SCIENCE COUNCIL OF CANADA

Report No. 4

Towards a National Science Policy for Canada

OCTOBER 1968

©Crown Copyrights reserved

Available by mail from the Queen's Printer, Ottawa,
and at the following Canadian Government bookshops:

HALIFAX
1735 Barrington Street

MONTREAL
Æterna-Vie Building, 1182 St. Catherine Street West

OTTAWA
Daly Building, Corner Mackenzie and Rideau

TORONTO
221 Yonge Street

WINNIPEG
Mall Center Building, 499 Portage Avenue

VANCOUVER
657 Granville Street

or through your bookseller

Price: 75 cents Catalogue No. SS22-1968/4

Price subject to change without notice

ROGER DUHAMEL, F.R.S.C.
Queen's Printer and Controller of Stationery
Ottawa, Canada
1968

October, 1968.

The Right Honourable PIERRE ELLIOTT TRUDEAU, P.C., M.P.,
Prime Minister of Canada,
House of Commons,
Ottawa 4, Ontario.

Dear Mr. Prime Minister,

In accordance with the provisions of sections eleven and thirteen of the Science Council of Canada Act, I have in the past forwarded to you reports from the Council covering a number of specific areas of Canadian science. I now take pleasure in forwarding to you the Council's recommendations on some broad goals and emphases for the future development of Canadian science in the report entitled "Towards a National Science Policy for Canada". It is the Council's hopes that these recommendations will lay a firm basis for the evolution of a comprehensive national science policy for Canada.

The report lays special emphasis on the role of science in helping to solve several of the important social and economic problems that now confront the nation.

Yours very truly,

O. M. SOLANDT,
Chairman.

CONTENTS

PAGE

SUMMARY 1

SECTION

1. Introduction 3
2. Some definitions and concepts 7
3. National Goals as a Framework for Policy 13
4. Past Trends in Funding R&D in Canada 19
5. General Consideration of the Organization of Science and Federal Support Programs 23
6. The Concept of Major Programs 29
7. Specific Areas for Action 35
   - (a) Prototype Major Programs 36
   - (b) Areas for Immediate Planning 38
   - (c) Areas for Continuing Consideration 46
8. Manpower 49
9. Expenditures 51

APPENDIX: Notes and References 55

SUMMARY

In publishing this report, the Science Council is attempting to lay down broad guidelines for the future use and development of science and technology in Canada. The recommendations made represent the first steps toward the formulation of a comprehensive national science policy and pay particular attention to the role which mission-oriented programs can play in shaping the growth of Canadian science. In this document the Science Council has elected to concentrate on science and technology as they are harnessed to serve the nation, and consequently little is said of the important positions which basic research and "Little Science" must continue to play in Canada. It should also be noted that the action proposed has far-reaching implications for the development of the social sciences and the Council would support all efforts to promote expansion of the nation's activities in these sciences.

Science and technology affect society and the economy in two different ways. On the one hand they are all pervasive and can affect almost every activity in some way, and the health of our economy will depend partly on how widely science is used in this broad way. On the other, they can be highly concentrated and can give impetus along some chosen line of action. It is this latter aspect which receives most attention in this report.

It is the opinion of the Science Council that the application of science and technology will make significant contributions to the solution of economic and social problems in Canada and in so doing will contribute to the realization of the goals of the nation. In order to have this happen, changes are necessary. In particular, more emphasis in future must be placed on development and innovation—on using science and technology to produce new or improved goods and services—and more research and development must be done close to the point where innovation will be initiated. This argument leads the Science Council to expect that an increasing share of Canadian R & D will be performed outside government laboratories, by the universities and by all levels of Canadian industry—primary, manufacturing and service.

Throughout the report it is stressed that expenditures on science and technology must compete with many alternatives in the allocation of national resources. It is argued that even on this directly competitive basis the expenditures on science and technology will be selected because of the social and economic benefits that will result.

The report recommends that comprehensive, mission-oriented "major programs" be set up to co-ordinate the efforts of all sectors of the economy and to bring a multi-disciplinary approach to the solution of important national problems. Within these programs the role foreseen for the Federal

Government is predominantly that of initiator, co-ordinator and provider of funds for much of the research and development while the other sectors will be mainly performers of research and innovators.

