, conformément à l'Article 7 du présent Accord Spécial, prend des dispositions pour l'utilisation équitable et sans discrimination de la station terrienne par tous les signataires et tous leurs organismes de télécommunications dûment autorisés devant être desservis par cette station, soit seule, soit en liaison avec d'autres stations.

(b) Dans la mesure du possible, le Comité attribue au signataire ou à l'organisme dûment autorisé une part de l'utilisation du système de satellites par chaque station terrienne approuvée conformément à l'Article 7 du présent Accord Spécial, et correspondant au potentiel total de télécommunications requis pour l'ensemble des signataires et des organismes de télécommunications dûment autorisés à être desservis par cette station terrienne.

(c) Dans l'établissement de ces attributions, le Comité tient compte des quotes-parts des signataires qui sont desservis par chaque station terrienne.

ARTICLE 9

(a) Le Comité détermine l'unité d'utilisation du système de satellites; il fixe et revise ultérieurement le taux unitaire de redevance à un niveau tel qu'en principe celui-ci soit suffisant, sur la

base de l'utilisation totale prévue du secteur spatial, pour couvrir l'amortissement et la rémunération adéquate du capital engagé dans le secteur spatial, et les dépenses prévues d'exploitation, d'entretien et de gestion du secteur spatial.

(b) Pour la fixation du taux unitaire de redevance en application des dispositions du paragraphe (a) ci-dessus, le comité fera entrer dans l'estimation des dépenses d'exploitation, d'entretien et de gestion du secteur spatial les dépenses supportées de façon directe et indirecte par la Société et correspondant à l'exercice de ses fonctions de gestion dans l'exploitation et l'entretien du secteur spatial, y compris la rémunération appropriée des services rendus par la Société, à fixer en accord entre celle-ci et le Comité.

(c) Le Comité prend toutes dispositions pour que les redevances d'attribution du système de satellites soient réglées trimestriellement à la Société. Les redevances sont calculées et payées en dollars des États-Unis, ou en devises pouvant être librement converties en dollars des États-Unis.

(d) Les éléments constitutifs du taux unitaire de redevance qui correspondent à l'amortissement et à la rémunération du capital sont portés au crédit des signataires en proportion de leurs quotes-parts. En vue d'éviter des mouvements de fonds inutiles entre les signataires et de maintenir au niveau le plus faible possible le volume des fonds détenus par la Société pour le compte des signataires, le Comité prend les mesures nécessaires pour que les fonds correspondant aux éléments susmentionnés soient, lorsqu'il y a lieu, conservés par les signataires, ou, si lesdits fonds ont été encaissés, répartis entre ceux-ci de telle façon que tous les montants portés au crédit des signataires soient effectivement réglés à ces derniers.

(e) Les autres éléments constitutifs du taux unitaire de redevance couvriront les dépenses d'exploitation, d'entretien et de gestion, ainsi que les réserves que le Comité jugera utile de constituer. Le solde subsistant après ces affectations sera réparti par la Société, en dollars des États-Unis, ou en devises pouvant être librement converties en dollars des États-Unis, parmi les signataires et en proportion de leurs quotes-parts. Si les disponibilités ne permettent pas de couvrir les dépenses d'exploitation, d'entretien et de gestion, les signataires verseront à la Société, en proportion de leurs quotes-parts, les sommes que le Comité jugera nécessaires à la couverture du déficit.

(f) Le Comité prendra les mesures appropriées pour sanctionner les retards de trois mois ou plus dans les paiements prévus au présent Article.

ARTICLE 10

(a) Tous les contrats attribués par la Société ou par tout autre signataire en vertu d'une autorisation du Comité, et relatifs à l'étude, à la mise au point et à la fourniture de matériel pour le segment spatial devront, sauf si le Comité en décide autrement, être fondés sur les réponses aux demandes de prix ou aux appels d'offres. Ces demandes de prix ou ces appels d'offres sont adressés à des personnes ou à des organisations choisies parmi celles indiquées au Comité par les signataires et qui sont qualifiées pour exécuter les travaux prévus dans le contrat proposé.

(b) Pour les contrats dont le montant est supérieur à 125,000 dollars des États-Unis, l'envoi par la Société de demandes de propositions ou d'appels d'offres devra être fait conformément aux conditions que le Comité pourra déterminer. La Société tiendra le Comité pleinement informé des décisions prises relatives à ces contrats.

(c) La Société consultera le Comité avant tout envoi de demandes de propositions et d'appels d'offres concernant les contrats d'études, de mise au point et de fourniture de matériel pour le secteur spatial dont la valeur est estimée supérieure à 500,000 dollars des États-Unis. S'il résulte, du dépouillement des réponses aux demandes de propositions et aux appels d'offres, que la Société désire placer un contrat d'un montant supérieur à 500,000 dollars des États-Unis, celle-ci devra soumettre les résultats du dépouillement et ses recommandations au Comité. L'approbation par le Comité devra être donnée avant attribution d'un tel contrat, que celui-ci soit placé par la Société en tant que gérant ou par tout autre signataire en vertu d'une autorisation du Comité.

(d) Le Comité approuvera le programme de lancement de satellites et des services associés, la source de lancement, et les arrangements relatifs aux contrats.

(e) Sauf si le Comité en dispose autrement, et sous réserve des paragraphes (c) et (d) du présent Article, tous les entrepreneurs sont choisis par la Société et tous les contrats sont passés au nom de la Société, exécutés et administrés par elle en tant que gérant.

(f) Sauf si le Comité en dispose autrement, tous les contrats et sous-contrats passés pour les travaux de conception, de mise au point et pour la fourniture de matériel destiné au secteur spatial contiennent des dispositions appropriées prévoyant que tous les renseignements, inventions et données techniques découlant directement de tout travail effectué conformément à ces contrats (à l'exclusion des renseignements, des inventions et des données techniques relatives aux lanceurs et aux lancements) sont communiqués au Comité et peuvent, aux termes des dispositions provisoires actuelles comme à ceux des dispositions définitives, être utilisés seulement pour la conception, la mise au point, la fabrication et l'utilisation de matériel et de composants destinés au secteur spatial établi au titre des présentes dispositions provisoires ou au titre des dispositions définitives qui succéderont aux dispositions provisoires, sans paiement de redevance, par chaque signataire ou par chaque personne relevant d'un signataire ou du Gouvernement qui a désigné de signataire.

(g) Sauf s'il en décide autrement, le Comité veille à ce que soient inscrites, autant que possible, dans tous les contrats passés pour les travaux de conception et de mise au point, des dispositions propres à assurer que les renseignements, inventions et données techniques appartenant à l'entrepreneur bénéficiaire des contrats et à ses sous-traitants, et qui sont directement incorporés aux travaux effectués conformément à ces contrats puissent être utilisés à des conditions justes et raisonnables par tout signataire ou toute personne relevant d'un signataire ou du Gouvernement qui a désigné ce signataire, pourvu que cette utilisation soit nécessaire et ce, dans la mesure requise pour l'exercice du droit prévu au paragraphe (f) ci-dessus.

(h) Les dispositions du présent Article ne sont pas applicables aux contrats pour la conception, la mise au point, la construction et la création du secteur spatial auxquels la Société est partie à la date de l'ouverture de l'accord à la signature. Sous réserve des dispositions de l'Article 4 (c) de cet Accord, de tels contrats seront reconnus pour raisons budgétaires par le Comité comme des obligations continues.

ARTICLE 11

Tout signataire tient les registres, archives, pièces justificatives et comptes nécessaires relatifs à toutes les dépenses pour lesquelles il est autorisé à être remboursé en vertu du présent Accord Spécial pour la conception, la mise au point, la construction, la mise en place, l'entretien et l'exploitation du secteur spatial, et les soumet à intervalles raisonnables à l'inspection des membres du Comité.

ARTICLE 12

Outre les fonctions déjà précisées au présent Accord Spécial, la Société, en sa qualité d'organe exécutif, conformément à l'Article VIII de l'Accord:

(a) prépare et soumet au Comité les programmes et budgets annuels;

(b) lui recommande le ou les types de secteur spatial à établir;

(c) prépare, dirige, organise les recherches et travaux de conception et de mise au point pour l'amélioration du secteur spatial, et y participe;

(d) exploite le secteur spatial et en assure l'entretien;

(e) fournit au Comité les renseignements demandés par tout représentant au Comité dans le but de s'acquitter de ses responsabilités en tant que tel;

(f) organise la participation de techniciens, choisis par le Comité avec l'approbation de la Société parmi les personnes désignées par les signataires, à l'examen des projets et à l'établissement des spécifications relatives au matériel destiné au secteur spatial;

(g) s'efforce d'obtenir que les renseignements, inventions et données techniques découlant directement des travaux financés en commun aux termes des contrats passés avant la date où l'Accord est ouvert à la signature soient communiqués à tout signataire et mises gratuitement à la disposition de celui-ci ou de toute personne relevant d'un signataire ou du gouvernement qui l'a désigné, en vue de la conception, de la mise au point, de la fabrication et de l'utilisation du matériel et des composants du secteur spatial.

ARTICLE 13

La Société en tant que signataire ou en tant qu'organe exécutif, non plus qu'aucun autre signataire ne sera responsable envers les autres signataires pour les dommages résultant d'une défaillance ou d'un arrêt dans le fonctionnement d'un satellite au moment du lancement ou après celui-ci, ou d'une défaillance ou d'un arrêt dans le fonctionnement de toute autre partie du secteur spatial.

ARTICLE 14

Des dispositions seront prises en vertu desquelles les différends d'ordre juridique s'élevant à propos du présent Accord Spécial ou à propos des droits et obligations des signataires, pourront, s'ils ne sont pas réglés autrement, être soumis au jugement d'un tribunal impartial à établir conformément à ces mêmes dispositions et qui tranchera ces questions conformément aux principes généraux du droit. A cette fin, un groupe d'experts juridiques, nommés par les signataires et par les signataires prévus et indiqués dans la liste annexée à l'Accord Spécial quand celui-ci a été ouvert à la signature, proposera un projet d'accord supplémentaire contenant les dispositions susvisées. Après examen du projet, les signataires concluront un Accord additionnel à cette fin dans le délai de trois mois après la date où le présent Accord Spécial est ouvert à la signature. Cet Accord additionnel s'appliquera également de façon obligatoire à tous futurs signataires du présent Accord Spécial.

ARTICLE 15

Toute proposition d'amendement au présent Accord Spécial est soumise en premier lieu au Comité. Si ce dernier en recommande l'adoption, elle entre en vigueur à l'égard de tous les signataires lorsque les notifications d'approbation auront été déposées auprès du Gouvernement des États-Unis d'Amérique par deux tiers des signataires; toutefois aucun amendement ne peut imposer à l'un quelconque des signataires, sans son consentement, d'obligations financières supplémentaires.

ARTICLE 16

Le présent Accord Spécial entrera en vigueur pour chaque signataire, au jour de sa signature, à condition que l'Accord soit déjà entré en vigueur à l'égard du Gouvernement signataire ou ayant désigné le signataire en question, ou qu'il ait été provisoirement appliqué par lui. Il restera en vigueur aussi longtemps que l'Accord.

EN FOI DE QUOI les soussignés dûment autorisés ont apposé leur signature au présent Accord Spécial.

FAIT à Washington le vingt août 1964, en langues anglaise et française, les deux textes faisant également foi, en un seul original qui sera déposé dans les archives du Gouvernement des États-Unis d'Amérique, lequel en transmettra une copie certifiée conforme à chaque signataire ou gouvernement adhérent et au gouvernement de chaque État membre de l'Union Internationale des Télécommunications.

