SCIENCE COUNCIL OF CANADA

A Space Program for Canada

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Report No. 1

A SPACE PROGRAM FOR CANADA

JULY 1967

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1967

July 4, 1967.

The Right Honourable LESTER B. PEARSON, P.C., M.P.,
Prime Minister of Canada,
Parliament Buildings,
Ottawa, Canada.

Dear sir,

In accordance with the provisions of sections eleven and thirteen of the Science Council of Canada Act, I submit herewith the views and recommendations of the Council with respect to Canadian activities in the upper atmosphere and space, in the form of a report under the title "A Space Program for Canada".

Yours very truly,

O. M. SOLANDT,
Chairman.

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I

INTRODUCTION

1. The Science Council interprets its function to be the furthering of science and its application in the economic, social, and cultural life of Canada. Thus it is concerned with a range of scientific activity which extends from fundamental scientific research (which has no objective other than that of expanding understanding); through the development of technology, which involves the selection of scientific principles and their application to the production of some potentially useful process or device, to the final phase of the utilization of the technology to achieve some recognized cultural, social, or economic end. Over this range of activity the scope broadens and much more than applied science is involved in the utilization phase. It is natural that a council composed of scientists should be primarily concerned with research and technological development, but their approach to these aspects is conditioned by the utilization phase. The space research that the Council advocates tends to be mission orientated; the Council is interested in rockets and satellites, not simply as research tools but as extensions of man's capability for controlling and using his environment.

2. The subject of this report, *A Space Program for Canada,* is an attempt to secure an integrated approach to the understanding and utilization of space for the greatest advantage of the Canadian people. It is not a critique of the scientific research into space phenomena which has been conducted to date—and which has been excellent—but a plea for its development and direction towards clearly defined practical objectives. A space program is suggested, but not defined in detail: the proposed national space agency is the suggested means for both continually defining the objective and realizing it through the stimulation, coordination, and direction of effort.

3. Scientific investigation into the problems of space and its utilization has been undertaken in Canada on a rapidly increasing scale over the last ten years. Several departments and agencies of the government, a number of universities, and some sections of industry have undertaken research and development projects with various objectives in mind. In the realm of space *research,* various government agencies have provided funds for university workers and have carried on some work with their own forces. All of the research groups concerned have been represented on the Associate Committee on Space Research of the National Research Council. The programs of each have been fully known to the others; moreover, it has been possible to select from offered programs those that seemed most likely to yield new and valuable scientific information. In spite of this coordination of research,

no common objectives for Canadian activities in the upper atmosphere and space have been defined, and there has been considerable fragmentation in the total space effort.

4. The Royal Commission on Government Organization (January 1963) called attention to the fragmentation of government non-military space research and suggested that it be consolidated into a single agency. With regard to the programs involved the Commission said (in Volume 4, p. 274):

> "The research should comprise:
>
> "All upper atmosphere research conducted by the Defence Research Board which is not of direct significance to defence, whether or not it involves the use of rockets.
>
> "All upper atmosphere and satellite research now conducted in other divisions of the National Research Council, for example, that on cosmic rays.
>
> "The research now conducted in the Radio and Electrical Engineering Division on meteors and satellites and the operation of minitrack instrumentation.
>
> "Research on satellite communications on behalf of the Department of Transport, which should not be encouraged to set up its own facilities."

The Commission made no specific recommendation as to the appropriate agency but noted that:

> "all non-military space and telecommunications research could be transferred to the Radio and Electrical Engineering Division of the National Research Council"

5. In May 1966, the Science Secretariat of the Privy Council Office commissioned the first comprehensive study of Canadian upper atmosphere and space programs. A study group consisting of the following members was established for the purpose:

Dr. J. H. Chapman, Defence Research Board (Chairman),
Dr. P. A. Forsyth, University of Western Ontario,
Dr. P. A. Lapp, de Havilland Aircraft of Canada Ltd.,
Dr. G. N. Patterson, University of Toronto.

This group submitted its report to the Science Secretariat at the end of 1966. It was published in February 1967 as Special Study No. 1 of the Science Secretariat, under the title *Upper Atmosphere and Space Programs in Canada*. It has become known as the Chapman report and is so referred to in this report.

6. The Science Council of Canada Act requires the Council to make recommendations to the Minister on (among other items),

(i) the adequancy of the scientific and technological research and development being carried on in Canada;

(ii) long term planning for scientific and technological research and development in Canada;

(iii) the responsibilities of departments and agencies of the Government of Canada in relation to those of universities, private companies and other organizations, in furthering science and technology in Canada.

It was natural therefore that the subject of Canadian activities in the upper atmosphere and space should be high on the Council's agenda and that it should request the formal submission of the Chapman report for study and assessment.

7. Preliminary copies of the Special Study were made available to members of the Council in advance of its meeting of January 16, 1967, at which time the subject was carefully reviewed. Following public distribution of the Science Secretariat Special Study, the Council was able to review public and official comments and the reactions of the press. The subject was further considered at Council meetings in March, May, and June 1967. In its findings and recommendations the Council has taken fully into account the comments and recommendations of the Chapman report but has not endorsed them as such.

8. Since the Chapman report formed the initial source of background information for the Council, the procedures adopted by the study group for the assembly of information and their organization of it will be briefly reviewed. The study group, appointed in May 1966, invited the submission of briefs from universities, industrial corporations, government departments and agencies, technical associations, and professional persons who had interests in upper atmosphere or space topics. Hearings were held in Halifax, Quebec, Montreal, Ottawa, Toronto, London, Winnipeg, Saskatoon, Calgary, Edmonton, and Vancouver, during the period from June 30 to October 31, 1966. A total of 112 briefs and other communications were submitted.

9. A visit was made by the whole study group to the headquarters of the National Aeronautics and Space Administration in Washington to review United States and Canadian joint programs in space, and to explore the potential availability of satellite boosters for possible future Canadian programs. Certain members of the group also visited European and Japanese space facilities.

10. The report of the study group, to the extent that the authors could achieve it, is a consolidation and a consensus of the views of the interested technical community, as presented in the 112 briefs, and 11 hearings. Three issues were raised repeatedly in the briefs, indicating a wide measure of agreement in principle among the views of industry, the universities, and certain government departments and agencies on these questions, namely:

(i) The need for a central organization for space activities in Canada;

(ii) The need for Canadian satellites for domestic telecommunications by 1970 or 1971;

(iii) The growing need for a Canadian satellite launching capability.

11. The Chapman report is in three parts. The first describes current and projected government, university, and industrial programs for the 1961 to 1971 period in considerable detail. Statistical information on these programs is compiled from the original sources. The comments and recommendations of the study group are included. The second part is devoted to the texts of agreements, memoranda of understanding, and other international arrangements in effect on October 31, 1966, and which record the official undertakings with regard to the Alouette-ISIS Scientific Program, the International Communications Satellite Program, the St. John's, Newfoundland, Tracking and Telemetry Station, and the operation of the Churchill Research Range. Part three of the report is in the nature of an appendix to the first part, presenting the High Altitude Research Program of McGill University in considerably greater detail.

12. No attempt has been made to reproduce the material of the Chapman report in this report of the Science Council. In the third section certain background material deemed necessary to assist the layman in understanding the recommendations of the Council has been provided, but for greater detail the reader, particularly the professional reader, should refer to the Chapman report, published as the Science Secretariat Special Study No. 1 and entitled *Upper Atmosphere and Space Programs in Canada.*

13. Throughout the discussions and in the Council's findings the terms upper atmosphere and space are used, usually together, to refer to the continuum to which the scientific activity under discussion is directed. There is no defined boundary between upper atmosphere and space. The combination is the earth-bound region in which phenomena of space merge with phenomena of the earth and its atmosphere.