An existing major program deserving special mention and continuing support is that in Nuclear Power. Two prototype programs, covering Canada's interests in Space and Water Resources management and development, are ready to start immediately and should be supported. The Science Council is establishing task forces to prepare detailed plans for major programs in four areas—Transportation, Urban Development, Computer Applications, and Scientific and Technical Aid to Developing Areas. The report lists other areas which are expected to figure prominently in the next round of planning activities.

The Council has had preliminary investigations made into the supply of manpower expected in Canada and the possible expenditures on research and development over the next decade. These indicate that the demands on Canada's manpower and financial resources which will be made by the major programs should not be excessive and that they could be met if the nation decides to do so.

Section 1

INTRODUCTION

The rapid growth of science and technology in today's world is clearly recognized as one of the major forces leading to change in contemporary society. It is becoming rapidly more evident that in an era when science and technology are expanding so quickly, change becomes the natural state of human society, and that the institutions and patterns of social organization which characterize that society must either adapt to this change or disappear.

Not many years ago, the average citizen and most people in government and industry regarded science as an interesting and important phase of human activity, but one which did not touch their lives closely. Today almost everyone recognizes that many of the changes, both for better and for worse, which have come about in their lives have been initiated by science. People everywhere have come to fear the growth of science as the source of new weapons to destroy them, of automation which will leave them unemployed and in poverty, and of a technologically-dominated social structure that will leave scant room for man's nobler aspirations. Nonetheless, these same people hail science as a benefactor contributing in a major way to better health, to the removal of drudgery, and to many improvements in the quality of life. With this realization of the way in which science and technology permeate almost every aspect of modern industrial society has come a need for understanding the actual and potential roles of science in society and for evolving policies to guide its use and development. The task of the Science Council is to try to evolve such general policies for Canada.

Obviously, a complete and coherent policy for the use of science in Canada would be almost as complex as a similar statement of policy for the development of Canadian society as a whole. Consequently, what the Science Council, with the support of the Science Secretariat, has done is to attempt first to obtain a broad general picture of how science is in fact being used in Canadian society, and then to seek ways in which this use could be improved or supplemented. The results to date of this study are summarized in the present report.

This first policy report does not catalogue all of the ways in which science can be effectively used in Canada, nor does it attempt to provide any comprehensive list of priorities. Its emphasis is on those directions in which change is obviously needed and it recommends action which can be expected to induce the desired alterations.

In this report, the Science Council will make scant reference to two important aspects of science. First, science challenges and satisfies man's

creative intellectual urge to explore and to understand his environment and as such is one of man's greatest cultural expressions. Second, there is "Little Science"—the individual scientist pursuing his interests in research in areas of his own choosing. The number of scientists who follow this course in any generation is small, but their contribution to knowledge has been high and the cost of supporting them, modest. No nation can afford not to support these people.

This policy statement is concerned principally with the major areas in which society has a need to know more and therefore is looking to the scientist to provide answers to questions which, themselves, are at times poorly articulated. The absence of emphasis on the two aspects mentioned above should not be taken as a denigration of their importance but as an acknowledgment of the greater need which Canada has for a policy for the rational development of those areas of applied science on which our society depends.

The Science Council is quite conscious of the fact that many members of Canada's scientific community expect that this first policy report will seek to establish short-term priorities for Federal scientific programs which in turn will give specific guide-lines for planning and budgeting. It must be clearly understood from the outset that the Council has not attempted to do this but rather has sought to provide strategic advice on the development of science on a national, rather than simply Federal Government scale. If the recommendations of this report are followed, then officials in the Federal Government responsible for science will be able in future to decide upon short-term priorities in the light of the long-term goals proposed by the Science Council.

A study of Canada's record in the use of science indicates that there is no need to be apologetic about past performance or to be revolutionary about the approach to the future. Rapid evolution rather than revolution should be the keynote.

Experience and analysis indicate that Canada's past major concentration of the performance of research and development in government laboratories is no longer necessary. In future a role of growing importance for government should be the initiation, co-ordination and financing rather than the performance of research. New scientific activities should no longer automatically first appear in government departments or agencies; a detailed consideration of the ultimate aims and time scale of each program will indicate how the activity will best be divided between the sectors of the scientific community.