ANNEXE

LISTE DES SIGNATAIRES PRÉVUS DE L'ACCORD SPÉCIAL

Pays	*Nom du signataire*	*Quote-part*
Allemagne	Deutsche Bundespost	6,1
Australie	Overseas Telecommunications Commission (Australia)	2,75
Autriche	Bundesministerium für Verkehr und Elektrizitätswirtschaft, Generaldirektion für die Postund Telegraphenverwaltung	0,2
Belgique	Régie des Télégraphes et Téléphones	1,1
Canada	Canadian Overseas Telecommunication Corporation	3,75
Danemark	Generaldirektoratet for Post og Telegrafvesenet	0,4
Espagne	Gouvemement de l'État Espagnol	1,1
États-Unis D'Amérique	Communications Satellite Corporation	61,0
État de la Cité du Vatican	Gouvemement de la Cité du Vatican	0,05
France	Gouvemement de la République Française	6,1
Irlande	An Roinn Poist Agus Telegrafa	0,35
Italie	à désigner	2,2
Japon	Kokusai Denshin Denwa Company Ltd.	2,0
Norvège	Telegrafstyret	0,4
Pays-Bas	Gouvemement du Royaume des Pays-Bas	1,0
Portugal	Administração Geral dos Correios, Telégrafos e Telefones	0,4
Royaume-Uni	Her Britannic Majesty's Postmaster General	8,4
Suède	Kungl. Telestyrelsen	0,7
Suisse	Direction Générale des PTT	2,0

SECTION 4

CHURCHILL RESEARCH RANGE

4.1 EXCHANGE OF NOTES WITH ANNEX CANADA-US 11 JUNE 1965

EXCHANGES OF NOTES (JUNE 11, 1965) BETWEEN THE GOVERNMENT OF CANADA AND THE GOVERNMENT OF THE UNITED STATES OF AMERICA CONCERNING THE CONTINUED JOINT USE, OPERATION AND MAINTENANCE OF THE CHURCHILL RESEARCH RANGE AT FORT CHURCHILL, MANITOBA.

The Secretary of State for External Affairs to the Chargé d'Affaires a.i. of the United States Embassy in Canada.

DEPARTMENT OF EXTERNAL AFFAIRS

No. 59

Ottawa, June 11, 1965.

Sir:

I have the honour to refer to recent discussions between representatives of the Governments of Canada and the United States of America concerning the future use, operation and maintenance of the Research Range at Fort Churchill, Manitoba, after the expiry on June 13, 1965 of the present agreement of June 14, 1960[1] concerning the utilization of the existing Upper Atmosphere Research Facilities at Fort Churchill, Manitoba.

These discussions indicated that the mutual interest of Canada and the United States would be served by the continued availability of the Range, and that the Range should be operated and maintained by the Canadian Government for the joint use of Canada and the United States. To facilitate the orderly transfer of responsibility for the Range to the Canadian Government, however, it is proposed that the present agreement be extended until and including December 31, 1965 and that on January 1, 1966 a new Agreement come into force.

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[1] Canada Treaty Series 1960 No. 12 Recueil des Traités

During the period July 1 until and including December 31, 1965 the National Research Council of Canada is designated as the appropriate authority of the Canadian Government and it is understood that the Department of Defense (United States Air Force) is the appropriate authority of the United States Government to deal with the Range. The National Research Council will arrange with the Canadian Departments of Public Works and of Transport for the continuation of the support functions previously supplied to the Range. The equipment associated with the functions previously performed by the Northern Laboratory of the Defence Research Board, and the air surveillance radar previously operated by the Canadian Department of Public Works shall be made available to the United States Department of Defense (United States Air Force) during this interim period. During the period July 1 until and including December 31, 1965 the Canadian Government undertakes, subject to the conditions set out in the Annex hereto, to contribute towards the costs of the Range an amount equal to one half of the agreed costs of operation, maintenance and support.

I propose that if the foregoing is agreeable to your Government, this Note and your Note in reply to that effect shall constitute an Agreement regarding this subject between our two Governments, which shall enter into force on June 14, 1965.

Accept, Sir, the renewed assurances of my high consideration.

PAUL MARTIN

The Honourable Joseph W. Scott,
Chargé d'Affaires a.i.,
Embassy of the United States of America,
Ottawa.

ANNEX

The Canadian Government undertakes to pay one-half of the costs incurred in the operation, maintenance and support of the Range, that is to say:

(1) Costs agreed upon by the National Research Council and the Department of Defense (United States Air Force) which are incurred at Fort Churchill by the National Research Council and by other Canadian agencies in supporting the Range;

(2) Those costs assumed by the Department of Defense (United States Air Force)

(a) In continuation of the functions previously performed by

the Defence Research Board of Canada through its Northern Laboratory, and

(b) In maintaining on air surveillance capability for range safety purposes previously provided by the Canadian Department of Public Works; and

(3) Costs previously borne by the Department of Defense (United States Air Force) for operation and maintenance of the Range, but

(a) Excluding those costs attributable to the Range incurred at higher headquarters of both Governments' authorities and of other Governmental agencies; and

(b) Excluding, with respect to persons employed by an operating contractor on or after July 1, 1965, those costs that reflect any bonuses or benefits paid by such contractor to or on behalf of United States citizens or residents which are not paid to Canadian citizens resident in Canada.

4.2 EXCHANGE OF NOTES US-CANADA 11 JUNE 1965

The Chargé d'Affaires, a.i. of the United States Embassy in Canada to the Secretary of State for External Affairs.

EMBASSY OF THE UNITED STATES OF AMERICA

Ottawa, June 11, 1965

No. 257

Sir:

I have the honor to acknowledge receipt of your Note No. 59 dated June 11, 1965 and the annex thereto, covering the future joint use, operation, maintenance and support of the Research Range at Fort Churchill, Manitoba, Canada.

I have the further honor to inform you that the proposed terms and conditions set forth in your Note and the annex thereto concerning the operation, maintenance, support and further joint use of the Range are acceptable to my Government. My reply and your Note and the annex thereto under reference shall together constitute an agreement between our two Governments regarding this matter, which shall enter into force on June 14, 1965 and which shall remain in force until December 31, 1965.

Accept, Sir, the renewed assurances of my highest consideration.

JOSEPH W. SCOTT

The Honorable
Paul Martin,
Secretary of State for External Affairs,
Ottawa.

4.3 EXCHANGE OF NOTES WITH ANNEX CANADA-US 11 JUNE 1965

The Secretary of State for External Affairs to the Chargé d'Affaires a.i. of the United States Embassy in Canada.

DEPARTMENT OF EXTERNAL AFFAIRS

Ottawa, June 11, 1965.

No. 60

Sir:

I have the honour to refer to discussions which have taken place between representatives of the Governments of Canada and the United States of America concerning new arrangements whereby the Churchill Research Range might continue in operation for a further period following the expiration, in June 1965, of the Agreement of June 14, 1960 concerning the utilization of the existing Upper Atmosphere Research Facilities at Fort Churchill, Manitoba.

These discussions revealed that the mutual interests of Canada and the United States would be advanced by the continuing availability of the Range. I therefore have the honour to propose the conclusion of an Agreement between our two Governments to provide for the operation, maintenance and support and further joint use of the Churchill Research Range in accordance with the terms and conditions set forth in the Annex of this Note. This Agreement would supersede the Agreement signed at Ottawa, on June 14, 1960, as extended, which will expire on December 31, 1965.

If this proposal meets with the approval of the Government of the United States, I also have the honour to propose that this Note, together with the Annex hereto, and your Note in reply to that effect,

shall constitute an Agreement on this matter between our two Governments, which shall enter into force on January 1, 1966 and remain in effect until June 30, 1970 and for such additional periods as may be mutually agreed. I further propose that either Government may, after consulting with the other Government, and upon giving of suitable advance notice in writing of its intention, terminate the Agreement at any time. Each Government agrees that in determining the amount of such advance notice which it gives to the other Government, it shall be guided by consideration of the time required by the other Government to make alternative arrangements for conducting its rocket research programme.

Accept, Sir, the renewed assurances of my high consideration.

PAUL MARTIN

The Honourable Joseph W. Scott,
Chargé d'Affaires a.i.,
Embassy of the United States of America,
Ottawa.

ANNEX

TERMS AND CONDITIONS COVERING THE USE, OPERATION, MAINTENANCE AND SUPPORT OF THE CHURCHILL RESEARCH RANGE AT FORT CHURCHILL, MANITOBA

(Hereinafter unless the context otherwise requires, "Canada" means the Government of Canada, "United States" means the Government of the United States of America, and "Range" means the Churchill research range and related installations.)

1. *Canadian Government Responsibility*

As of January 1, 1966, the Range shall be operated and maintained by Canada for the joint use of Canada and the United States.

2. *Co-operating Agencies*

Co-operating Agencies shall be designated by each Government to carry out, in consultation, the provisions of this Agreement For Canada the Co-operating Agency shall be the National Research Council of Canada (hereinafter referred to as NRC). For the United States the Co-operating Agency shall be the National Aeronautics and Space Administration (hereinafter referred to as NASA). Either Government may change its Co-operating Agency by means of notice in writing to the other Government.

3. *Joint Range Policy Committee*

A Joint Range Policy Committee (JRPC) shall be established to consist of representatives designated by the Co-operating Agencies. The respective senior representatives of the Co-operating Agencies shall be co-chairmen of the Committee with each presiding at alternate meetings. Decisions of the Committee shall be made by the two co-chairmen after full discussion by all members of the Committee. The Co-operating Agencies in consultation shall have the power to fix the size of the Committee, which shall consist initially of eight representatives including four persons from each country, to form subcommittees and to determine their terms of reference. The powers and functions of the Committee shall be as follows:

(a) To determine, in conformity with the scientific programs of the respective Co-operating Agencies, the level of activities to be conducted in terms of the number of launchings at and utilization of the Range.

(b) To determine annually the budget for the operation and maintenance of the Range.

(c) To determine, as necessary, adjustments of the respective Government's financial contributions to the operating budget on an equitable basis.

(d) To determine use of the Range by a third country or its nationals sponsored by a Co-operating Agency, taking into consideration the views of both Governments and the availability of the Range. Any final decision as to whether a particular third country or its nationals may use or have access to the Range shall rest with Canada. However, the United States reserves the right to withhold approval of the use of United States equipment including the equipment, materials, supplies, goods and other property specified in paragraph 4 (b) herein below, by or on behalf of any such third country.

(e) To determine whether and under what conditions studies other than rocket-borne experiments, such as those referred to in paragraph 4 (f) below, may be carried out at the range.

(f) To consider and decide on:

(i) developments involving expansion of the Range or requiring acquisition of major items of equipment;

(ii) replacements of major items of equipment and facilities;

(iii) modification of any United States equipment or property made available for operation and maintenance of the Range in accordance with provisions of paragraph 4 below; and

(iv) allocation of the financial charges for the foregoing.

(g) By agreement of the co-chairmen, to consider and decide on any other matters relating to the operation of the Range.

4. *Operation, Maintenance and Use*

(a) The Range shall be operated and maintained by Canada through its Co-operating Agency for the joint use of the United States and Canada to conduct scientific activities. The operation and maintenance of the Range may be performed by qualified contractors of either country.

(b) The United States will make available for the joint use of the United States and Canada equipment, materials, supplies, goods and other property currently at the Range and necessary for its continued operation, in accordance with an agreed inventory. Modification of any United States equipment or property made available for operation and maintenance of the Range shall require the approval of the JRPC.

(c) Ownership and right of disposal of such equipment, materials, supplies, goods and other property and any other removable property subsequently brought into or purchased in Canada by the United States or by contractors on its behalf, including readily demountable structures, shall remain in the United States. The United States shall have the right to dispose of, or remove, all such property, provided that the removal or disposal shall not impair the operation of any installation the discontinuance of which has not been determined by the JRPC.

(d) The Canadian Co-operating Agency, subject to the provisions of paragraph 5 below, shall be solely responsible for the maintenance, operation, protection and preservation of the Range, including all United States equipment; for the replacing of parts and supplies arising from normal attrition; and for minor improvements.

(e) The United States will, to the extent feasible and subject to the provisions of paragraph 5 below, make available through the United States Co-operating Agency parts, supplies and services from United States resources as may be mutually agreed.

(f) Although the primary function of the Range shall be the launching of rocket-borne experiments, the availability of scientific measurement apparatus at the Range will allow other studies including ground-based and balloon-borne experiments. Such studies may be carried out by and for scientists of either country or a third country, subject to decision by the JRPC. The JRPC shall also determine the necessary controls to prevent interference with the primary function of the Range and to apportion or to arrange recovery of the cost of such programme.