14. The ionosphere and the aurora are typical of this region, and indeed Canadian interest started in studies of these phenomena and cosmic rays. Roughly speaking the upper atmosphere is just above the levels currently used by high-flying aircraft and above the zone in which phenomena that constitute the weather occur. In the text that follows, although the full phrase upper atmosphere and space will be used where necessary for emphasis, the term space used by itself should be given the same meaning: that is, it includes the upper atmosphere. Any more specific meaning for *space* is suitably qualified, for example, *outer* space, *inter-planetary* space, etc.

II

FINDINGS AND RECOMMENDATIONS

15. The space that envelops the earth necessarily concerns all nations both individually and collectively. During the last decade the science and technology of the upper atmosphere and space has been the subject of active development programs by several of the leading countries, and has already yielded spectacular results. The geographical location and extent of Canada makes the development of space facilities of particular importance to her political and economic future. Although significant contributions have been made by government and other Canadian organizations working in this field, a coordinated, expanded, and sustained national effort will be required if Canadian use of space is to be developed under Canadian leadership, to meet the needs of the Canadian economy.

16. The Science Council of Canada recommends the establishment of a broadly conceived central agency responsible to the Government of Canada for the advancement of Canadian capability in the science and technology of the upper atmosphere and space; for furthering the development of Canadian industry in relation to the use of the upper atmosphere and space; and for the planning and implementation of an overall space program for Canada.

17. There is some difficulty in defining initially the full extent of the role that may be played by a central agency. Certainly the primary role is to advise upon, coordinate, encourage, and, where necessary, initiate projects that collectively would constitute the national space research and development program. The agency should be competent to enter into contracts with government or other research establishments, or with industry, for the performance of specific research or development assignments. The nature of space research is such that large installations (such as launching facilities) must be built and shared by several interests: the agency should be competent to undertake the development and operation of such facilities. It is not contemplated that the agency would undertake the operation of a commercial enterprise such as a satellite communications system, although it might be called upon to fill a gap in the developing commercial structure on an interim basis. The role of the agency with respect to a commercial satellite communications system might parallel that of Atomic Energy of Canada Limited with respect to commercial power systems. In specific areas it might function as the research arm of the commercial enterprise, on a quasi-commercial basis.

18. The primary jurisdictions of government departments such as Defence, in military matters, and Transport, in the allocation of radio frequencies, the regulation of communications, or the operation of the Meteorological Service, would not be changed by the establishment of a national space agency. However, these departments and others would undoubtedly use the services of the space agency in pursuing their departmental programs. In particular, the space agency should be free, under suitable circumstances, to undertake work on behalf of the defence agencies. This of course, would not be of an operational nature. It will be necessary also to establish close cooperation with the National Research Council in several areas, including particularly the administration of university grants in the space field.

19. It is evident that such an agency will have to achieve close working relations with existing governmental agencies, with universities, and with industrial and commercial interests. The agency should be free to develop the administrative and operating procedures that would be most effective for the achievement of its particular objectives, and as far as possible it should be independent of existing government departments and departmental procedures. In order to provide the desirable degree of flexibility the proven pattern of a Crown Corporation might well be considered.

20. The Science Council recommends the appointment of a Board of Directors drawn from industry, the universities, and the public service, responsible as an agency or corporation to the appropriate Minister of the Crown for, *inter alia*,

(i) advising the Minister on all matters pertaining to Canada's utilization of space;

(ii) recommending the most satisfactory distribution of operating responsibility among government departments and agencies for existing and future government-financed space activities;

(iii) planning and coordinating (financially and otherwise) all upper atmosphere and space research and development projects undertaken in government departments and agencies or supported by government in university and industry;

(iv) coordinating all Canadian scientific space and upper atmosphere programs, including the establishment of procedures for the appraisal and selection of rocket and satellite experiments;

(v) developing and coordinating cooperative relationships with other national and international research and planning organizations in relation to the use of the upper atmosphere and space;

(vi) control of all facilities in Canada capable of launching rockets or satellites into the upper atmosphere or space and of all launches by or on behalf of Canadian institutions;

(vii) initiating and conducting by contract or otherwise such projects in the upper atmosphere or space as the Minister may approve.

21. The Council believes that Canada should approach the challenge of space as a partner in the world-wide assault on its secrets and its potentialities. This cannot be done from a meagre base, nor could it be achieved in partnership with only one nation. Relationships should be maintained with all countries active in the field and with the international bodies that may exist, such as the United Nations Committee on the Peaceful Uses of Outer Space; the Committee on Space Research of the International Council of Scientific Unions; and regional groups such as the European Space Research Organization and the European Launcher Development Organization. The fullest exchange of information is necessary to avoid duplication of effort: nothing should ever be invented twice.

22. Canada could stand aside in space matters and leave the costly development efforts to the U.S.A., the U.S.S.R., and to France and Great Britain, secure in the knowledge that in due course the hardware and the services would be available, and for sale. The Council's conviction that a much more dynamic policy is required arises not out of a spirit of competitive nationalism but out of a realization that sociologically and economically Canada cannot afford to expose herself to the degree of economic and technological dependence that the alternative would involve.

23. The satellite has opened up some revolutionary possibilities. New communications networks based on satellites could now be developed to reach the remotest Canadian communities for telephone, television, and data transmission services. Satellites equipped to observe the earth's surface (and even under the surface) can explore, pinpoint, and record the secrets of Canada's vast store of natural wealth. Satellites and rockets observing the atmosphere can measure and map, and facilitate forecasting of the weather of the continent. These and other potentialities involving satellites in space will inevitably be exploited. The national interest of Canada demands that Canadian scientists and technologists be enabled to play their part: that Canadian labour be used in Canadian plants to manufacture at least a fair share of the equipment; that Canadian organizations operate the systems, and that Canadians reap the benefit of the discovery and development of their resources. If these results are to be secured a strong sustained national effort will be required involving manpower, planning effort, and adequate financing.

24. In terms of gross national product (based on 1964 figures), the Canadian government is spending only about three cents out of every hundred dollars (0.032 per cent) on space projects. Expenditures of France and Britain are 0.063 per cent, and 0.083 per cent of their respective gross national products. On comparable activities (excluding the Apollo program, to place a man on the moon, and military expenditures) the U.S.A. is spending about 0.1 per cent of gross national product. The Council is satisfied that the budget available for research and development in the space field must be expanded significantly. It feels that a growth rate of about 20 per cent per annum would be consistent with other rapidly expanding fields. Continued over a period of some five years, this would indicate that the

figure of $60 million per annum suggested in the Chapman report (representing about one-tenth of one per cent of the gross national product) may not be unreasonable, but further evaluation by the proposed agency will be necessary to establish the appropriate level. This expenditure would not, of course, include the cost of a commercial satellite communications system or the operation of such a system. However, such an expenditure should secure the retention and expansion of the scientific manpower now active or interested in the space field and should enable industry, through development contracts, to consolidate its position and take the lead in meeting Canadian requirements for space-oriented equipment.

25. The Council is aware that in giving its strong support to the reorganization and expansion of Canada's research and development programs relating to the upper atmosphere and space it may be interpreted as singling out this particular activity for pre-eminence among Canadian efforts. The assessment made by the Council is that this is a field of special importance to Canada, since her geographical size makes her one of the few countries of the world that will need satellites for domestic communications and that could effectively use satellites for resource exploration. Moreover, Canadian scientists and Canadian industry have already demonstrated significant interest and capability in the field and can contribute greatly to the advancement of scientific knowledge and to Canadian social and economic development.

26. There are of course other fields of scientific, technological, and commercial endeavour of comparable importance. No attempt has yet been made to set one against another. Tentative projections as to desirable future expenditures on scientific research and development indicate that the expenditure to be contemplated on the space program is only a small fraction of the total of such expenditures, if realized, and could not seriously affect other important projects that are already in hand or that may emerge in the future. Important functions of the central agency will be a continuing assessment of the contribution of the program to the Canadian economy, and the tendering of advice to the government based on such assessment.

27. In advancing the concept of a national space program the Council is attempting to throw the emphasis on objectives, and is urging the selection of a limited number of mutually consistent objectives related to national needs and reasonably within national capabilities. It recognizes that the space program will be a fabric of subsidiary programs. Some will be shared internationally, but all should use some Canadian capability and lead towards some achievement in industrial, social, or economic advancement appropriate to the Canadian environment and within Canadian means.