In the past there has been a tendency to fail to carry work through from research and development to production and use. This report proposes the initiation of a series of major mission-oriented programs to be guided, financed and co-ordinated by the Federal Government, but to involve every appropriate sector of the scientific community and to be planned so that they will culminate in the production and use of goods and services. Major

emphasis must be placed on the importance of using science and technology effectively in support of the nation's social and economic goals. Applied research has become an indispensable activity of modern industrial society but, unlike fundamental research, it must never be regarded as an end in itself. Applied research, development and innovation are complex and costly activities which make great demands on public financing, and can only be justified to the extent that they contribute to the realization of the aspirations of those providing the support. The *First Annual Report*[1] of the Science Council contained the warning that

> "we must be sure that enough of our research and development effort is successfully directed toward profitable projects to ensure the continuity of the production which supports all our research. Research is an exploration into the unknown, and many of its activities must necessarily prove to have little immediate applicability. However, if our industry becomes unprofitable there will be no money for any kind of research. Therefore, where the results of research are not expected to be tangible or immediate, the advisability of investing in it will have to be scrutinized with greater care. It is one of the main jobs of the Science Council to see that the balance in Canada's research effort is such as to keep the economy healthy and growing, and the scientific community strong and active."

This concern for the social and economic uses of much of Canada's science has led the Science Council to its belief in the need for the establishment of comprehensive mission-oriented programs, aimed at solving some nationally important problem. While the programs will have significant research elements, their fundamental aim will be the implementation of solutions to national problems, and not simply the performance of research. This emphasis however does not mean that these programs are more important than basic research, but rather highlights the Science Council's opinion that changes are more urgently needed in Canada's applied science than in its efforts in the field of basic research. The Science Council would recommend that basic research continue to be supported at an expanding rate, as it has been in the past, and to have it flourish both as "curiosity-directed research" and as "mission-oriented basic research" in fields of general interest and importance to the major programs proposed.

As will be seen, the course of action proposed in this report has major implications which spread far beyond the boundaries of the scientific community. The major programs proposed will call on the talents of social scientists, financial experts and management specialists, as well as natural scientists and engineers, and the programs must be supported by aggressive marketing if they are to realize the full potential of their contributions to the nation's economy. It must therefore be understood that the Science Council's emphasis in this report on science and technology is in no way intended to diminish the importance of the contributions which will be needed from these other areas. Indeed, it may well be the case that in some areas, for example in the fields of "social technology" or in the enhancement of the quality of management, there may be as great a need to strengthen Canada's national resources and capacities as in the areas discussed at length in this report.

Section 2

SOME DEFINITIONS AND CONCEPTS

Throughout this report "science" is taken as meaning "man's accumulated and systematically arranged knowledge about himself and his world and the research by which he continually adds to this body of knowledge" and "technology" as "the body of scientific knowledge that has been effectively adapted to practical use and is fully available to meet man's immediate needs".

The activities which either generate this knowledge or seek to implement it, and that are most often discussed in this report, are:

(1) *Basic or Fundamental Research* which is a generalized search for new knowledge without specific application in mind, and which is one of man's crowning cultural achievements. Any piece of basic research is judged on the contributions which it makes to the conceptual development of science.

(2) *Applied Research* is the search for new knowledge to provide a solution to a specific problem which is defined at the outset of the research program. It does not differ radically from basic research in methods or scope, but in motivation. Applied research programs must be judged by their relevance to the pre-selected objective.

(3) *Development* is really a final stage of applied research which is most clearly seen in the evolution of new goods or services. It is a costly activity in as much as the building of prototypes, the construction of pilot-plants or the conduct of full-scale trials are costly undertakings.

(4) *Innovation* is the practical implementation of the results of research and development to provide new or improved goods or services. Innovation is often a capital-intensive activity since new production facilities are often required. In deciding to undertake programs of development and innovation, the expenditures foreseen must be weighed against the probability of achieving economic gain or social benefit.

These activities have no distinct boundaries, but merge into each other and are part of what could be considered a "spectrum of scientific activities". A further component of this spectrum, which is barely referred to in this report, consists of the "*scientific services*" such as geological surveying or meteorological services. Because of Canada's great size, the peculiarities of her geography, and the importance of natural resource development to her economy, these scientific services are more important to Canada than they

are to many other nations. The usual definitions of research and development exclude these activities and this has left them outside the scope of many research and development incentive schemes. It would be unwise of Canada to continue this practice and to ignore the importance of these services.