(g) The Range shall continue to be made available for launching meteorological rockets furnished by the United States Air Force, provided that these launchings do not significantly affect the costs of operating and maintaining the Range for the purpose described in paragraph 4 (a) above. Also, this use of the Range shall not be taken into account under paragraph 3 (c) above in calculating the relative use made of the Range by the two countries. The Range may be made available for similar use by or on behalf of other weather agencies; proposals for such use shall be considered by the JRPC in accordance with the provisions of paragraph 3 above.

5. *Financial Arrangements*

(a) Subject to the availability of funds the costs agreed upon by the JRPC for the operation, maintenance and support of the Range shall be shared on an equitable basis by the United States and Canada, pursuant to detailed financial arrangements concluded between the Co-operating Agencies. It is contemplated that initially these costs will total approximately U.S. $4,000,000 (four million) annually, and that each Government will contribute half of such costs. It is also contemplated that the financial contributions of the respective Governments to the annual budget may be adjusted periodically as determined by the JRPC in accordance with paragraph 3 (c) above.

(b) Developments involving expansion of the Range or requiring acquisition of major items of equipment or replacement of major items of equipment or facilities shall be separately

financed under arrangements to be determined by the JRPC under paragraph 3 above.

6. *Definition of term "United States personnel"*

For the purpose of this Agreement, the term "United States personnel" shall mean:

(a) civilian personnel (including persons who are not United States citizens) engaged in or connected with United States activities on the Range but excluding

(i) Canadian citizens and persons ordinarily resident in Canada, and

(ii) personnel employed by a contractor engaged by the Canadian Co-operating Agency for the operation and maintenance of the Range; and

(b) members of the United States "force", "civilian component" and their "dependants" as defined in Article I of the North Atlantic Treaty Status of Forces Agreement signed on June 19, 1951.

7. *Canadian Immigration and Customs Regulations*

Except as otherwise provided, the direct entry of United States personnel into Canada shall be in accordance with Canadian customs and immigration procedures which shall be administered by local Canadian officials designated by Canada.

Canada shall take the necessary steps to facilitate the admission into, and the departure from, the territory of Canada of United States personnel. The United States, at the request of Canada, will assist in arranging for the departure from Canada of any such personnel without expense to Canada.

8. *Taxation*

(a) Canada shall grant relief to the United States from all federal taxes and customs duties on materials and equipment to be used in the construction, maintenance or operation of the Range, provided that it is administratively possible and economical to determine the amount of taxes and duties applied to such equipment and materials. Such relief shall be granted on a proportionate basis either directly or by way of rebate of a part of the United States financial contribution referred to in paragraph 5 (a) above. In addition, Canada shall grant remission of customs duties and federal excise taxes on goods imported by or on behalf of the United States specifically for its own use at the Range and of federal sales and excise taxes on goods purchased by or on behalf of the United States in Canada which are to be used exclusively be the United States at the Range. Canada shall also grant refunds by way of drawback of the customs duty paid on goods imported by Canadian manufacturers specifically for the exclusive use of the United States at the Range.

(b) The personal effects and goods of United States personnel shall be brought into Canada free of import duties and taxes, provided that, except as authorized by the appropriate Canadian authorities, such personal effects and goods may not be disposed of in Canada by way of sale or gift or otherwise.

(c) Income derived by United States personnel from rendering services to the United States in Canada shall be deemed not to have been derived in Canada and shall be exempt from taxation in Canada. Such personnel shall not be subject to Canadian tax in respect of income derived from sources outside of Canada.

(d) Where the legal incidence of any form of taxation in Canada depends upon residence or domicile, periods during which United States personnel are in Canada shall not be considered as periods of residence therein, or as creating a change of residence or domicile for the purposes of such taxation.

(e) Personal property which is situated in Canada solely because the United States personnel are in Canada shall, in respect of the holding by, transfer by reason of death, or transfer to or by such personnel be exempt from taxation under the laws of Canada relating to estate and gift duty.

9. *Liability of Third Parties in Case of Accident*

In case of an accident arising in connection with the operation of the Range, responsibility to third parties shall be determined in accordance with Canadian law. Where, as a result of such determination, the operator of the Range is found liable, the Canadian Co-operating Agency shall bear the cost thereof.

10. *Claims Against the United States*

(a) Claims for damage to property or injury to persons arising from acts or omissions of United States civilian personnel, who are employed by or directly connected with NASA, may be considered and settled in accordance with the provisions

of Section 203(b) (13) of the United States National Aeronautics and Space Act (42 U.S.C. Sec. 2473), and as it may be amended.

(b) Claims for damage to property or injury to persons arising from acts or omissions of members of the United States "force" as defined in paragraph 6 (b) above will be considered and settled in accordance with Article VIII of the North Atlantic Treaty Status of Forces Agreement, signed in London on June 19, 1951.

(c) In the case of other claims against the United States arising from activities at the Range, the United States may also offer to settle these in accordance with applicable provisions of United States law. If any such offers are acceptable, the United States may so settle them.

(c) No liability shall attach to either the United States or Canada based solely on title in the equipment and facilities at the Range.

11. *Status of Forces*

The United States may assign military personnel to the Range in such numbers as may be agreed upon from time to time by the Co-operating Agencies. In such cases, the North Atlantic Treaty Status of Forces Agreement, signed in London on June 19, 1951, shall apply.

12. *Surplus Property*

The disposal in Canada of excess equipment, property, materials and supplies to which the United States has retained title shall be carried out in accordance with the provisions of the exchange of notes of August 28 and September 1, 1961, between the Secretary of State for External Affairs and the United States Ambassador in Canada. Where items of equipment or new and additional facilities have been acquired or provided by special agreements, the residual value, if any, of such property, shall be disbursed *pro rata* in accordance with the amounts contributed by each party for its acquisition, unless otherwise agreed.

13. *Safety*

In establishing operational procedures, the utmost precaution shall be taken to ensure that objects launched from the Range do not fall in populated areas and that they do not constitute a hazard to aviation or shipping. Range safety requirements and control measures established by the appropriate Canadian authorities shall be observed.

14. *Data Exchange*

The scientific data derived by each Government from the conduct of activities pursuant to this Agreement shall be made available on request within a reasonable period of time to the Co-operating Agency of the other Government, provided that the normal protection is given to the interests of prime experimenters. Scientific data will also be made available to the international scientific community, subject to the protection of the experimenters' rights.

15. *Information*

The public release of information relating to operations under this Agreement will, unless otherwise determined by the JRPC be the subject of prior consultation and agreement by the Co-operating Agencies.

16. *Supplementary Agreements and Administrative Arrangements*

The Co-operating Agencies designated by the two Governments are authorized to conclude supplementary agreements and administrative arrangements from time to time in implementation of this Agreement.

4.4 EXCHANGE OF NOTES US-CANADA 11 JUNE 1965

The Charge d'Affaires, a.i. of the United States Embassy in Canada to the Secretary of State for External Affairs.

EMBASSY OF THE UNITED STATES OF AMERICA

No. 258

Ottawa, June 11, 1965

Sir:

I have the honor to acknowledge receipt of your Note No. 60 dated June 11, 1965 and the annex thereto, concerning the future joint use, operation, maintenance and support of the Research Range at Fort Churchill, Manitoba, Canada.

I have the further honor to inform you that the proposed terms and conditions set forth in your Note and the annex thereto concerning the operation, maintenance, support and further joint use of the Range are acceptable to my Government. My reply and your Note and the annex thereto under reference shall together constitute an agreement between our two Governments regarding this matter, which shall enter into force on January 1, 1966 and which shall remain in force until June

30, 1970 in accordance with the terms and conditions concerning duration as stated in your Note.

Accept, Sir, the renewed assurances of my highest consideration.

JOSEPH W. SCOTT

The Honorable
Paul Martin,
Secretary of State for External Affairs,
Ottawa.

Part III

HARP–McGILL

CHAPTER 1

INTRODUCTION

HARP-McGill is a major Canadian program, operated by the Space Research Institute (SRI) of McGill University, to exploit the use of large-caliber guns for launching high-altitude and orbital payloads. HARP stands for High Altitude Research Program, and Harp-McGill relates to that part of HARP which is jointly funded by Canada and the US. HARP is, however, very closely integrated with HARP-McGill; and in this report no distinction will be made between the 2 programs (except where funding is involved), and the Program will be referred to simply as HARP.

HARP activities encompass engineering development of launching techniques and vehicle design, scientific measurements using HARP vehicles, and establishment and improvement of range, launching and laboratory facilities. The Program evolves from 2 basic techniques for reaching extreme altitudes: gun-launching of a ballistic glide vehicle which coasts to its peak altitude after leaving the gun barrel; and gun-launching of a single- or multi-stage rocket wherein the gun replaces the usual first rocket stage, and imparts to the rocket a significant portion of the payload velocity to be achieved for the mission, in a fixed and known direction.

There are several advantages of this technique over conventional rockets; the primary ones are:

EFFICIENCY: The projectile muzzle velocity is achieved more efficiently than with conventional rockets, because very little energy is expended in accelerating propellant which is later burned; that is, the most efficient conventional rocket is one where all of the propellant is burned instantaneously (neglecting drag).

FUEL ECONOMY: Due to the containment of the gun barrel, the powder or explosives used to accelerate the projectile are far cheaper per unit of impulse than conventional rocket motors.

ACCURACY: The vector direction of the projectile as it leaves the muzzle can be specified with considerable precision, due to the fixed geometry of the gun barrel. This degree of predictability and control of velocity vector can be achieved with conventional rockets only by using relatively complex guidance and control systems, which are further complicated by the need for thrust-vector control in the early launch phase where aerodynamic forces are of insufficient magnitude to be used for control purposes.

There are 2 primary disadvantages of this technique over conventional rockets:

ACCELERATION: The vehicles, and all of the components therein, must be capable of withstanding the high peak accelerations experienced in the gun barrel. These accelerations are typically 10,000 g, (that is, 10,000 times the acceleration due to to gravity) but can vary from a few thousand g up to many 10's of thousands depending on gun caliber and vehicle weight. This acceleration is impulsive in character, and components contained within the vehicle may also experience relatively high impulsive accelerations in the opposite direction upon leaving the barrel due to the relaxation of compressive strains in the vehicle structure. These high impulsive accelerations constitute perhaps the major objection to the use of guns for launching useful payloads.

PAYLOAD DIMENSION: The ability of gun-launched ballistic glide vehicles to reach extreme altitudes improves as the ballistic coefficient is increased. The ballistic coefficient relates to the mass/drag ratio of the projectile, and, for a given gun launcher, the desire to reach extreme altitude is an inducement toward the use of sub-caliber, high-density vehicles which can set severe limitations on payload dimensions. Gun-launched rocket vehicles, on the other hand, are not affected by this factor, but obviously are restricted in dimension by the muzzle diameter.

In spite of these disadvantages, gun-launched vehicles have been fired in large numbers; the limitations imposed by acceleration, although still severely restricting, are slowly being overcome in a variety of instruments, components and mechanisms.

The vehicles developed in HARP are called Martlets; Martlets 1 and 2 are ballistic glide vehicles, and Martlets 3 and 4 are rocket vehicles. The major gun installation for vertical firings is located in Barbados, where a 16.4-inch-bore gun is installed with an extended barrel length of 120 ft. Further installations are located at Highwater, Quebec. HARP-US operates facilities at Yuma, Arizona, Wallops Station, Virginia, White Sands Missile Range, New Mexico, and BRL in Maryland.

CHAPTER 2

HISTORY[1,2]

As a result of discussions with G.V. Bull at CARDE in the fall of 1959, BRL initiated a study on the use of guns for upper-atmosphere research. In 1960 BRL started the development of a 5–inch gun probe system, and by the summer of 1961 had demonstrated both the altitude capability and the low dispersion of apogee and impact achievable with such a system.

In late 1961 Dr Bull had moved to McGill and initiated plans to install a 16-inch gun system in Barbados. USN supplied a surplus 16-inch gun barrel to McGill through an ONR contract with the University of Toronto. In January 1962 BRL initiated a contract with McGill which allowed for the transfer of guns, powder and surplus equipment. BRL also obtained a second 16-inch barrel from USN for use by McGill. Other logistic support was provided by BRL over the next 2 years.