28. Space science reaches out into many spheres and requires a purposeful and imaginative approach. Although Canada does not contemplate manned flights into space or even distant un-manned explorations, the vision of using space in the mobilization of Canada's enormous potentialities should provide a stimulating objective and incentive for a national space program.

29. The Science Council of Canada has examined several proposals that would establish specific policies relating to research and to the technological development of space facilities, their provision, use, and control. While the Council endorses the proposals which follow in this report (paragraphs 30 to 54), it believes that their further consideration is the function of the proposed central space agency. Together these could form the basis of a space program for Canada. The Council therefore suggests that they be referred to the proposed corporation or agency with the anticipation that they will be given high priority for study and implementation, if approved. It will be observed, however, that some of the matters raised require urgent action and some interim decisions may have to be made. It is important that such decisions be not inconsistent with the establishment of the proposed agency.

Space Facilities

30. Many aspects of space research require extremely costly equipment, which, once provided, tends to channel efforts into activities that will utilize it. Thus it is not only important to avoid duplication, but each major expenditure on space facilities should be properly planned in relation to the overall program that Canada may expect to follow. Although the program will take time to evolve in detail, it is important that arrangements be made whereby proposed investments in space facilities are fully coordinated with the emerging program through the proposed central agency. Similar consideration should be given to programs that are funded from outside Canada, since they constitute part of the total Canadian effort and draw upon the limited Canadian manpower.

Satellite Communications

31. Communication by means of satellites will obviously be international and continental in scope as well as domestic. A given satellite may serve more than one function. It is therefore essential that Canada participate fully by international agreement in the development and use of international communications satellite systems, while preserving Canadian control of domestic communications and of the satellites that may be required specifically for domestic purposes. There are significant technical, administrative, regulatory, and international problems to be handled in Canadian use of satellites for communication purposes. The Department of Transport and other government departments, including External Affairs, will clearly be involved. Much relevant work is already in hand. The following paragraphs indicate some of the areas that will need particular attention and in which the proposed agency might assist.

32. There is only one orbit in which satellites are stationary with respect to the earth. It is about three earth diameters above the equator, and it must serve all the nations of the world. Canada should press for international agreement on the use of this synchronous orbit, and should seek rights to

station Canadian satellites in it at locations between longitudes 75°W and 115°W. Moreover, Canada should be prepared to demonstrate her intention to exercise these rights, within a reasonable time.

33. There is an urgent need for a comprehensive survey of the ways and means of providing the wide range of communications services required throughout Canada now, and over (say) the next two decades. The role of satellites in meeting these requirements should be specifically evaluated. It is important to recognize that the interests involved are much broader than those of the telephone industry. Two transcontinental microwave radio relay common carrier systems already operate in Canada; two radio and television networks exist; a Crown Corporation handles the Canadian end of overseas telecommunications by submarine telephone cable and satellite; proposals for satellite systems for Canadian domestic services to include northern Canada have been advanced or are being studied by more than one interest. Both the study and the resulting policies must take cognizance of these and other interests in the field.

34. Clearly defined policies are required with respect to the ownership, operation, and use of satellites, or a satellite 'network', serving Canadian needs; and the ownership and operation of ground facilities associated with them and linking them with radio and television broadcasting facilities, and with rural, urban, and inter-urban telephone and common-carrier services. The Communications Satellite Corporation of the United States is providing overseas satellite communication services on a commercial basis (and has made an application for exclusive domestic rights). It is not necessary to accept this as a model for a Canadian counterpart but a decision should soon be made regarding the ownership and operation of Canadian communications satellite facilities.

35. The manufacture of equipment for both space and ground components of telecommunications systems has important industrial potential. Canada has already achieved notable success in this field, and has demonstrated her capability for building satellites as well as ground support equipment. It is extremely important that policies be evolved which, subject to reasonable cost differentials, will secure the optimum use of Canadian capabilities in both the development and manufacture of such equipment or its major components. This applies not only to equipment for domestic use but to a share of the facilities used by international agreement.

36. The radio frequencies assigned by the International Telecommunications Union for satellite communications in North and South America are not satisfactory to most users. For technical reasons it is necessary to share bands with ground systems. For example, one band assigned is already widely used by the two transcontinental radio relay systems which carry most of the long-distance Canadian television and telephone traffic. The sharing of frequency bands for satellite systems with land-based microwave systems is undesirable from an engineering viewpoint. Canada should continue to press for a solution that would increase the band width available and remove the

limitations due to interference with the present radio relay services in Canada. It is also desirable to secure an early allocation of frequencies suitable for direct television broadcast from satellites.

Resource Exploration by Satellite

37. While a detailed assessment of all the means of locating and appraising resources by observations from satellites has still to be made, there is considerable evidence that the broad vision and the differentiation that is feasible with certain sensors now provides an entirely new approach to the determination and delineation of surface geology and natural resources. Canada has already established some capability in this new field and Canada itself is wide open for such exploration. Obviously Canadian territory is also wide open for such exploration by outside interests. If protection be needed the only means would appear to be for Canada to be first in the field with information about her latent resources. Thus there may be a need for establishing a higher priority for Canadian satellite resource surveys than might arise from normal economic considerations.

38. Ordinary photographic, infrared, and spectrographic observations, when applied to great areas, can reveal data that would pass unnoticed at close range. The nature of the soils; the distribution of water, ice, permafrost, erosion, and sedimentation; the extent, type, and condition of vegetation; the mineral content of vegetation (and hence the mineral distribution near the surface) and the condition and yield of crops are required types of information. Surveys from space could greatly facilitate the task of obtaining them. Much more sophisticated investigations are to be anticipated: the key to these applications is the combination of trained personnel and the development of instrumentation. An adequately financed program of development, including contracts with instrument manufacturers and survey organizations, may well be required.

39. There is a strong case for proceeding with satellite surveys, using existing camera equipment, without waiting for the more elaborate techniques. A single satellite circling the earth a dozen or more times a day would cover the whole world in two or three weeks. There is an obvious case for international cooperation rather than duplication of effort. Compared with any other large-scale survey method the cost would be comparatively small. A satellite meeting primarily the needs of North America might, by arrangement, include other areas and provide maps as an external aid service to developing countries. Canadian participation in an experimental satellite program using infrared and visible light photography should be arranged without delay. The resulting photographs of large areas of the country may be expected to yield stimulating and important results. They would greatly facilitate the training of staff, expert in their interpretation, and provide the basis for more extensive use of the potentialities of satellites in this field. More sophisticated sensors can be carried by later satellites which, if justified, might be Canadian.

Satellite Launching Systems

40. It is not suggested that Canada can or should aim at being self-sufficient in all satellite launching facilities. The economical development of facilities for the launching of the larger satellites will require a greater level of utilization than any one country is likely to provide. There is in fact a strong case for the larger launch facilities being international. Thus Canada should preferably negotiate for the purchase of the launching services that will be required for communications satellites (while insisting on full Canadian control of the specification of the satellites and of associated equipment), but might well justify launch facilities for her innumerable experimental rockets and an increasing number of small satellites.

41. Canada already possesses certain launch facilities. The Churchill Research Range (at Churchill, Manitoba) is operated by Canada and financed jointly by Canada and the United States under an agreement that extends to 1970. The range is used for routine launching of meteorological rockets and for both United States and Canadian rockets containing scientific equipment. The actual launch facilities are supported by extensive technical facilities and numerous remote stations in the area. The smallest rockets launched (about 5 feet long) carry some 12 pounds of meteorological instruments to an altitude of 50 miles, at which level the instruments are ejected and descend by parachute. These are launched at the rate of three per week. The largest rocket handled by the range is the 4-stage 'Javelin', about 48 feet long, which carries 125 pounds to an altitude of 500 miles. Canadian scientific experiments are carried in the Canadian developed Black Brant series of rockets, of which about a hundred have been launched.