This report lays stress on the value of comprehensive *mission-oriented programs* as necessary parts of the development of Canadian science. Each must contain healthy components of fundamental research, applied research, development and innovation. Fundamental research should be undertaken in fields generally allied to the principal mission, supported not only as a possible source of new and vital discovery, but also as a means of comprehending and absorbing advances made elsewhere in the world; the components of applied research, development and innovation should emphasize the full deployment of the new technology throughout the economy, to ensure maximum benefit from each program.

Scientific and technological activities within a single nation do not exist in a vacuum. They are parts of an international system and the knowledge which they generate flows remarkably freely within the system. Because only a small fraction of all the world's research and development will be performed in Canada, Canada must import much of the scientific and technical information which will be used here. This calls for an efficient and highly developed scientific and technical information system and a study of Canada's needs in this respect, being carried out under the auspices of the Science Secretariat, is already at an advanced stage. This however is part only of the larger problem of providing all types of information—on business, finance, education, in fact on all facets of organized life—since modern society is dependent upon information. A specific and important task of any information system will be to serve the needs of industry, and in this one must never forget the vast number of commercial, manufacturing and service organizations in Canada which at present do not support any research or development activities at all. However, no system, no matter how sophisticated, will be of any use unless industry is prepared to utilize the information that the system provides.

While much information flows freely in the international scientific community, the volume of "proprietary" information being generated annually is increasing, and in some cases foreign technology can be obtained only by trading and not by purchase. One reason for supporting R&D in this country is therefore to place Canada in a favourable bargaining position in this "information" market.

The problem of defining the costs and benefits of any applied scientific activity is complex, since both costs and benefits can have economic, social and cultural dimensions, but the problem is central to any science policy.

The initial economic cost of a program of research and development—in terms of the funds, facilities and manpower invested—is perhaps the least difficult component of the total cost to evaluate, but other costs are equally

real. Technological change has its corollary in obsolescence and so there are the continuing costs of that obsolescence which follow on the heels of successful innovation.

The rate of modern technological change is itself the source of an important social cost. Society and its institutions do not appear able to evolve rapidly enough to keep pace with technology—they respond to technological change too slowly to avoid the strains imposed on our civilization by new inventions. Too often organizational changes are made to redress the mistakes of the past instead of being designed to cope with the progress of the future. When a nation embarks on a course designed to promote scientific activity, it cannot expect to use yesterday's institutions to direct tomorrow's programs.

The benefits generated by scientific activities are many and diverse; they can be intellectual and cultural, economic or social; they can influence the health or security of the nation; they are often interrelated and to most can be ascribed some economic measure, no matter how indirect, but caution should be exercised in attempts to evaluate all benefits in solely economic terms.

Discussions on costs and benefits of scientific activities are useful in their proper context, but tend to lead to too narrow a consideration of the way in which science affects society as a whole and the economy in particular. From the broader point of view, science affects the economic and social life of the nation in two ways. On the one hand it is all pervasive and is diffused throughout the fabric of society and the economy, while on the other it can be concentrated and can provide strong direction along a particular course of action. These have been characterized as the "horizontal" and "vertical" effects of science.

From the "horizontal" aspect, science can become an important factor in every imaginable endeavour and probably every endeavour can be improved by the better application of science. However, there are few programs of national importance which can be considered solely from the point of view of science and therefore, if such undertakings are to be as effective as possible, it is important to ensure that science is not only well used but also well integrated with the other activities encompassed by the program. To have science deployed to best advantage in Canada it is important that all Canadians, whether scientist or not, appreciate the value of science, that scientists better recognize and accept the large economic role and responsibility of science and that government and industry in particular recognize the value of scientists in many activities which stretch far beyond the research laboratory.

From the "vertical" point of view, science can provide the focus for concentrated attempts to solve many of society's pressing problems, and it is this aspect which is particularly discussed in the present report. One objective of the programs proposed now by the Science Council is to emphasize the improvements required for the effective development and use of science

throughout the economy and to demonstrate how this can be achieved. It is important to remember that the effectiveness of science in fields outside the "missions" proposed must remain of equal concern to Canada.

In seeking solutions to the nation's economic and social problems, the policy-maker should always consider scientific research and development as one possible allocation of the resources available for the tackling of these problems, and the costs and benefits of a scientific approach must be weighed against those of any alternative means of seeking the desired solution. The extent to which science can provide the solution will vary with the problem, but the Science Council believes that research and development, followed by innovation, will be useful and often indispensable for the attack on almost every major problem.