During the summer of 1962 the US Army transported the range equipment, including the 2 140-ton barrels and 90 tons of carriage parts to the launching site in Barbados. By January 1963 the 16-inch gun installation was completed in Barbados with 2 test slugs and 2 Martlet 1 vehicles fired successfully. Maximum altitude attained was 73,000 ft.

In the spring of 1963 BRL extended McGill's program to include feasibility tests of gun-boosted rockets. By June 1963 a second firing series was completed in Barbados, involving several proof slugs and the successful launching of 3 Martlet 2's. Maximum altitude was 340,000 ft. In September 1963 2 of 4 gun-boosted rockets, Martlet 3's, were successfully launched.

[1] Report of the March 1965 Test Firing Series, Project HARP, H.T. Lockert, SRI-H-R-9, July 1965.

[2] Brief from the Director, SRI

In January 1964 8 Martlet 2 glide vehicles were successfully launched from Barbados with sodium and TMA payloads for wind measurements. In addition, 2 Martlet 3 gun-boosted rockets were launched with 250-mc telemetry which revealed the need for structural re-design of the vehicle.

July 1964 marked the start of Canadian Government financial participation, and in that month 23 Martlet 2's were fired from Barbados, though with only 13 successful launches due to propellant difficulties.

Five good TMA trails were obtained by cameras on Barbados, St. Vincent, St. Lucia and Grenada. Ten development rocket firings revealed problems which later were shown to be propellant failures. Six out of 7 telemetry transmitters operated to yield signals from sun-seekers and pressure switches. Late in 1964 a 22-ft muzzle extension was placed on the Barbados gun, but it failed at the ninth shot. A 51-ft extension was then planned. By March 1965 the Barbados gun extension was attached, a new hydraulic elevation system was installed, and 14 shots were fired, attaining a peak altitude of 430,000 ft. Five TMA trails, one fiberglass-body rocket and one steel-case rocket were successfully fired.

In August 1964 SRI came into being and inherited HARP and its staff from the Department of Mechanical Engineering, which had been operating HARP previously. SRI expanded to accomplish the added tasks created by Canadian Government financial support. The total combined Canadian-US support of HARP-McGill is at the level of about $2,000,000 per annum for the 3-year period 1 July 1964 to 30 June 1967.

Late in 1964 the main field laboratory was started at a 10,000-acre plot in Highwater, Quebec, where machine shops and horizontal-firing facilities were established. In 1965 the machine shops were expanded and installation of an extended 110-ft long, 16-inch gun was started. This gun was operational by February 1966 for horizontal test firings.

HARP's scientific activities were started during 1965 and have centered on the objective of relating mass transport in the ionosphere (wind shears in the E and F layers) to ionospheric drift measurements (motion of the sporadic E layers), using chemical releases from Martlet 2's. In addition, the studies incorporated composite and thermodynamic simultaneous measurements to investigate other correlative phenomena. Since March 1965 between 100 and 150 flights have been made yearly of the operational Martlet 2 vehicle. An altitude of 165 km was attained in October 1966 by a Martlet 2C, fired from the 16-inch gun at Yuma, Arizona.

In 1965 optimization of the ballistic glide vehicle design was undertaken, resulting in the firing of 3 Martlet 2G's from the Highwater horizontal 16-inch gun. This vehicle is a considerable improvement over the operational Martlet 2C in terms of payload, size and weight.

In late 1965 the gun-launched rocket design had progressed to full-bore vehicles and fibreglass bodies with flip-out fins. Horizontal firing of the Martlet 3E full-bore 7-inch vehicle were carried out at Nicolet, Highwater and BRL in 1966. Also 4 horizontal firings of the Martlet 3D full-bore 16-inch vehicle were carried out at Highwater in April 1966, representing the first stage of the Martlet 4A orbital capability vehicle. This contains about 1,600 lb of solid rocket propellant, and is the largest vehicle fired so far in HARP.

Currently, design and development work is under way on the Martlet 2G-1 vehicle, which carries a 300-lb rocket payload. This will be used for re-entry tests, but a 2-stage rocket version will have the capability of orbiting a 15-lb payload. First horizontal firings are being scheduled at Highwater in early 1967; orbital flights may be carried out in mid-1967.

The major large-vehicle development now under way is the Martlet 4; this is a 3-stage gun-launched rocket with 150-lb 300- to 400-nautical mile orbit capability in its most advanced version (all liquid rocket stages). Other current activities include special test programs and other applications of the gun-launching technique.

Chapter 3

ENGINEERING PROGRAMS

3.1 BALLISTIC GLIDE VEHICLES[1,2,3]

The initial ballistic glide vehicles were fired by BRL, starting in June 1961. By December 1962 an altitude of 215,000 ft had been achieved with a 5-inch system. The first McGill vehicles, designated the Martlet 1A and 1B, were fired from the 16-inch gun in Barbados in January 1963, and achieved a maximum altitude of 73,000 ft.

The Martlet 1 vehicle was used to develop sabot-launching techniques for a large gun, and consisted of an 8-inch diameter after-body, an ogive nose, and cruciform fins. The projectile weighed 470 lb and, including the wooden pusher sabot, the all-up shot weight was 668 lb.

In designing for maximum altitude, maximum muzzle velocity and maximum ballistic coefficient (mass/drag ratio) must be achieved. For a given all-up shot weight, the parameters that affect muzzle velocity for any given bore diameter are: barrel length, maximum allowable peak pressure, powder-burning and ignition characteristics, and charge web size and weight. The ballistic coefficient increases with decreasing projectile diameter; this is the reason for using sub-caliber projectiles.

The original 16-inch gun was designed to fire 3,000-lb shells at muzzle velocities of 2,800 ft per sec; however, velocities as high as 6,000 ft per sec can be obtained for shot weights of the order of 400 lb. Extension of the gun barrel to its optimum length for this lighter shot weight could increase the muzzle velocity to nearly 8,000 ft per sec.

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[1] Development of Gun Launched Vertical Probes for Upper Atmospheric Studies, G.V. Bull, CASI Journal, October 1964.

[2] Orbit Injection Control for HARP, H.A. Raymond, CASI Journal, May 1965.

[3] The Development of Large Bore Gun Launched Rockets, F.W. Eyre, CASI Journal, April 1966.

The Martlet 1 vehicles were far from optimum. The firings did, however, help to prove sabot-launching techniques and encouraged the development of more nearly optimum designs, the Martlet 2 series.

The Martlet 2 program is a progression of development glide vehicles and firings leading to the optimization of a gun-vehicle design for given payload-altitude combinations. This led to an operational system which is now firing about 100 to 150 shots a year.

The Martlet 2A was first fired in June 1963. This vehicle was designed to carry a useful payload, which initially consisted of bulk materials such as gases and liquids which could be expelled in flight, thereby releasing a trail at some predetermined time after launch. The Martlet 2A is a 5-inch diameter projectile varying in length from 49 in to 57 in, depending on its payload, and weighing about 180 lb. The sabot is of the rear pusher type, using an aluminum pusher plate with a forward steel insert to spread the load, and 4 wooden petal arms to position the airframe in the barrel during launch. The all-up shot weight for Martlet 2A is about 410 lb. A typical payload consisted of 5 lb of a mixture of TMA (80%) and triethyl-aluminum (20%) released in the trail at some predetermined time after launch. To effect proper ejection, a piston with pressurized nitrogen was used. Nearly 50 Martlet 2A's were fired over the period June 1963 to March 1965, and altitudes of 115 km were achieved.

The progression from Martlet 2A through 2B to 2C was to accommodate larger chemical payloads and continue optimization of the vehicle-gun design. The Barbados 16-inch barrel was lengthened to 120 ft in early 1965, providing higher muzzle velocities for the Martlet 2's, and the workhorse of the series became the Martlet 2C vehicle. This vehicle weighs 185 lb and the all-up shot weight is about 400 lb. Martlet 2C is designed to attain altitudes of 200 km with the extended 16-inch gun, and can carry a payload of 30 lb of TMA. Currently about 100 to 150 Martlet 2C's are being fired per annum and in October 1966 an altitude of 165 km was attained with the Yuma gun using a non-optimum powder charge.

The sabot weight of Martlet 2C is of the order of 215 lb, which is a large percentage of the all-up shot weight. Further development of the vehicle has been devoted to the reduction of sabot weight with an attendant increase in vehicle and payload weight while achieving the same trajectory. The Martlet 2D was an attempt at this, in which the sabot consisted of a pusher plate and a front-end bore rider. Although this was unsuccessful, it led the way to the Martlet 2G vehicle, which is about to replace the 2C in the operational role.

Martlet 2G uses a center sabot, along the lines of the BRL 5-inch vehicle. This tends to yield very small sabot weights in relation to the vehicle weight, but exposes the rear of the vehicle to hot gun gases. This latter aspect may cause some limitations to the nature of the payload in the case of rearward-looking sensors.

The Martlet 2G vehicle weighs 280 to 300 lb, with a 100-lb center sabot. It is 7 in in diameter and 89 in long, and has an internal cavity for payload 5 in in diameter and 55 in long. Its altitude capability is designed to be 200 km. A typical payload would consist of 25 lb of TMA, 10 lb of valving, 10 lb of pressurization and 5 lb of telemetry, making up a 50-lb payload. Design was started in January 1966, and 3 were fired at the horizontal Highwater range in July 1966.

Four other vehicles are involved in the Martlet 2 series. The Martlet 2E is a test vehicle for the Martlet 4 guidance and control system. This is much like a Martlet 2C, but is shorter, with an 8-inch base diameter. Three have been fired at Highwater to prove the vehicle, and work is proceeding at a very low level, due to funding limitations, to install the payload. Martlet 2F was only a design study to achieve extremely high altitudes with a small vehicle launched at a very high muzzle velocity (8,000 ft per sec). Martlet 2H is at the other end of the spectrum for launching a very heavy vehicle to relatively low altitudes. The US Atomic Energy Commission is interested in launching about one ton of special powder to an altitude of 50 km. Martlet 2H is a 2,500-lb full-bore projectile which is being designed to accomplish this task.

Finally, in the Martlet 2 series, the Martlet 2G-1[1,2] is currently being constructed at Highwater for firing in January 1967. This vehicle is to be used for re-entry purposes (as a target for Nike-X) and contains a rocket payload. It has a steel shell and is 11.35 in in diameter, 169 in long, weighs 1,100 lb, uses a center sabot, and possesses a relatively high ballistic coefficient (8,000 lb per sq ft). It contains a 350- to 400-lb Aerojet rocket motor, 10 in in diameter, which coasts to an altitude of about 100 nautical miles. It also contains a simple guidance and control system which rotates the vehicle to re-entry attitudes prior to ignition of the rocket motor. The rocket accelerates a 50-lb payload to re-entry velocities as high as 25,000 ft per sec.

[1] Orbital and High Altitude Probing Potential of Gun Launched Rockets, G.V. Bull, D. Lyster and G.V. Parkinson, R-SRI-H-R-13, October 1966.

[2] A Gun Launch Target Placement System, G.V. Bull, B. Aikenhead, L. Palacio and D. Lyster, SRI-2-TN-4, August 1966.

The Martlet 2G-1 vehicle also possesses orbital capability. A 2-stage version of the Aerojet rocket is capable of placing about 16 lb into a low earth orbit, (203-nautical-mile apogee, 96-nautical-mile perigee) for a muzzle velocity of 8,000 ft per sec. This may be accomplished in 1977. As a high-altitude probe, the Martlet 2G-1 could send 30 lb to a height of 2,500 nautical miles, or 100 lb to 600 nautical miles.

3.2 GUN-LAUNCHED ROCKET VEHICLES[1,2,3,4]

Gun-firing artillery rockets have been developed extensively since World War II and normally must withstand barrel acceleration loads of the order of 30,000 g along with the rotational loads superimposed by shell spin. The performance of this type of rocket is of only marginal interest in the vertical-probe application where non-spinning (from a stress viewpoint) vehicles are flown at acceleration levels of less than 10,000 g and relatively large rocket motors are desired with high mass fractions.