42. Operation of the Churchill Research Range is assured until 1970, when the present agreement expires. At that time Canada should assume full responsibility for the range and make launching services available to the United States or other countries on a reimbursable basis.

43. The High Altitude Research Program of the Space Research Institute of McGill University has developed a gun technique for launching upper atmosphere probes. The major installation for vertical firings is located in Barbados where a 16.4-inch gun with a 120-foot barrel is installed. Many successful firings have carried ballistic glide vehicles into the upper atmosphere. Gun-boosted rockets capable of orbiting small satellites are currently being developed.

44. To date no satellites have been launched by either facility. It is important that studies be undertaken as soon as possible to determine, first, a realistic program of Canadian satellites for all purposes, taking into account the auxiliary services that will be required, and then the most appropriate launching facilities to meet Canadian needs. If it is concluded that Canada should develop launching facilities for certain types of satellites, then detailed design and development programs should be established without delay.

45. The suitability of gun-launching for vehicles to provide simple synoptic atmospheric sounding measurements has been established, and there is some evidence of a desire by aeronomists to use data from such synoptic measurements. If the need for such data can be established, funds should be provided for the launching. While the launching of a small satellite using a gun as the first stage is clearly possible, the economic advantage of using this technique instead of rockets, has not been established. The new agency should consider the desirability of supporting the cost analysis studies necessary to provide a basis of comparison. The studies envisaged would not depend upon the continuation of the present program of firings.

Industrial Development

46. A major program of research and technological development in the upper atmosphere and space could provide an important opportunity for the further development of Canadian industry. The opportunity is not simply to secure a certain volume of business that might be placed elsewhere, but to achieve the type of production, the manufacturing facilities, and the know-how that will be part of the industrial technology of the future. What is developed for space research today, may well determine the bread and butter production of the next few decades.

47. Study programs, and research and development projects on space facilities and components, should, as far as possible, be placed with Canadian industry. In many cases these must be fully funded by the central agency, but cost-sharing should be maintained or developed in so far as it is economically justified. Systems management contracts and prime contracts for the development and supply of the major hardware portions of the program, should be awarded directly to Canadian industry. This should not, however, preclude the negotiation of agreements with other countries or international agencies on a reciprocal basis for the sharing of development and production in the space field.

48. The success of an industrial development program arising out of the space effort will depend on the extent to which the new technology and production methods are transferred to other fields of activity, in the everyday lives of people. It is expected that a special study and development activity will be required to effect this transition. Partly, the solution lies in the dissemination of information, and in such services as market analysis and industrial design, but essentially it is the modern equivalent of the old-fashioned entrepreneurial genius that is needed.

University Space Research Programs

49. The universities have already played a major role in Canadian space efforts. An increased research and development program for Canada necessarily involves increased university participation, since the universities not only provide specific research and development activity; but, through it, the trained personnel on whom much of the future effort will depend. It is obvious that the central agency must give full support to university projects that fit in with the overall program, and encourage particular avenues of

research by offering support. At the same time the university's independence and freedom in the pursuit of knowledge must be respected.

50. Certain Canadian universities have already established institutes or similar groups which have become internationally recognized as centres of excellence for space research and education. Essentially they are post-graduate and interdisciplinary, and are integrated into the university structure in such a way as to ensure a concentrated effort with efficient management of space-oriented funds. Their activities indicate a recognition that no one institute can or should cover the whole field, and that some constraints must be accepted in order to participate effectively in a national space program, planned and coordinated to meet Canada's special needs.

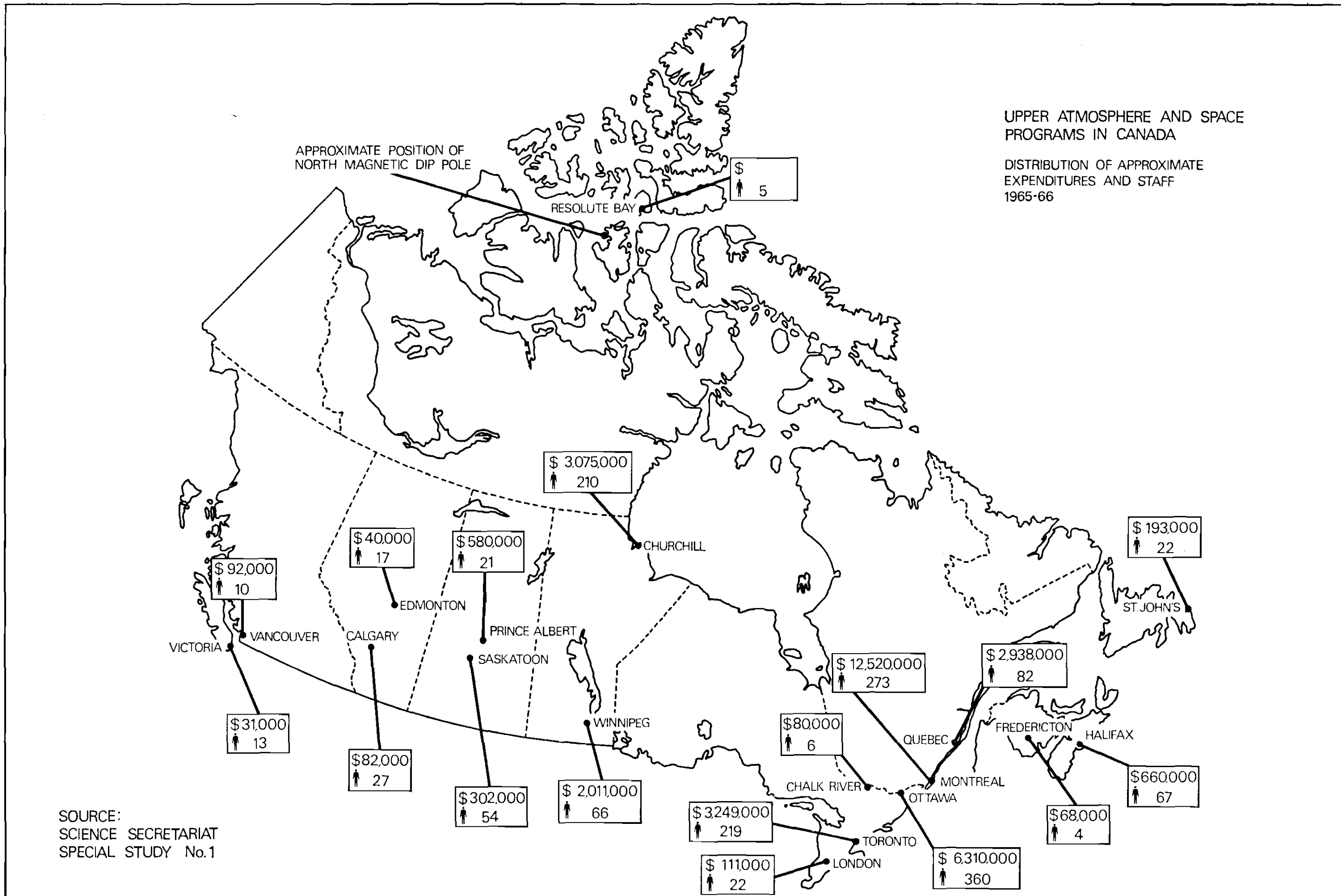
51. In general, it would appear that the programs of university space institutes and research groups could be integrated into a national space program without weakening the role of these institutions as centres of academic research and advanced education. It would be necessary to provide direct financial support for such bodies, partly in the form of sustaining grants to maintain and develop the institute itself, including facilities, accommodation, and personnel, and partly as grants-in-aid to encourage the work of individual scientists who have shown a competence to contribute to the space program. Contracts for the performance of specific studies or projects on behalf of government or industry may also be an appropriate method of support.

52. The space program presents an opportunity for bringing together a considerable range of disciplines, not only in the development of the facilities but in their use. Research scientists from fields not obviously connected with space, such as chemistry and the life sciences, should be encouraged to use the opportunities offered by the space program for the design and carrying out of specialized experiments that relate to their own disciplines.