When it has been decided to allocate funds to science in a given program, one further important question of policy must be resolved. The level of investment in original research and development within any particular program should be evaluated against the comparative economic and policy value of borrowing or buying technology from external sources. However, from the national standpoint, it must be recognized that a degree of independence may be worth some added financial cost, and from a practical viewpoint, it is important for the buyer to be knowledgeable in the related technology in order to purchase intelligently.

The Science Council has had a series of background studies carried out to examine some important questions which underlie policy for science and technology. Brief reports on three of these studies—on manpower, on expenditure projections, and on the inflation/sophistication factor as an element in rising R&D costs—are being published separately[2].

Another difficult problem which has been studied by both the Science Council and the Economic Council is that of identifying any firm relationship between the performance of research and development and economic growth. One apparent correlation which has been suggested[3] relates the export performance of particular industries to their level of R&D activity, whether measured as a function of the manpower employed or the money spent, but this argument has been challenged[4] by those who argue that government support of R&D is a subsidy to the industries involved. While those economists interested in this complex question continue to search for a means of quantifying the contributions to economic growth which stem from R&D, the Science Council believes that it would be unwise at present to lean too heavily on what at best are partially-evaluated theories. Since economic studies to date provide no detailed prescriptions for science policy the Science Council has had to rely on its own informed judgement in arriving at the recommendations in this report.

The Science Secretariat, with expert economic assistance, is continuing a study of the relationship of R&D to economic growth and will publish any significant findings but, in the interim, the layman who seeks an introduction to the complexities of the question can consult the chapter on "Science,

Technology and the Economy" in the *Fifth Annual Review* of the Economic Council.

A continuing study of these basic problems which underlie the formulation of a science policy will remain an important part of the Science Council's future program. The Council is encouraged to see that a number of Canadian universities have embarked on studies of this kind and it is hoped that these activities will continue to receive the necessary support.

Section 3

NATIONAL GOALS AS A FRAMEWORK FOR POLICY

Before the Science Council could construct a sound policy for the use and development of science in Canada, it had first to erect a frame of reference for this policy. Starting with the axiom that the value of any scientific enterprise to a society is determined by the social, cultural and economic goals that that society seeks, such a framework could be built in four stages, following in logical order:

(1) identifying a set of goals which, while not comprehensive, appeared to contain the main aspirations of most Canadians;

(2) identifying the various factors on which the ultimate attainment of each goal will depend; in most cases these factors can equally well be considered as elements of the main goal;

(3) identifying the contributions that science and technology can make towards the attainment of the goals; and

(4) identifying the conditions that will permit these contributions to be made.

Six goals were chosen to provide this focus for policy discussions:

—National prosperity.

—Physical and mental health and high life expectancy.

—A high and rising standard of education, readily available to all.

—Personal freedom, justice and security for all in a united Canada.

—Increasing availability of leisure and enhancement of the opportunities for personal development.

—World peace, based on a fair distribution of the world's existing and potential wealth.

It is not suggested that this list is in any way complete, nor that the short notes which follow make up an essay on national goals; the comments on each goal are provided only as a brief outline of the frame of reference for the recommendations which are made later in this document.

GOAL 1: NATIONAL PROSPERITY

Elements of the Goal[5]

—High rate of economic growth.

—Reasonable price stability.

—Equitable distribution of rising income.

—Viable balance of payments.

—Full employment.

—Reduction of regional economic disparities.

Contributions of Science and Technology

—Increased industrial productivity, without which the nation will not be able to afford to expand its attempts to deal with mounting social problems. Contributions to productivity in manufacturing industry are perhaps the most obvious, but improvements in productivity in Canada's primary industry should release manpower to still more productive sectors of the economy, and increased productivity in non-profit service industries (health care, education) is also needed to reduce costs.

—Innovation, in selected manufacturing and specialized service industries that have inherent comparative advantages in a Canadian setting to improve their competitive position in international trade.

—Continued improvement in the management practices in Canadian industry, for example by more extensive and effective utilization of computers by management.

—Improvement of the efficiencies of the services industries, particularly in distribution systems.

—Development of sound programs for the use, conservation and replenishing of resources.

—Development of techniques for rational decision-making on complementary activities, such as the balancing of different kinds of food production against each other, or in the choosing between the exporting of raw materials and the processing of those materials in Canada.