About 25% of HARP has been devoted to gun-launched rockets. In May 1963 work was started on the Martlet 3A rocket-assist vehicle as part of HARP. The original objective of this activity was the development of a 16-inch gun-launched probe which would carry some 40 lb of payload to altitudes in the 500-km range.

The principal engineering problem is the method of supporting the rocket grain so that it can withstand launch accelerations. Primarily, these techniques center around end-loading, shear loading and hydrostatic containment. Whereas a combination of end and shear loading probably results in the highest mass fractions, the early Martlet 3 vehicles used shear loading for simplicity, in spite of the inherently heavy case walls needed to support the grain acceleration loading (and resulting in a low mass fraction).

The Martlet 3A was an aluminum 7¼-inch diameter, 72-inch long sub-caliber vehicle containing a 6-inch diameter, 40-inch long, double-base propellant rocket motor to be launched by the 16-inch Barbados gun. During September 1963 the first successful round was

[1] Development of Gun Launched Vertical Probes for Upper Atmospheric Studies, G.V. Bull, CASI Journal, October 1964.

[2] The Development of Large Bore Gun Launched Rockets, F.W. Eyre, CASI Journal, April 1966.

[3] Brief from the Director, SRI.

[4] Orbital and High Altitude Probing Potential of Gun Launched Rockets, G.V. Bull, D. Lyster and G.V. Parkinson, R-SRI-H-R-13, October 1966

flown. A total of 11 Martlet 3A's ~~was~~ were fired. They proved that the vehicle could withstand accelerations up to 6,000 g. Beyond this, break-up occurred, as the acceleration became too great for the strength of the aluminum airframe.

The Martlet 3B was a steel vehicle containing an 8-inch rocket motor. This has been used for operational development and has been flown with both radial- and end-burning grains as well as composite propellants and extruded and cast double-base propellants. Radial- or center-burner grains are desirable due to their relatively fast burning characteristics, as compared with end-burning grains. This places less restriction on flight trajectories.

Fibreglass bodies have also been fired using the Martlet 3B configuration and have shown promise for the future because of their high strength/weight ratio. Martlet 3C, another sub-caliber vehicle, has demonstrated hydrostatic containment techniques with an 8-inch rocket motor at Highwater.

Martlets 3A, 3B and 3C proved that relatively long rocket motors could be fired from a gun at accelerations as high as 11,000 g. However, the optimization of a gun-assisted rocket involves the use of full-bore projectiles and a maximum efficiency rocket (that is, high mass fraction, high specific impulse). The next phase of the engineering program led to 2 full-bore vehicles, the Martlets 3D and 3E. The design of these vehicles was based upon all that had been learned in the earlier programs. Extensive research on fibreglass full-bore rocket cases was conducted during the winter of 1965-1966 using the 6-inch gun at Nicolet, Quebec, with over-the-ice recovery, and at Highwater.

Martlet 3D is a full-bore 16-inch diameter fibreglass rocket carrying 1,575 lb of fuel. It uses a pusher plate and a center-burning grain that is case-bonded. The center of the motor is filled with liquid, which is ejected after firing. The vehicle experiences a maximum acceleration of about 4,500 g.

The propellant for Martlet 3D has been the subject of a design study of motor strength, density, specific impulse, and burning time. Since different motor manufacturers offer substantially different combinations of these parameters along with economic and manufacturing differences, several separate motor-development programs were followed. In essence, the motor-development program is so critical that full advantage must be taken of all pertinent technology.

This vehicle is capable of firing 200 lb of payload to an altitude of 700 nautical miles with a muzzle velocity of 4,000 ft per sec. Four Martlet 3D's were fired in the horizontal range at Highwater in April 1966. This vehicle is intended to be the first stage of one version of the Martlet 4.

Martlet 3E is a full-bore 7-inch rocket weighing 145 lb with an 88.5-inch length fibreglass body and mass fraction of about 0.70. It will use an Aerojet propellant with a sea level specific impulse of 247 sec.

The vehicle experiences a peak acceleration of 8,000 g and achieves a muzzle velocity of 4,000 ft per sec. This is an optimized design capable of firing 10 lb of payload to an altitude of 250 nautical miles. Horizontal firings have taken place at Highwater and BRL. Vertical firings are scheduled at Wallops Station early in 1967.

The principal engineering problems outstanding with full-bore single-stage rockets relate to the development of reliable flip-out fins and self-destruct systems.

Martlet 4 is a 3-stage full-bore rocket capable of reaching extreme altitudes (for example, several hundred lb to 1,000 nautical miles) or orbiting a significant payload. Currently, the project is in the design study phase, and 3 basic vehicle designs are under consideration. The 3 stages are designated Martlet 4A, 4B and 4C, and the designs are as follows:

	Martlet 4A	Martlet 4B	Martlet 4C
Design 1	Solid Fuel (Martlet 3D)	Solid Fuel	Solid Fuel
Design 2	Solid Fuel (Martlet 3D)	Liquid Fuel	Liquid Fuel
Design 3	Liquid Fuel	Liquid Fuel	Liquid Fuel

Design 1 should be capable of orbiting 60 lb at an altitude of about 300 nautical miles, but this design is unlikely to be built, because of the better possibilities predicted for liquid rockets with their expected higher specific impulses, and their ability to be re-started in flight. Design 2 should be capable of orbiting 100 lb at a 300-nautical-mile altitude. Predictions on Design 3 would be highly dependent on specific liquid-fuel performance, but would be in the order of 145 lb at 300 nautical miles. These payloads are based on current muzzle velocities of 4,500 ft per sec. Improvement of gun capabilities may increase the muzzle velocity closer to 6,000 ft per sec, in which case the payloads cited above could be increased by about 30 to 35%.

Currently there are 3 groups working on liquid-fuel rockets for gun launching. At SRI cans of liquid are being fired from the Highwater gun to establish design criteria for liquid containment and survival. At Aerojet General in the US, storable liquid engines have been designed to withstand the launch accelerations, with vacuum specific impulses of 292 sec. The most feasible present design has a mass fraction of about 0.60, but future developments could improve this to approximately 0.80.

During the summer of 1966, I.E. Smith of Cranfield, England, conducted design studies on 2 classes of liquid engines:[1,2]

(a) storable propellants, nitrogen tetroxide and hydrazine, which promise vacuum specific impulses in excess of 320 sec and mass fractions perhaps in excess of 0.80,

(b) cryogenic propellants, liquid oxygen and hydrazine, with a theoretical vacuum specific impulse of 370 to 380 sec and a mass fraction in the order of 0.80.

Work is currently proceeding in this area in the United Kingdom.

Figure I and Table 1 summarize the performance of the HARP high-altitude probe vehicles.

Although design studies are continuing this year, no definite plans can be formulated on the future of Martlet 4 until the funding situation is clarified beyond 1 July 1967.

3.3 GUN ENGINEERING

A continuing program of gun maintenance and improvement is being carried out by SRI. Modifications are being planned for the existing guns, including fibreglass extensions, recoil redesign for increased loads, redevelopment of loading and elevating systems, travelling charge techniques and muzzle brakes for sabot separation. In November 1966 a 25-ft fibreglass extension was added to the 16-inch Highwater gun. Ignition tests are being carried out on a stub gun at Highwater, where multiple-point ignition techniques are being explored prior to incorporation on the long guns.

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[1] A Design Study of a Gun-Launched Nitrogen Tetroxide-Hydrazine Rocket Vehicle, I.E. Smith, R-SRI-H-TN-3, September 1966.

[2] A Design Study of a Gun-Launched Liquid Oxygen-Hydrazine Rocket Vehicle, I.E. Smith, R-SRI-H-TN-2, September 1966.

PAYLOAD CAPABILITIES OF HIGH ALTITUDE PROBES
(SEE TABLE I FOR PROBE DETAILS)

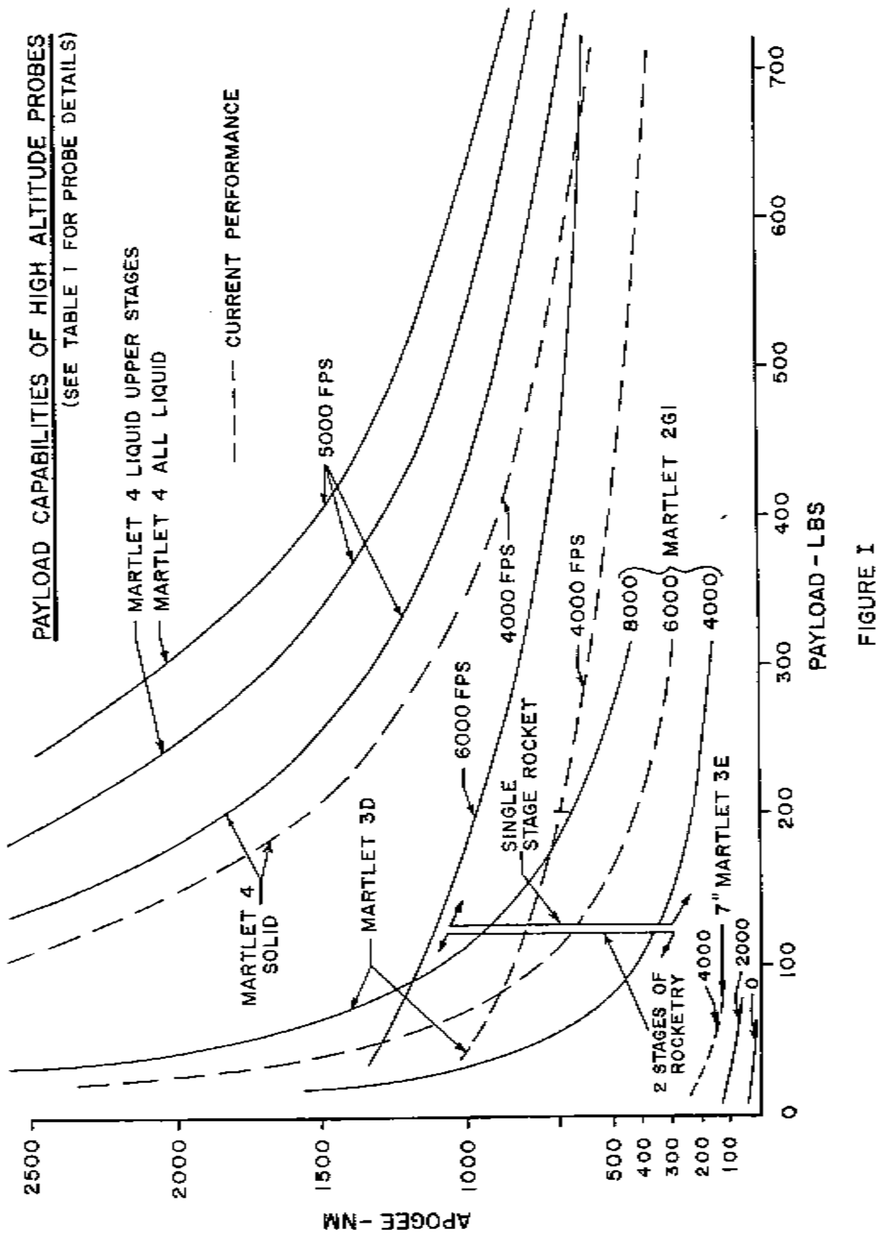

FIGURE I

The optimum gun length for launching projectiles is in the order of 200 calibers or more. Gun extension programs are underway, and a whole new family of guns is currently being designed. Guns with diameters of 32 in, 64 in and 128 in are included. The advantages of larger diameters, aside from payload dimension, are as follows:

(i) shot weight goes up as the cube of diameter,

(ii) peak acceleration drops inversely with diameter.

These relationships hold true for constant-caliber guns of the same maximum breech pressure and same propellant and ratio of charge weight to chamber volume.

The resulting improvement in rocket mass fractions and relaxation of peak g have encouraged a complete engineering and cost study to be carried out on the 32-inch system. This has included the engineering of the Martlet 2G-2 vehicle, based on the 2G-1 design.