Space and the Law

53. International law with regard to the use of space, particularly in the vicinity of the earth, is no doubt rapidly being formed by international conferences, by agreements, and by the simple process of occupation. In the international discussion involved, those with the largest commitments will tend to speak with the strongest voice; but Canada may well play an important role in the process, provided she can speak with the authority that comes from knowledge and capability. Sandwiched between two leading powers in space matters, Canada has a vital interest in the law that may become a major factor in her security and future development.

54. It is not only international law that is involved. There appears to be a strong case for reviewing Canadian law as it relates to the use of space facilities over Canada, the services that will be required to support them, and the use that may be made of information gained from space and of facilities for distributing information by means of space. While the use of space opens up visions of enormous opportunities, the public may well need protection in its use.


UPPER ATMOSPHERE AND SPACE PROGRAMS IN CANADA
DISTRIBUTION OF APPROXIMATE EXPENDITURES AND STAFF 1965-66
APPROXIMATE POSITION OF NORTH MAGNETIC DIP POLE
RESOLUTE BAY
$ 5
$ 3,075,000 210
CHURCHILL
$ 40,000 17
EDMONTON
$ 580,000 21
PRINCE ALBERT
$ 92,000 10
VANCOUVER
VICTORIA
CALGARY
SASKATOON
$ 193,000 22
ST. JOHN'S
$ 12,520,000 273
$ 2,938,000 82
QUEBEC
MONTREAL
FREDERICTON
HALIFAX
WINNIPEG
$ 31,000 13
$ 82,000 27
$ 302,000 54
$ 2,011,000 66
$ 80,000 6
CHALK RIVER
OTTAWA
$ 660,000 67
$ 68,000 4
$ 3,249,000 219
TORONTO
$ 111,000 22
LONDON
$ 6,310,000 360
SOURCE:
SCIENCE SECRETARIAT
SPECIAL STUDY No. 1

III

CANADIAN ACTIVITIES IN THE UPPER ATMOSPHERE AND SPACE

55. This section is intended to sketch broadly the background of Canadian activities in the upper atmosphere and space, to which the Council's recommendations relate. No attempt is made to describe all activities. This is effectively accomplished in the Science Secretariat Special Study No. 1 entitled *Upper Atmosphere and Space Programs in Canada* (the report of a special study group under the chairmanship of Dr. J. H. Chapman) to which the reader may refer. The omission of reference in this review to any particular project must not be construed as an assessment of its significance.

56. One of the striking features of Canadian activities in space is their wide dispersal across the country, as shown on the accompanying map. Scientists and supporting personnel are at work in nearly every province. Installations for launching vehicles by rocket or gun, tracking stations, radar facilities, radio stations for communicating with satellites, ground stations for a variety of measurements and observations, laboratories for developing the instruments to be carried into space, and laboratory facilities for simulating space are widely distributed. Even though this distribution results in a difficult fragmentation, there is a sense in which the efforts are a "grass roots" activity and some aspects are peculiarly Canadian.

57. An important factor is Canada's unique location as the natural theatre from which some of the most important ionospheric phenomena may be observed. The north magnetic (dip) pole is within Canadian territory (just south of the 75th parallel of latitude and close to the 100th meridian), and the roughly oval auroral cap is tilted south over northern Canada. Canada thus has particular advantages for observations of magnetic, ionospheric, and auroral phenomena. The midwinter meteorology of the upper atmosphere over Canada to at least 130 kilometers also tends to be unique and of great practical importance. By virtue of having a monopoly of the locations for certain observations Canada has perhaps acquired a moral obligation to make them.

58. The most obvious characteristic of the new scientific study of space is that it is carried out largely by "direct" observation and measurement by instruments in space vehicles that are projected or carried into space by rockets, guns, or large balloons. The vehicles may be probes which return to the earth, or satellites which are directed into suitable orbits and have a relatively long life.

59. While the primary emphasis is on the investigations that are undertaken by the space vehicle, many investigations are also conducted from the ground by photographic, radar, and radio techniques, and by measurement of radiations reaching the ground from outer space. Other ground-based investigations involve the simulation of space conditions for particular experiments, and also purely mathematical studies.

60. Although space research can involve a wide range of disciplines in the experiments involved, the use of space vehicles gives rise to the specialized technology required for vehicles moving in an environment almost totally different from the conventional environment on the surface of the earth. The vehicle itself requires specialized design to meet conditions that rapidly change between extremes. The payload of instrumentation that is carried aloft operates under radically different and extreme conditions of temperature, pressure, acceleration, etc., and usually must have minimum weight and size.

61. In most cases it is necessary to keep track of the vehicle from the ground, its equipment must be operated from the ground by remote control, while the data it is collecting may be relayed to the ground to be processed and interpreted. Ground installations are thus vital not only for launching the vehicle but throughout its operation. Apart from the launching, the technology involved for the ground facilities is largely in the communications field, although often pushed to unusual limits.

62. Rocket vehicles, satellites, rocket launching ranges, gun ranges, tracking and telemetry facilities, space engineering laboratories, computer facilities and so forth are very expensive. For the last complete year, 1965-66, for which figures are available, the total level of expenditure in Canada on space research and development projects was about $30 million, of which some $17.5 million was Canadian government expenditure, some $4.5 million came from United States participation, and nearly $6.0 million was spent by industry. The total number of scientific, engineering, and technical supporting personnel was about 1,500, rather more than 50 per cent being technical supporting staff. The distribution of personnel and expenditures is shown on the map facing page 14.

63. Expenditures in 1966 for 15 major government-supported programs are shown in the accompanying table. "Internal" refers to in-house expenditures while "external" are those made outside, to or through, universities, research institutes, or industry. Where relevant, reference numbers given in the text that follows refer to the numbers of the projects in this tabulation, from which the responsible branch of the government can also be determined. United States expenditures in Canada on these projects are also included.

64. Canadian interest in space can be roughly divided into three fields. First is the study of the physics of the upper atmosphere, with a pure science emphasis (and a meteorological interest) undertaken initially from the ground and later from balloons, rockets and satellites. The second field is the provision of the rockets, and small satellites and the launching facilities

Current Government Programs (1966)

Program	Responsible Agencies	Expenditures $ Thousands			U.S. Expenditures in Canada $ Thousands
		Internal*	External*	Total	
1. Alouette-ISIS	Defence Research Board	1,018	3,204	4,222	—
2. Churchill Research Range	National Research Council	—	2,170	2,170	2,170
3. Missile Re-entry	Defence Research Board	1,895	105	2,000	600
4. Engineering Support, Rockets	National Research Council	310	1,440	1,750	—
5. HARP/McGill	Department of Industry	—	1,500	1,500	1,150
6. Upper Atmosphere Research	Defence Research Board	1,237	—	1,237	—
7. Rocket Development	Department of Industry and Defence Research Board	600	370	970	—
8. Aerology	Defence Research Board	703	115	818	—
9. University Support	Defence Research Board and National Research Council	—	740	740	410
10. Satellite Communications	Defence Research Board and Department of Transport	731	—	731	—
11. NRC Space Research	National Research Council	612	—	612	—
12. P.A.R.L.	Defence Research Board	458	60	518	—
13. Industrial Research Support	Defence Research Board	—	225	225	—
14. St. John's Tracking Station	National Research Council	—	200	200	—
15. Cosmic Ray Research	Atomic Energy of Canada Limited	80	—	80	—
		7,644	10,129	17,773	4,330

* This subdivision is only approximate, due to the lack of precise information.

required: here the emphasis is on the new technology and on the engineering skills involved. The third field combines the new technology of satellites with communications technology (which has been derived in no small measure from a knowledge of the physics of the upper atmosphere) to provide a new system of communications by means of satellites, free from certain technical limitations and probably less costly than existing methods when long distances and sparsely populated areas are involved. The first section tends to be shared by government and the universities, the second involves the universities, government, and industry while the third tends to be the field of industry and government agencies. The somewhat arbitrary division into these three sections will be used in describing Canadian activities in more detail, but the particular role of the universities, contributing manpower and research effort, will be discussed more specifically between the first and second sections, where the context is reasonably convenient. A fourth field, that of observation and resource surveys by satellite, is a subject of increasing interest. Although no activity on a significant scale has as yet been undertaken, informal discussions have been held with United States authorities on the subject of Canadian participation in the Earth Resources Observation Satellite (EROS) project. The Surveys and Mapping Branch of the Department of Energy, Mines and Resources has cooperated with the United States Coast and Geodetic Satellite Triangulation Program with a view to improving the Canadian geodetic network and its connections to other networks.