3.4 HARP ORBITAL SYSTEMS[1]

The optimization of a gun-launched system involves a selection of launch angle corresponding to the selected launch velocity, rocket staging, vehicle parameters and orbit height. A further optimization is entailed between the amount of chemical energy carried aboard the vehicle, and the kinetic energy imparted to the vehicle by the launcher. This can be considered in 2 limiting cases: first, a relatively light vehicle launched at high velocities; and, secondly, a relatively heavy vehicle launched at much lower velocities. These 2 extremes are currently being studied in HARP, in the form of the orbital version of Martlet 2G-1 for the first case, and in the form of the Martlet 4 for the second case.

Due to the effects of scaling described under Gun Engineering above, the advantage of the 32-inch gun over the 16-inch gun is a factor of 8 in payload weight. This has encouraged further studies with particular emphasis on orbital performance, where the payload weights become far more meaningful in terms of user applications. For example, the Martlet 2G-2 has a capability of orbiting about 140 lb in a 169- by 98- nautical-mile elliptic orbit; and the 32-inch version of Martlet 4 (solid first stage, liquid upper stages) can orbit 870 lb with a 4,500 ft-per-sec muzzle velocity, or 1,130 lb with a 6,000 ft-per-sec

[1] Orbital and High Altitude Probing Potential of Gun-Launched Rockets, G.V. Bull, D. Lyster and G.V. Parkinson, R-SRI-H-R-13, October 1966.

TABLE 1

HIGH-ALTITUDE PROBE DETAILS

TYPE	1st STAGE TOTAL WT lb	1st STAGE FUEL WT lb	1st STAGE ISP sec	2nd STAGE TOTAL WT lb	2nd STAGE FUEL WT lb	2nd STAGE ISP sec	3rd STAGE TOTAL WT lb	3rd STAGE FUEL WT lb	3rd STAGE ISP sec	GEOMETRY OVERALL LENGTH ft	GEOMETRY DIA-METER in
Martlet 4 - Solid	1960	1620	280	500	400	290	200	160	290	28	16.6
- Liquid Upper	1960	1620	280	537	435	350	128	103	355	28	16.6
- All Liquid	1960	1620	340	537	435	350	128	103	355	36	16.6
Martlet 3D	1960	1620	280	-	-	-	-	-	-	17	16.6
Martlet 2G1 - 2 Stage	287	240	295	91	75	295	-	-	-	14.1	11.35
- 1 Stage	380	320	295	-	-	-	-	-	-	14.1	11.35
7-Inch Rocket (Martlet 3E)	135	108	280	-	-	-	-	-	-	7.4	7.15

muzzle velocity, at an altitude of 300 nautical miles. All of these performance figures are also accomplished at half the peak accelerations encountered in the 16-inch gun.

These obvious advantages of scale may lead to the abandonment of the 16-inch gun for operational orbital use, except for prototype and development testing. Nevertheless, it was felt desirable to conduct a special study to evaluate and compare the time and cost of creating an orbital capability using guns and conventional rockets.

A special study group was assigned the task of evaluating the feasibility and limitations relating to the development of an orbital launch capability for Canada using:

(i) the HARP 16-inch gun-launching technique,

(ii) a multi-stage rocket system based on the use of Black Brant rocket components.

A nominal requirement to place 100 lb into a 300-nautical-mile circular polar orbit was to be assumed. The launch range and other ground-support needs were to be assessed separately from the launch vehicle.

This special study concluded that it was feasible to meet this objective using the Martlet 4 vehicle with a solid first stage, and liquid upper stages. At this time, no liquid rocket has been fired from a gun, and this perhaps represents the greatest unknown. Furthermore, the liquid stages were assumed to have a vacuum specific impulse of 350 sec and mass fraction of 0.80. Whereas in general a weight penalty of 20% has been suggested for payload components in gun-launched systems, a recent study by Aerojet[1], published after the special study was completed, shows a considerably greater penalty for the components of a liquid rocket engine, which required 300 lb of propulsion system and structure for 400 lb of fuel (mass fraction of 0.57). Also, these particular propellants have a vacuum specific impulse of 292 sec.

There is, therefore, a large degree of uncertainty surrounding the performance of a gun-launched liquid rocket which makes it extremely difficult to estimate time and cost to operational orbit capability. Improvements in gun performance (muzzle velocity) may well offset any failure of the liquid rocket motors to meet their assumed performance, but this can only be conjecture at this time.

[1] Liquid Rocket Propulsion System Gun Launch, E. Latin, Aerojet General Corporation, Report #1 on P.O. 96683 Phase 1A, 10 October 1966.

The special study brought out the effects of aerodynamic heating. An effect of the initial high Mach number will be to subject the payload heat-shield to high temperature at high density, so that high heat-flux rates will result. At a muzzle velocity of 4,500 ft per sec, or Mach 4, the stagnation temperature will be about 1600°F, and parts of the heat shield outer surface will rapidly reach this temperature. However, this high velocity lifts the vehicle to the stratosphere in about 10 sec, so that the total heat load is not excessive. It does mean that the heat shield must be capable of protecting the payload from these high heat fluxes, and it may consequently be heavier relative to the payload than that for a rocket-launched vehicle. However, this is likely to be only a minor difference, since the rocket-launched vehicle takes nearly 3 times as long to reach the same altitude and so is exposed to somewhat lower temperatures for longer periods, which will result in generally similar total heat flux to the payload.

3.5 ATTITUDE CONTROL[1]

Essential to any orbital mission is a control system for sensing and controlling the attitude of the vehicle prior to the firing of the stages. Figure II is a typical trajectory for Martlet 4 (Design 1, all-solid). Although inherent aerodynamic stability of the vehicle might be counted on to control the orientation of the thrust vector prior to and during first-stage firing, the thrust-vector direction for the second- and third-stage firings cannot be achieved aerodynamically, and an attitude-control system of some sort is needed. The required function of the control system becomes one of setting and holding the vehicle's roll axis tangent to the trajectory path for the second- and third-stage firings. These angles are approximately 24° and 0° respectively, relative to the local horizontal. A tolerance of ±1° has been established as a reasonable compromise for these angles between the desired tolerance on orbital elements and the accuracy of equipment that is capable of withstanding the launch accelerations (a design case of 10,000 g was used). It has been shown[2] that errors in third-stage attitude will cause an error in apsidal heights of the order of 2 nautical miles per degree, and errors of a few degrees in the second- and third-stage ignition angle will cause orbit errors of 10 to 20 nautical miles.

[1] Orbit Injection Control for HARP, H.A. Raymond, CASI Journal, May 1965.

[2] Optimization and System Study, C.B. Jeffery, Geospace Engineering Company, Report No. 5, 8 June, 1966.

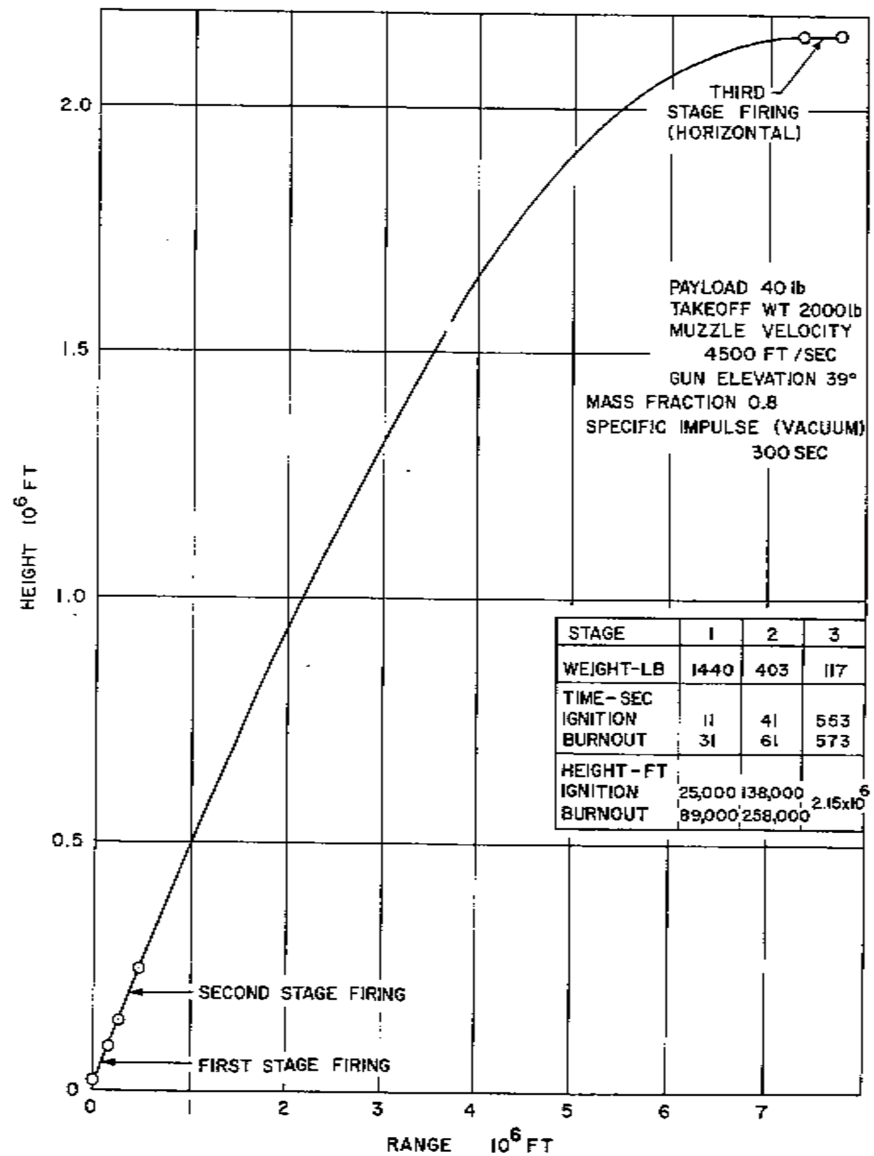

FIGURE II
LAUNCH TRAJECTORY FOR ORBITAL VEHICLE

Aviation Electric Limited AEL in Montreal commenced activities on this problem in 1963. Cold-gas reaction jets were selected as the control medium, using nitrogen stored at 3,500 psi feeding to 4 nozzles through solenoid valves. A separate control system maintains the roll rate of the vehicle between limits, as measured by a centrifugal spin sensor, and an electronic logic system processes signals received from horizon and sun-angle sensors into pitch and yaw commands to operate the solenoid valve nozzles.

The horizon sensors consist of forward- and aft-looking infrared telescopes, mounted rigidly on the vehicle, which scan from earth to space to earth as the vehicle rotates. The relative mark/space ratios from the 2 telescopes give a measure of the angle between the roll axis and local horizontal. Sun sensing is accomplished using photovoltaic cells which produce a pulse once during each vehicle revolution. The pulse amplitude is proportional to the angle between the sun line and a plane normal to the roll axis. Auxiliary sun sensors are included to provide all-round coverage in the event of tumbling or gross misorientation.

Three closed-loop control systems are involved—pitch, yaw and and roll rate. Pitch and yaw commands are phased by an earth-center pulse generator derived from the horizon sensors to minimize yaw-pitch coupling. Simulator studies show the system to be quite stable, for the selected values of roll/pitch/yaw inertia ratios, and nutations up to 10° are damped to acceptably small limit cycles.

Firings of all of the components and sub-systems have been carried out at Nicolet, Quebec, and 3 systems will be completed in 1966 for firing in the Martlet 2E vehicle in 1967.

Chapter 4

FACILITIES

4.1 SPACE RESEARCH INSTITUTE

SRI came into being on 1 August 1964. Inheriting the nucleus of a program and staff from the Department of Mechanical Engineering, it then expanded to accomplish the tasks outlined in the joint Canadian-US agreement on HARP and to incorporate other laboratory research programs.

SRI is located at 892 Sherbrooke Street West, Montreal, Quebec, where over all planning, monitoring and administration are done, along with considerable technical work in the electronics laboratory and design offices. The staff comprises approximately 70 persons. SRI is essentially a contract-operated research laboratory with no fixed or basic budget from any source.