The Physics of the Upper Atmosphere

65. For some 20 years the Defence Research Board has conducted an active research program in the physics of the upper atmosphere (6), particularly the ionosphere. This started by means of ground-based radio measurements and by ground-level and balloon-borne optical measurements. Beginning with the International Geophysical Year in 1957, rockets were first used to investigate spectroscopic and ionic characteristics of the upper atmosphere. An important part of the work has been directed toward understanding the physics of the ionosphere with a view to improving communications. This has involved using radio waves of varying wavelength for ground-based measurements in conjunction with rocket and satellite measurements. At the same time a program of communications research has proceeded.

66. Another part of this program has been carried out by means of infrared and visible radiation to obtain a better understanding of the luminescent and chemical properties of the atmosphere and their relation to its energy balance and composition. The possibility, albeit remote, of modifying these conditions and so producing a modification of climate by human intervention is attracting considerable attention.

67. The Prince Albert Radar Laboratory (12) was built as one of the necessary facilities for carrying out a program of ionospheric research, initially with a defence orientation. The laboratory comprises a high-power ultra-high-frequency radar capable of being used in a variety of researches in radio propagation and also capable of tracking objects, such as satellites, at

long range. Associated with the radar are a number of auxiliary facilities for the recording of fluctuations in the earth's magnetic field and variations in ionospheric conditions. The unique capability of the installation for auroral investigations has been only partially exploited. 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 its location within radar range of the auroral zone ionosphere, particularly that over Fort Churchill, should be exploited. The present decision is that the Prince Albert Radar Laboratory will be closed on July 1, 1967, since the Defence Research Board program will then be complete. Sponsorship of the laboratory by other agencies has been sought but as yet without success. The facility might be valuable as a tracking and control station if Canada develops satellite launch facilities. It has recently been used in radioastronomical measurements of quasars.

68. The Alouette-ISIS program (1) has aroused considerable interest since the satellites are built entirely in Canada. They are launched by the National Aeronautic and Space Administration in the United States. Alouette I was launched in 1962 in a 1,000-kilometer circular orbit, and after over four years continues to work as planned. In addition to equipment for sounding the ionosphere from the topside, it contained three experiments relating to cosmic noise and energetic particles. Following the success of Alouette I, agreement was reached between the U.S.A. and Canada to embark on a joint program of launching four further satellites, which would constitute the ionospheric research satellite program of both the U.S.A. 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 the United States at intervals during the half cycle of sunspot activity from 1964 to 1969. One of the conditions made by the Government of Canada was that Canadian industry should be brought into this program to the fullest extent possible in order 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, through the Defence Research Board.

69. Alouette II was launched in November 1966 into an orbit of 500 kilometers perigee and 3,000 kilometers apogee. More than a year after launch, it is operating perfectly and providing seven hours of data a day. Work on the ISIS-A satellite began in March 1964. The spacecraft is being built at the contractor's plant in Montreal. Launch into a 90° inclination orbit of 500 kilometers by 3,500 kilometers is planned for 1968. The satellite will carry ten experiments provided from United States and Canadian research centres.

70. Twelve experiments will be carried in ISIS-B, on which work is just commencing. The spacecraft injection into a 1,700-kilometer circular orbit of 70° inclination is planned for 1969. The ISIS-C spacecraft has not yet reached the planning stage, but its orbit is expected to reach out six to ten

earth radii. In addition to the satellites that have been described, the program entails the operation of two telemetry stations, one at Ottawa and one at Resolute Bay; a data processing centre at Ottawa; and a satellite control centre, also at Ottawa.

71. The Alouette-ISIS program will probably continue to 1972 or 1973, and might be followed by a further joint program. Universities were invited to make proposals for experiments but initially no funding was available. However, the opportunity has now been provided for the inclusion of university-conceived experiments for ionospheric research and funds are being provided by National Research Council grants for the purpose. The contribution to satellite tcehnology and industrial competence made by this program is considered later.

72. The interest of the National Research Council (11) in ionospheric physics, including meteor physics, goes back over a longer period than that of the Defence Research Board. An early interest in cosmic ray research has expanded into extensive measurements of energetic particle fluxes in the auroral ionosphere, using rockets and satellites. A number of rockets, instrumented to study electron densities and temperatures, have been flown. Others have counted the number of micrometeorites encountered. In a related ground-based study, auroral radars were operated at a number of northern stations during the International Geophysical Year and some of these have continued to the present time. Much of the value of this program lies in the fact that these atmospheric parameters are being measured simultaneously by other groups using different techniques.

73. Another program involves the reception of satellite telemetry transmissions. Starting in 1961 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 satellites were in operation, receiving stations were set up in Ottawa and Frobisher Bay. This work was undertaken by the Meteorological Branch of the Department of Transport with the cooperation of the National Research Council and the cloud-cover photographs were sent to the meteorological office in Toronto for analysis. The prototype equipment built at the National Research Council led to the manufacture by industry of operational automatic picture transmission equipment which is now being used at Toronto and at an additional Automatic Picture Transmission experimental station opened by the Meteorological Branch at Halifax.

74. For a number of years the National Research Council has provided the payload engineering support (4) necessary for the rocket experiments carried out by its own staff and by the universities. This work has 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. Trajectory information was

also supplied. Responsibility for this work now rests with the Space Research Facilities Branch of the National Research Council, which has operated the Churchill Rocket Range for the past two years.

75. 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 cooperation with the National Aeronautics and Space Administration of the United States, operates a Solar Flare Patrol Program in which a watch is kept on the sun for flare activity in order to provide warnings of increased 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.

76. The Department of Transport has an active program in its Meteorological Branch. In addition to the weather satellite observations which are described above (paragraph 73), 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 kilometers for information on wind, temperature, and pressure at these heights. Only the Churchill Research Range is at present being used for meteorological rocketsondes, but it is intended that four more Canadian stations will later 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 are reported to the Regional Data Centre in College, Alaska. The objective of this work is to study the dynamics of the region near 80 kilometers in height where the clouds are formed. Since noctilucent clouds are generally observed only between latitudes 45° and 75°, Canada is favourably situated for these studies.

77. Following the original work on cosmic rays carried out by Rose and others at the National Research Council laboratories (paragraph 72), the study of cosmic radiation and its relationship to interplanetary space has more recently been undertaken in the Atomic Energy of Canada Limited laboratories at Chalk River (15). 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 cooperation. 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 present neutron and meson counters are installed at Chalk River (the largest such installation in the world and the internationally

accepted reference standard), at Sulphur Mountain in Alberta, at Inuvik, at Goose Bay, and at Alert. A mobile station has also been used to investigate the latitude dependence of cosmic ray intensity.

78. It should also be noted that certain Canadian companies have important research programs in hand (some under contract from United States and Canadian organizations) for quite fundamental research on plasma physics and topics associated with the physics of the upper atmosphere and space. The relevant part of the expenditure is of the order of half a million dollars a year.

University Research and Scientific Training

79. The range of interest in space research in Canadian universities (9) is quite broad. Some groups are engaged in space-oriented laboratory work such as experiments in chemical aeronomy, and 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 the direct investigation of the physics of the upper atmosphere using ground-based facilities: for example the measurement of cosmic ray particles and the determination of the properties of the ionosphere by the scattering of radio waves. The advent of rocket and satellite techniques has opened the way for a considerable extension of these studies; programs include the use of rockets and satellites for such investigations as the 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.

80. 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 the Space Research Facilities Branch of the National Research Council. Grants are also provided to fund the university contribution. This arrangement makes it possible for small university groups to participate effectively in upper atmospheric studies. Indications are that more universities will become involved in this activity. Nevertheless, most of the work in universities is either laboratory work or ground-based observational work and only a small part, at present, involves rocket-borne or satellite-borne observations. It is probable that the appropriate balance has not yet been reached. However, the present level of funding would not permit a significant increase in the proportion of the work done in high altitude vehicles.

81. The trend of space research in Canadian universities is indicated by the variety of large facilities available or under development. Shock tubes and light gas guns have been constructed for the simulation of re-entry

physics, meteor impact phenomena, and the dynamics of the magnetosphere: a plasma tunnel has been developed for the 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. Ground-based radar facilities and cosmic ray detectors will be further developed for more extensive observations.

82. The consensus of space interests in the universities appears to be that, for the further development of an effective program of research in the upper atmosphere and space, the present rocket launching capability must be extended to include an orbital launching facility for small or moderate-sized satellites. Canadian university views also agree, almost unanimously, that the development, construction, and management of launching facilities must be a responsibility of the federal government. However, the scientific experiment (for which the launching is necessary) should continue to be the prime responsibility of the principal investigator.

83. The present and projected funding of research in the universities does not indicate a significant expansion into the more expensive activities based on rocket and satellite techniques. Federal funds spent directly in universities on space research amount to only a very small fraction of those spent in government laboratories for this purpose. At the same time it is argued that the expenditure per researcher in government laboratories is very much higher than in universities. It is difficult to make a meaningful comparison, since the universities draw heavily on other sources for salaries and overhead, and part of the government in-house expenditures indirectly supports university research. It is claimed that present and anticipated funding is not sufficient to maintain a meaningful laboratory research program for a professor and his students. It would appear, however, that typical grants for space research are already as much as three times the general level of grants in other fields, and where rocket experiments are involved the total cost is very much more. If a significant part of the program is to use rockets and satellites, a very substantial increase in the level of support must be anticipated.

84. The expected growth rate of the universities is well known. The predicted growth in the number of staff members doing space research in the years to 1971 represents an increase of 150 per cent. This is perhaps not too unrealistic but, coupled with the need for a higher level of funding per research worker, a very significant expansion of the total financial support will be required.

85. An important development in recent years has been the establishment of University Institutes for space research. These occupy a position somewhere between the rather restricted laboratory and research facilities of a conventional university department and the commercially oriented research laboratories of industry. They permit the concentration of several disciplines and the assembly of all necessary facilities (many of which are special to

space problems) for a continuous research and development program. They provide a centre for advanced studies but in addition to graduate students they can involve undergraduates, particularly during the summer, thus stimulating recruitment to the new field of space studies.

86. While these institutes have built up excellent reputations as centres of space research they also become centres of technological development and sources of extremely valuable technical skills. Their relation to the parent institution guarantees their academic function and continuity of management, while the degree of independence they possess permits a more continuous pursuit of a given project and the possibility of contracting for the performance of individual projects. The continued existence of such institutes appears to depend upon the development of a method of financing the overheads for buildings, equipment, and basic salaries independent of grants to individual research workers for specific projects. Notable examples of such institutes are: the Institute of Space and Atmospheric Studies of the University of Saskatchewan, the University of Toronto Institute for Aerospace Studies, and the Space Research Institute of McGill University.

87. An impressive list of the space research projects of Canadian universities appears as Appendix C of the Chapman report. While the bulk of the activity is concentrated in the three Research Institutes referred to above, several other universities have active programs. A most significant indication of university activity and of the prospective supply of professional research workers in the space field is the number of graduate students in space research programs. These total 175, as follows:* University of Toronto (UTIAS)—50; University of Western Ontario—24; McGill University (SRI)—23; University of Saskatchewan (ISAS)—21; University of Calgary—12; York University—12; Laval University—8; University of British Columbia—5; others—20. The professional staff involved in the universities is about 75 while the corresponding number in government departments and industry is some 112. If it were inferred that about 50 graduate students would join the professional team per annum the rate of increase of 20% to 25% would appear reasonable, but this obviously depends on the maintenance of active programs.

Rocket and Satellite Technology

88. The major Canadian rocket development and production activity has been the Black Brant development on the part of Bristol Aerospace Ltd., with the close cooperation of the Canadian government (7) through the Canadian Armament Research and Development Establishment of the Defence Research Board, and the Department of Industry. The Bristol Company has established a plant at Rockwood, Manitoba, for the manufacture of solid propellants, which is capable of producing 2.5 million pounds of propellant annually. Black Brant rockets are being used for the Canadian research program, and have been sold to organizations in the United States

*Source: Physics in Canada; Science Secretariat Special Study No. 2, p. 130.

and the German Federal Republic. Over a hundred Black Brant rockets have been flown, with a high percentage of successful flights. Current sales of Black Brant rockets and services are running at a level in excess of $2 million per year.

89. The Churchill Research Range (2) was first used for scientific rocket-borne experiments during 1956 in preparation for the International Geophysical Year, and was operated by the United States Army for the joint benefit of American and Canadian scientists. It was reopened in 1962, under the management of the Office of Aerospace Research, United States Air Force. In 1965 a new agreement provided for its transfer to civilian agencies and for its management by the National Research Council of Canada. The cooperating agency of the United States is the National Aeronautics and Space Administration.

90. In the first six months of 1966, 53 small 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 three launchers for larger solid fuel rockets, one for liquid-fuel rockets, and one for the meteorological sounding rockets. Three sophisticated radars keep track of the rockets during flight and a doppler velocity and position system can also be employed. Data from rockets are received at the main and backup telemetry stations. Nosecone 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 Fort Churchill for smaller rockets and for recovery of payloads, while much of Hudson Bay is available for the impact of larger, higher altitude rockets. Although facilities for the actual launching are approaching the stage at which small satellites may be orbited, facilities for guidance and control would need considerable development before a rocket payload could be launched into orbit.

91. The HARP-McGill program, which is now centred in the Space Research Institute of McGill University, started early in 1962 as an engineering research effort to utilize large-bore guns to launch projectiles to high altitudes. (HARP stands for High Altitude Research Program). Work began in the McGill University Department of Mechanical Engineering, with a contract from the United States Army Ballistics Research Laboratory. A 16-inch vertically firing gun was installed on the island of Barbados, and firings commenced early in 1963. The projectiles or vehicles were designed at McGill University and fall into two categories: ballistic glide vehicles and rocket vehicles. The development of the ballistic glide vehicle has been quite rapid. Over the past two years about 100 to 150 firings per year have been conducted with a vehicle which can carry a 30-lb. payload to altitudes of 165 kilometers. The main unknown with rocket vehicles is the ability of the payload instruments to withstand the high launch accelerations. The early rocket program was devoted to this problem for solid propellants, and a range of sub-calibre vehicles were fired. By 1965, solid propellant rocket

motors had successfully withstood launch accelerations as high as 11,000 g. Work is now progressing on the more advantageous full-bore rocket vehicles. One is a 16-inch vehicle capable of firing 200 pounds of payload to an altitude of 700 nautical miles.

92. Future gun-launched vehicles are planned to have orbital capabilities. One vehicle is sub-calibre and will carry a 350- to 400-pound two-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-pound payload may be orbited by this method. A second vehicle is a full-bore three-stage rocket, capable of orbiting 60 pounds at 300 miles, in an all-solid propellant version, or 100 pounds at 300 miles with two liquid propellant upper stages.

93. The Canadian Government joined the HARP-McGill program in 1964, and funding (5) was increased substantially by a sharing arrangement between the United States Army and the Department of Industry. 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 United States Army will have invested $3,716,000.