SRI is related to McGill University through the SRI Management Committee, whose main functions are to:

act with and under the authority of the Board of Governors of McGill University,

review and authorize budgets, leases, and capital expenditures, and accept contracts, all as recommended by the Director of SRI,

consider and authorize any change in the program of SRI having a financial implication.

The SRI Management Committee meets monthly, and its membership includes the Principal of McGill University, the Dean of Graduate Studies and Research, the Director of SRI, the Executive Assistant to the Principal or the Comptroller, the Dean of Engineering, the Scientific Representative of the Committee on Research and the Secretary of the Board of Governors.

4.2 HIGHWATER, QUEBEC

This is an engineering development and scientific program laboratory located in the Eastern Townships of Quebec, near the Vermont border. Eighty people are currently employed at this 10,000-acre facility, which started late in 1964, originally as a light gas-gun range. Several gun installations have been added which include:

(i) a 16-inch gun, 110 ft long with a 25-ft fibreglass extension,

(ii) 2 – 6.3-inch guns, one long, one short,

(iii) a 5-inch BRL-type vertical-firing gun (an additional 10,000 acres is being acquired, which will serve to accommodate this facility),

(iv) a stub gun for ignition tests,

(v) 2 light gas-gun ranges.

In support of the above guns, a very well-equipped camera installation exists at Highwater, including 2 Beckman-Whitley framing cameras (1,500,000 and 4,500,000 frames per sec, 100 frames per run), Fastax cameras, etc. Furthermore, extensive machine shops, an electronic laboratory, a microbiology laboratory and other supporting facilities, all-in-all about 14 buildings, exist at Highwater.

4.3 BARBADOS

This is the primary vertical-launching base, permitting long-range flights and orbital missions. The land is provided rent-free by the Government of Barbados. This 16-inch, 120-ft gun-launching facility consists of Barbados-based launch control, vehicle preparation areas, machine shops, electronic shop, tracking and surveillance radars, telemetry receiving stations (250 mc to 400 mc, 1750 mc (GMD 2)), photographic and ionosonde stations. A 5-inch BRL gun also is located at Barbados for meteorological sounding.

The Barbados range is managed by CDC, which has about 50 people under contract to SRI; the radar is operated by the Reeves Electronics Corporation. Off-island observation posts exist on the islands of St. Vincent, St. Lucia, Tobago and Grenada. These posts are operated by Space Instruments Research, Atlanta, Georgia.

After the vehicles reach approximately 20 km they are acquired and tracked by the Eastern Test Range (ETR) facility at Trinidad.

All launchings are co-ordinated through the US Army Field Office at Cape Kennedy with ETR. ETR furnishes various radar telemetry and camera coverage through its down-range ship facilities, as well as (where possible) through its land facilities.

4.4 YUMA PROVING GROUND, ARIZONA

This is a 16-inch and 5-inch vertical-firing station engineered by SRI and operated by the US Army. SRI continues to carry engineering responsibility, and has staff there during a firing program, or when the guns are being modified. The advantage of the Yuma facility is that the vehicles can be recovered. Furthermore, it is located close to the West-Coast aerospace industry, and is attracting considerable interest there in gun-launching applications.

4.5 OTHER RELATED FACILITIES

Small-gun firings are carried out at Wallops Station, Virginia (operated by NASA for the US Army), BRL, White Sands Missile Range New Mexico, and Fort Greely, Alaska. Also, the facilities of the Inspection Services of Canada at Nicolet, Quebec, have provided over-the-ice recovery on Lac St. Pierre for many test shots from their 6-inch gun.

Chapter 5

SCIENTIFIC PROGRAMS

5.1 INTRODUCTION

Not all of the scientific research programs conducted by SRI are directly related to HARP. They are all included, however, in the summary below, because they do relate to the basic technology concerned in HARP.

5.2 IMPACT PHYSICS (Funded by NASA)

The collision at hypervelocities of a solid body (such as a meteoric particle) with a thin plate produces a high-temperature high-pressure plasma, which expands from a nearly condensed phase into a free vacuum. A theoretical model was postulated in 1961 and was developed along both approximate model and more exact theoretical lines. Experimental light gas-gun ranges were developed and were instrumented with a capability of 12-km-per-sec impacts. Beckman-Whitley framing cameras (1,500,000 and 4,500,000 frames per sec, 100 frames per run) were required along with image-converter and field-emission flash X-ray equipment. Development of special pressure transducers (mis-matched bar techniques) was carried on as a graduate research program. Experimental studies mapping the pressure-expansion field downstream of the bumper have been carried out.

5.3 CLOUD EXPANSION IN FREE SPACE (Rome Air Development Command USAF)

This is a theoretical study of the expansion of released liquids and powders at altitudes of 150 km. The studies include formation of solid pellets (frozen particles), and make use of observed diffusion rates from the TMA releases over Barbados.

5.4 PYROPHORIC EFFECTS IN HYPERVELOCITY IMPACTS (Wright Air Development Command USAF)

The impact of a small pellet at hypervelocities with a tank containing a reacting gas leads to the generation of detonation-combustion fronts. The purpose of the first phase of this study is to identify the principal features of the basic non-stationary processes and chemical reactions. The light gas-gun facility (Blue Range) is is being used for this study, along with special high-speed spectrographic equipment.

5.5 UNDERWATER TOWING CHARACTERISTICS OF BODIES (DRB Grant)

A theoretical study of underwater-towing characteristics is being conducted for NRE.

5.6 EXOBIOLOGICAL STUDIES (NRC Grant)

The effect of gun acceleration on bacteria (survival rate, mutations, etc) is being investigated by research-capsule firings from powder guns.

5.7 WIND-SHEAR-DRIFT MEASUREMENTS (HARP)[1]

TMA trail releases are being used to determine wind-shear profiles to 150 km, with extension to 250 km using smaller gun facilities planned during the coming year. The trail releases are being combined with ionosonde soundings to correlate drift and shear. Sodium trails are scheduled for twilight and sunrise scattering studies, as well as for wind-shear measurements. Currently some 100 to 200 flights per annum are scheduled, divided among Barbados, Yuma and Highwater and including simultaneous firings.

5.8 COMPOSITION AND THERMODYNAMIC STUDIES (HARP)

Both ground-based and airborne pilot experiments have been run to determine ionospheric composition. Langmuir probes are currently being flown piggy-back on most synoptic series flights. Ground-based spectrometry is being used to determine some neutral-particle densities, with emphasis on special chemical releases. This program is one closely co-ordinated with the other HARP-US agencies. Considerable emphasis at the current time is on the development of instruments. Grenade experiments for temperature are scheduled for the near future.

[1] Upper Atmosphere Winds Measured by Gun Launched Projectiles, C.H. Murphy, G.V. Bull and H.D. Edwards, Journal of Geophysical Research, October 1966.

5.9 METEOR SHOWER (HARP)

A plane-wave detonator is rocket-boosted from the apogee of a Martlet 2C or 2G airframe, to re-enter known particles (size, geometry, material) at velocities up to 15 km per sec, with possible extensions to 20 km per sec. Ground-based equipment (radar photographic, spectrographic and spectrometric) will be used to observe the re-entry burnout phenomena. The experiments are planned to start in October 1966.

5.10 NOSE-CONE RE-ENTRY HEATING (LAHIVE-Redstone)

Re-entry configurations are flight tested at Highwater to determine high Reynolds number, high temperature and heat transfer of specific interest in Army missions.

5.11 AIRBORNE INSTRUMENTATION

Supporting the scientific program is the concurrent development of payload instrumentation. Multi-channel telemetry able to withstand the high-g launch is now available from BRL, Harry Diamond Laboratories and Geophysics Corporation of America in the US, and CDC. Development work is progressing on such instruments as temperature and pressure gauges, spectrometers, Langmuir probes, accelerometers, radiation detectors and general meteorological packages.

5.12 FUTURE SCIENTIFIC EXPERIMENTS

A joint study[1] has recently been conducted by NRC and CDC of the various aspects of telemetry systems suitable for use in gun-launched probes. This study listed a number of upper-atmosphere

[1] Telemetry Systems for Gun-Launched Upper Atmosphere Probes, J.K. Pulfer, NRC Report ERB-742, June 1966.

experiments which might make use of gun-launching techniques. The most suitable experiments are listed below in the order of most likely probability of use. The most suitable are listed first:

- temperature sensors
- orientation magnetometers
- orientation solar sensors
- electric field probe
- conductivity probe
- unscanned plasma probe
- auroral photometers
- dayglow photometer
- infrared oxygen photometer
- micrometeorite detector
- infrared horizon sensor
- scanned plasma probe
- high-energy particles and gamma-ray detectors
- X-ray flux measurements
- low-energy particle detectors
- low-resolution ultraviolet detector
- high-pressure measurement
- high-resolution ultraviolet detector
- mass spectrometer.

It should be appreciated that the above experiments have not all been developed for gun launch (some have); the list intends only to reveal those experiments where there is a good possibility of development for gun launching.

Chapter 6

APPLICATIONS

6.1 INTRODUCTION

Applications of the gun-launching technique are continually being sought by and from SRI. Current applications programs include:

6.2 5-INCH GUN

Metsondes

The BRL 5-inch gun is being installed at a number of locations, including Fort Greely, Alaska, White Sands Missile Range, Wallops Station, Barbados and Highwater, for synoptic meteorological measurements, with the data being fed into the rocket network. CDC is currently proposing to market such a probe.

Project Gunfighter

This involves the use of gun-launched rockets for bombardment purposes and is sponsored by the US Naval Propellant Plant, Indian Head, Maryland. Firings have been conducted in the 5-inch gun at White Sands Missile Range. Both the gun and the vehicles are engineered by SRI and BRL.

Scientific Probe

The 5-inch gun is capable of sending scientific payloads to altitudes of 300,000 ft, and this gun has the advantage of mobility.

6.3 7-INCH GUN

Chemical Seeding

The 7-inch gun has been used by Fort Monmouth for heavy chemical seeding experiments. Vehicles have ejected caesium at altitudes of 100 km.

Scientific Probe

The 7-inch gun has a 400,000-ft capability and is still relatively mobile.

Scientific Rocket Probe

The 7-inch gun is the launcher for the Martlet 3E probe, which has a 250-nautical-mile altitude capability.

6.4 16-INCH GUN

LAHIVE

This is a high-Reynold-number hypersonic aerodynamic research tool, sponsored by Army Missile Command. It is used for re-entry heating studies, shock-on-shock tests (flying through simulated bursts) and ablation studies (USAF).

Re-Entry Physics

The Martlet 2G-1 vehicle might be used as a re-entry target for Nike X. The advantage of this technique is the high placement accuracy of the re-entry vehicle, which can also be used to simulate meteor showers and other phenomena related to high speeds in the upper atmosphere. The Martlet 2G-1 vehicle also has application as a deep-space probe for Van Allen belt and magnetosphere measurements.

Water Impact

The USN has used the Martlet 2C to impact the water at high speeds (5,000 ft per sec).

Fallout Simulation

The US Atomic Energy Commission will use a Martlet 2H to carry a ton of special powder to 50 km for use in fallout studies. The powder is intended to simulate debris from a reactor re-entering from orbit.

Scramjet

A supersonic combustion ramjet is being developed by the McGill Department of Mechanical Engineering, using triethylaluminum fuel. This is a full-bore payload, and 3 are currently being built at Highwater for firing at Barbados and Highwater in 1967.

Chapter 7

ACADEMIC ACTIVITIES

HARP has supported graduate work leading to 3 PhD and 5 MSc degrees to date. Currently under way are 3 PhD theses, with SRI currently accepting 20 additional post-graduate students. These students come from the usual distribution of North American and European universities, with a rather heavy emphasis on the Université de Montréal.

HARP, although concentrated in SRI, makes use, on a part-time basis (as well as summer employment programs), of staff from many departments of McGill University, University of Toronto, Université Laval, the University of the West Indies and in the past, Carleton University. SRI participates in the sandwich engineering employment program of the University of Waterloo. During the past 2 summers HARP has engaged an average of 30 students and professors. HARP provides financial support and thesis material for the post-graduate program. Aspects of the program have led to the development of oriented research in other departments.

Starting in the fall of 1966, special courses will be given in SRI built around the areas of major activity. The tentative schedule will provide courses in plasma dynamics, upper-atmosphere physics, payload and vehicle engineering, and fluid dynamics and impact studies.

Each course will be divided into distinct phases, with visiting specialists used to bolster in-house competence.

Chapter 8

FINANCE[1]

Prior to 1964 HARP-McGill was financed by the US Army. McGill University, under contract to the US Army, established in 1962 a 16-inch vertical-gun facility in Barbados and developed a series of probes for obtaining meteorological data. US funding at McGill University was essentially for non-weaponry aspects.

DDP was interested in the development being carried out by McGill University. It appeared to DDP that the level of US funding at that time was not sufficient to develop the full potential of HARP projectiles within a reasonably short time. It was also hoped that if the level of activity by McGill University was permitted to increase a suitable market fall-out might occur for Canadian industry as a result of possible user requirements. If the potential of HARP projectiles was to be explored, assistance in funding by the Canadian Government would have to be considered.

Consequently, in March 1964, a meeting was held between officials of DDP and Office of Chief of Research and Development (OCRD), US Army. It was decided at this meeting that OCRD would seek US authority for a jointly funded program with Canada.

The joint project agreement, which was signed by the US and Canada in November and December 1964, provided for equal sharing of costs during the period 30 June 1964 to 1 July 1965 on the basis of $1,200,000 Canadian and $1,200,000 US. It was recognized that the US Army would retain $400,000 out of its contribution of $1,200,000 for direct support of HARP-McGill by BRL. The agreement envisaged a program in effect until July 1967 and contained a work statement.

[1] Sources — DOI, DDP

This joint project agreement culminated negotiations that had been taking place during 1964 between DDP and OCRD. It was decided that DDP would fund an additional $400,000 as the Canadian share of work performed by the contractor up to 30 June 1964.

In September 1964 Treasury Board approved in principle Canadian participation in a joint project with the US Army, together with a contribution of funds from a vote provided to assist companies with a research and development capability to undertake the sharing of defence development and production tasks with the US and other allied governments, (Vote 5), for the US fiscal year ending 30 June 1965. Treasury Board also directed that, before recommending a contribution to the program beyond US fiscal year 1964-65, DDP should be prepared to provide further evidence of the ultimate market potential of results of the program, a verification of the cost estimate of the total program, and evidence of agreement with the US Army on a satisfactory sharing of costs for the rest of the planned program and for any overruns in cost that might occur beyond the estimate for the total program.

As directed by Treasury Board, DDP attempted to obtain further evidence of the ultimate market potential. By July 1965 contact had been made with various organizations and countries and, although there was a high level of scientific and military interest in the ultimate use of high-altitude gun-launching systems, it was at that time considered misleading to attempt to assign estimates of monetary value to possible market prospects. At that time, the Martlet 2A and 2C vehicles were considered operational and the Martlet 3C was expected to become operational in the next calendar year. The state-of-the-art and the lack of sufficient experience in routine daily firings did not permit possible users of the HARP technique to make predictions as to future requirements. It appeared that, whatever the market potential might be, the primary users of HARP-type probes would be the US Government or US-Government sponsored agencies. It was recommended, and accepted, that Canadian DOI Vote 5 support for the project be increased by $1,200,000 Canadian for the funding period 1 July 1965 to 30 June 1966.

It was recognized at this time that a decision would be necessary in the early part of calendar year 1966 as to future Canadian Government support for the project. If the Canadian Government was not to support beyond 30 June 1966, it would be necessary for McGill University to be aware of the situation in early 1966, in order to prevent cost overruns. Treasury Board observed that a further review would be made by the Inter-Departmental Committee for Export Development in January 1966 to determine if evidence of market potential of HARP would warrant continued financial investment from Vote 5 beyond 30 June 1966. The Board also made arrangements for a study to be made to determine whether the project should be supported for broader national reasons. Additionally, the Inter-Departmental Committee directed that the US Army and McGill University be acquainted with the plan to review the project in January 1966 and be made aware that the prospects for establishing an adequate market were not promising and that therefore there was danger that Vote 5 funding might be withdrawn in June 1966. This information was passed to both the US Army and McGill University.

Subsequently, a market survey was conducted by DDP in both Canada and the US. Although HARP is widely known and closely followed in a number of US agencies, the total market assessment at that time did not reveal a volume sufficient to justify further Vote-5 funding. Also, there did not appear to be a direct Canadian requirement.

Early in 1966 several Government agencies under the aegis of the Advisory Committee on Scientific Policy were requested to recommend to the Minister of Industry Government action as to possible support for reasons other than the criteria for DOI Vote 5. In addition, SRI informed the Minister of Industry that if the Canadian Government continued to fund the project jointly with the US for an extra year the SRI would then, with US support, be financially self-sufficient without further Canadian Government support.

As a result, the Government decided to continue funding HARP-McGill until 30 June 1967 at the same level as the previous year, and to cover half of a $600,000 overrun incurred in fiscal 1965-66. This funding was to be understood to cover a transitional period prior to full US funding in order to maintain the scientific team and programs at SRI.

US-Canada contributions to McGill University on behalf of Project HARP-McGill by US fiscal years, in Canadian dollars, are:

	Canada	United States
1962-63 / 1963-64	$ 400,000	$ 850,000
1964-65	1,200,000	858,000
1965-66	1,200,000	858,000
1966-67 (estimate)	1,500,000	1,150,000
Totals	$4,300,000	$3,716,000

HARP-McGill is under the direction of the HARP-McGill Steering Committee, whose function is to review the proposed research programs and funding for the Project and make recommendations to the US Army and DDP concerning program implementation and funding.

The Steering Committee consists of the Chairman, Vice-Chairman, Secretary (designated by DDP), and not more than 2 additional representatives from each country. The Director of SRI is a non-voting member, and attends open meetings of the Committee.

Chapter 9

INDUSTRIAL INVOLVEMENT

9.1 INTRODUCTION

In the matter of technological benefit to Canada and its industry the prime consideration is that of the engineering and scientific contribution resulting from the experience and learning of SRI, and associated range staff.

The main industrial organizations which have received subcontracts from SRI are AEL, CDC, Davie Shipbuilding Limited, CIL and Heroux Machine Parts.

9.2 AVIATION ELECTRIC LIMITED[1]

AEL started work on the design and development of an orbit-injection control system for the Martlet 4 vehicle in 1963. During this period the system was developed from the initial concept through to the design and manufacture of components such as sun sensors, horizon sensors, and spin-rate sensors. The system includes the command and control logic and the reaction jets. Considerable testing has also been carried out on the components, using test guns at Nicolet, Quebec.

As a result of this program, the staff required has increased over the past few years and during the peak period in early 1966 about 7 engineers and scientists were engaged on this program. AEL has also built and developed many pieces of laboratory and test equipment. Many specific techniques had to be developed to provide a system to withstand the accelerations of 10,000 g during the gun launch. The development program of the orbit-injection control system is now nearing completion and 3 systems will be completed by the end of

[1] AEL, Brief Submitted to the Science Secretariat, 27 September 1966.

1966 for evaluation in the Martlet 2E test vehicles. Further work will of course be necessary to develop the final configuration of the system for the Martlet 4 vehicle.

AEL designed and developed a valve for intermittent stream release of TMA for a Martlet vehicle for high-altitude research. The principles of fluidics were applied to produce a valve which would meet the requirements. This fluidic intermittent-stream release valve has now been manufactured. It is expected flight tests will be conducted in the near future.

The total expenditure to date is approximately $350,000, which covers the initial support provided by AEL during the installation of the 16-inch gun at Barbados, design and development of the intermittent-stream release valve and design and development of the orbital injection and control system.

9.3 COMPUTING DEVICES OF CANADA LIMITED

CDC has been engaged since March 1964 to manage the Barbados range. The annual contract is of the order of $300,000. The operation of this range is not dissimilar to that of a rocket range. Therefore CDC is attaining a field-operations capability which could be an asset in competition for similar tasks. Additionally, CDC has developed a 250-mc telemetry package for the high environment. Testing of the latest model is scheduled early in 1966. The significance of this development to CDC will depend upon the performance achieved. CDC has received $655,000 in HARP-McGill sub-contracts during the past 2 years.

9.4 DAVIE SHIPBUILDING LIMITED

Davie Shipbuilding has been employed in the installation and maintenance of the 16-inch gun at Barbados, including the current long barrel. Assuming that additional installations will be required in the future, Davie Shipbuilding should have a reasonable opportunity to be competitive. The value of HARP-McGill work to this company over the past 2 years is $150,000.

9.5 CANADIAN INDUSTRIES LIMITED

The Valleyfield, Quebec plant (formerly Canadian Arsenals Limited) has supplied a large proportion of the propellants for HARP-McGill firings prior to Martlet 3D, and has also produced rocket

motors in 8- and 16-inch diameters which have performed successfully. These motors, in the small quantitites required, have been less expensive than US motors, and are of a simple laminated construction. The gun propellants are modified versions of standard types but in much larger diameters than previously produced in Canada. The benefit to the Valleyfield plant has been to extend an existing capability in a new venture. CIL has received $222,000 worth of contracts in the last 2 years.

9.6 REDEV LIMITED

In an effort to decrease the payload-to-vehicle weight ratio, SRI investigated the use of filament-wound probe bodies. Two of these were fired in 1965. One was entirely successful at a launch acceleration near to the limit for rocket motors. This development is being continued at this company. The technique involves winding the motor casing onto the motor. The value of the work to date is very small.

9.7 HEROUX MACHINE PARTS

This company has been machining probes. The value of this work has been $416,000 during the past 2 years.

CHAPTER 10

THE FUTURE OF HARP IN RELATION TO CANADIAN REQUIREMENTS

DDP Vote–5 financial support of HARP-McGill ceases on 30 June 1967. At that time HARP will be entirely dependent on US funding, and it is not known at this time what level of activity this will provide. It is reasonable to expect, however, that the immediate future activities will be an extrapolation of the work in progress during the first half of 1967, and that new activities and directions will be stimulated by new applications as they arise and are supported.

At the time of writing, there appears to be no immediate Canadian scientific requirement for HARP-type vehicles, except perhaps as a synoptic upper-atmospheric and meteorological tool. The launch-survival problem appears to be the primary reason for this, and the same argument also applies to HARP-type orbital vehicles.

Sounding rockets are currently available to Canadian scientific experimenters, and rocket-type satellite launchers could also be made available. The gentler ride experienced by rocket payloads decreases payload design and development problems significantly, and experimenters are therefore naturally attracted to rockets. It has been estimated that both the payload weight and the cost are approximately 20% greater for gun launching than for rocket launching. The primary advantage in gun launching, therefore, must be in lower total cost of a launching to the user. In this event, the user may well be prepared to cope with the high-g environment, when it is at all feasible to harden his payload.

Intensive research and development is currently underway in the US, at such organizations as BRL and Harry Diamond Laboratory, on the hardening of components and systems for high-g environments. This work is related to equipment used in fuses and anti-ballistic missiles, where very high accelerations are encountered. These fields are critical to the US defence, and more and more components, devices and instruments are becoming available for high-g payloads.

As this information spreads throughout the Canadian scientific community, provided the services of SRI are available and made known to this community, then it is reasonable to expect a future Canadian interest in gun-launched vehicles if the total cost of a gun launching is significantly lower than that of a conventional rocket. The same argument applies to either a sounding probe or a satellite. It cannot be over-emphasized that both the advantages and the limitations of the gun-launching technique need to be disseminated and understood in an undistorted fashion throughout the Canadian scientific community before any appreciable Canadian interest can be expected.

Since lower total cost per launch is claimed to be the principal advantage of the gun-launching technique, it is essential to establish a user cost schedule for the various types of services and vehicles that can be provided. Until a market has been identified and/or established, there is little incentive to establish such price scales by the selling agency, whether it be a university, an institute or an industry. As far as Canadian requirements are concerned, the establishment of a central Canadian space agency would provide a focus wherein gun applications could be identified and funded, thereby providing a possible Canadian market in the future.