94. A considerable capability in satellite technology has been acquired through the design and development of the Alouette-ISIS satellites. Starting in government laboratories the work was later contracted to the RCA Victor Company in Montreal and the de Havilland Company in Toronto, with the result that a satellite manufacturing unit now exists that is capable of designing, constructing, and testing complex spacecraft of moderate size. Over the past six years RCA Victor has performed space work for 31 separate agencies to a total value of almost $29 million. Almost $9 million of space work was performed by the company in 1965.

95. The de Havilland Company of Canada Limited has carried out over $6 million of space business in the past seven years, of which $4.3 million was for export. The company has manufactured spacecraft frames for the Alouette and ISIS satellites; is associate contractor on the ISIS program; and has marketed STEM (storable tubular extendible member) devices, mainly in U.S.A., for over 100 satellites, for use as antennas, gravity-gradient stabilizers, etc.

96. Computing Devices of Canada Limited has participated in space work for over a decade. The company is manager of the HARP Barbados range, has established a light gas gun range at Stittsville near Ottawa, has developed instrumentation for use at high accelerations, and has contracts to operate telemetry and control facilities for the Alouette satellites at the Defence Research Telecommunications Establishment.

97. A number of other companies have participated in space work: Aviation Electric Limited, EMI Cossor Limited, Canadair Limited, CAE Industries Limited, Canadian Westinghouse Limited, Sinclair Radio Laboratories Limited, Ferranti-Packard Electric Limited, Barringer Research Limited, Canadian Industries Limited, and Atomic Energy of Canada

Limited. Some of these programs have been research or development sharing programs, some on HARP or domestic space projects, and some for 'export'.

Satellite Communications

98. The potentialities of satellites for long distance communications, particularly across the oceans, were quickly recognized. Many technical problems can be overcome by transmitting a message to a relay station in space which is equipped with energy sources to transmit the message back again to a point on the earth that may be a few thousand miles away from the point of origin. Satellites in various orbits can be used, but the transmitting and receiving stations must be equipped to follow their movements. By placing a suitably equipped satellite in orbit above the equator at approximately 22,000 miles, it becomes stationary with respect to the earth. However, there is only one orbit for geo-stationary satellites, and in due course it could become overcrowded. There is a need for careful planning and control of its use. Although the orbit passes only over the equatorial countries, it must serve the whole world.

99. Following the early success of the "TELSTAR" and "RELAY" satellite communication projects, Canada entered into an agreement with the United States under which Canada would participate in the testing of experimental communications satellites launched by the National Aeronautics and Space Administration. The agreement included a commitment to build the experimental communication satellite ground station near Mill Village, Nova Scotia, approximately 80 miles southwest of Halifax. This station may be expected to play a significant role in the development of domestic satellite communications (10).

100. The Communications Satellite Corporation (COMSAT) was established in the United States following the passing of the Satellite Communications Act by Congress in 1962. The United States then took the initiative for the establishment of an international organization for the purpose of building and operating a global satellite system. At that time much consultation on the subject had already taken place between Britain and European countries. Agreements were arrived at as a result of intense activity on the part of a group of 12 countries (including Canada) which had, in 1964, the largest overseas telephone traffic. The agreements were opened for signature by any member of the International Telecommunications Union, in August of that year. The main feature of these arrangements was the establishment of an Interim Communications Satellite Committee to be responsible for establishing the space segment of the system, coordinated with separately owned earth stations.

101. This global organization for international telecommunications satellites is now commonly referred to as INTELSAT. It is financed on an international basis with investment roughly in proportion to overseas traffic. Canada has an investment quota of 3.75 per cent in INTELSAT and has a seat on the interim committee, being represented by the Canadian Overseas

Telecommunication Corporation, while an engineer from the Department of Transport also participates in the Technical Committee of the Interim Communications Satellite Committee. Under the present arrangements the United States has a dominant position in INTELSAT, with a quota of 56 per cent. Any country or combination of countries with a quota of more than 1.5 per cent is entitled to a seat on the interim committee. To avoid complete United States domination, certain important questions can only be decided by the vote of the largest quota owner plus the votes of other countries with quotas totalling 12.5 per cent.

102. A possible difficulty in the early organization of a global satellite communications system is the peculiar status of the private company, COMSAT, which acts in three different capacities: as manager for the Interim Communications Satellite Committee; as United States representative on it; and as a United States common carrier company subject to the jurisdiction of the Federal Communications Commission. It appears unavoidable that a conflict of interest will arise. Inherent in this arrangement is also a tendency on the part of other committee members to be especially skeptical regarding COMSAT's ability to maintain an objective point of view on questions where political or economic interests of the United States are involved.

103. The Canadian Overseas Telecommunication Corporation (under an agreement with the Department of Transport) is now operating the Mill Village station commercially in cooperation with the American station at Andover, Me., which hitherto carried all the United States and Canadian commercial communication satellite circuits to Europe. The number of circuits is now only about 100, since there is still spare cable capacity. However, the demand is increasing rapidly. The total number of trans-Atlantic circuits estimated to be required by all countries by 1970 is some 3,000 to 4,000 as compared with about 600 today. At the European side the operations are shared between four ground stations in Britain, France, Germany, and Italy.

104. For a country of the size of Canada, internal or domestic telecommunications by satellite become of great importance. Ordinary telephone, telegraph, and data communication could now be extended by satellite to remote communities that are not now served by effective systems. The ground stations required would also be capable of receiving television and radio programs from the satellite for retransmission through local broadcasting facilities or over a cable distribution system. This type of satellite system would not broadcast programs directly to homes: the receiving equipment is at present too expensive for direct individual use by the general public.

105. A television 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°N latitude. For the first time it would become possible to provide a truly national television and radio program service to people in all parts of Canada. Such receiving and rebroadcast facilities may

be economically practicable for communities having as few as 300 inhabitants, but the opportunity would still exist for making the service available in smaller communities if national or other considerations made this desirable. It is possible that individual schools could be equipped for direct reception of educational television programs. It would of course be necessary to broadcast both radio and television to meet the needs of several time zones.

106. The consensus of various telecommunication authorities in the U.S.A. and Canada would appear to be that direct broadcasting to home television receivers from communications satellites is not immediately feasible with the power levels now available. The possibility that broadcasting of frequency-modulated radio programs directly to home and automobile receivers may be introduced within a few years, is much greater. 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. Equally it would be possible to transmit propaganda.

107. Most of Canada's long distance general telecommunications traffic is in an east-west direction. It would appear that circuits provided via satellites would be more economical than long-distance service provided over terrestrial radio relay systems for distances above 1,500 miles. Traffic over the existing transcontinental radio relay systems is increasing rapidly. A satellite communication system could provide bulk service between major cities. It might, for instance, be feasible to carry 600 or more circuits from Montreal to Winnipeg or Vancouver by satellite as the next stage in the expansion of the transcontinental systems.

108. The type of satellite circuits being discussed for domestic telecommunications would employ geo-stationary satellites in an equatorial orbit. A domestic satellite communications system would be capable of carrying all forms of telecommunications: telephony, telegraphy, Telex, television 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 are prepared to use or even provide satellite circuits for television distribution independently of the common carriers. A number of proposals have been advanced by several interests, but to date there has been no decision as to who may own or operate satellites and satellite systems.

109. Canadian manufacturing companies in the electronics and communications field have a competence equal to any in North America. Past accomplishments of Canadian manufacturers have demonstrated a capability to manufacture all elements of a domestic satellite communications system. The type of research, development, and manufacturing activity involved in the relatively small scale production of satellites and associated equipment is well suited to the pattern of Canadian industry. If from the very beginning

Canada handles her share of the international systems and all reasonable parts of the domestic system, there could be great benefit to the use and development of her industrial skills and to the competitive position of her industry. International cooperation is necessary and desirable in the launching of satellites, but the same principle of cooperation should make available to Canada a fair share of the industrial production, employment, and national income stemming from this new development.

REPORT NO. 1

SCIENCE COUNCIL
OF CANADA

A Space Program for Canada