—Reduction of costs of many basic elements, such as energy, housing, transportation, communications, as a contribution to improving the standard of living and to the maintenance of overall price stability.

—The development and application of new technology, for example in improving communications and transportation systems, as a contribution to efforts being made to reduce regional disparities of productivity and income levels.

—Better understanding of motivational factors that influence industrial productivity.

GOAL 2: HEALTH

Elements of the Goal

—Provision of medical services of rising quality and efficiency.

—Improvement of the environment in which Canadians live.

—Development and improvement of practices conducive to public health.

Contributions of Science and Technology

—Continued medical research to ensure that the standards of training and practice in Canada's health professions are of a quality that is high by world standards.

—Application of systems science to the provision of medical and other health services, particularly hospital care, to improve the efficiency of these services and to reduce their relative costs.

—Studies of individual and group behaviour in relation to physical and mental health.

—Improvements in the conditions of urban and rural life, to remove threats to both physical and mental well-being.

—Control of existing and threatened health hazards already created by the misuse of science and technology—e.g. pollution.

GOAL 3: EDUCATION

Elements of the Goal

—Opportunities for education of high quality, at all levels from elementary through to post-doctorate and including all forms of post-secondary training, should be readily available to all Canadians, to the limit of their individual abilities.

—Opportunities should be available for upgrading the education of adults, to assist those who have been by-passed in their youth and to allow others to keep pace with advances in their specialized fields.

Contributions of Science and Technology

—The continued provision of opportunities for first-class basic research in the universities as a vehicle for graduate teaching.

—Improvements to the quality of teaching at all levels.

—The application of the scientific method to studies of the current system of providing education.

—The introduction of a scientific curiosity-directed approach into all levels of education as a means of stimulating thought and creativity, and as a substitute for teaching by rote.

—The application of systems science and other techniques to the process of education, to increase its productivity.

—The development of advanced, computer-based educational aids, to increase the quality of the education being provided.

—At the secondary and higher levels, better understanding of student motivation, to allow educational procedures to be modified so that education can be seen as being directed to attaining appropriate goals for the individual and society.

—The provision of better information services for education.

GOAL 4: FREEDOM, SECURITY AND UNITY

Elements of the Goal

—Promotion of better understanding and co-operation between the different parts of Canada and between Canada and other nations of the world.

—Continued defence of the rights and safety of the individual.

—Improvements in the methods of crime prevention, detection and control.

Contributions of Science and Technology

In this case, much more than in the others, science and technology pose threats to society as well as conferring benefits. On the positive side lie contributions to:

—supporting Canada's national defence by providing the necessary military technology;

—expanding man's capacity to travel, to learn to co-operate, to foresee and guard against dangers and to summon help in case of need;

—improving communication between groups or regions of the country;

—the development of new techniques in criminology and forensic science as a contribution to the battle against crime.

On the negative side, science makes possible coercion, intrusion into privacy and concentration of power on an unprecedented scale. Strong political, moral and personal safeguards against these misuses of science are needed, and technology can contribute to these safeguards.

GOAL 5: LEISURE AND PERSONAL DEVELOPMENT

Elements of the Goal

—Reduction in hours of work and removal of need to perform menial tasks.

—Development of Canada's two principal cultures and of understanding between them to create an attractive and stimulating environment.

—Provision of opportunities for culture, recreation and challenging personal endeavour.

Contributions of Science and Technology

—Satisfaction of man's compelling urge to explore, to know and to understand himself and his universe, which has long been a great source of cultural development, by the promotion of fundamental scientific research as one of man's highest intellectual and cultural achievements and as an expression of creativity of a sophisticated kind. It must be acknowledged that, to many scientists, this idea in itself would rank as a major goal.

—Increased Automation.

—Development of devices to perform menial tasks.

—Development of efficient, inexpensive transportation systems to permit easy travel.

—Development of advanced communications media, which will permit man to widen his horizons immeasurably.

—Development methods to facilitate more widespread Canadian bilingualism.

—Development of the accessories and hardware of modern leisure.

GOAL 6: WORLD PEACE

Elements of the Goal

—International peacekeeping and maintenance of world order.

—Contributions by the wealthy nations of the world to the development of less fortunate nations, particularly by the elimination of poverty and hunger in the short term, and by facilitating the development of self-generating and self-sustaining growth forces in the long term.

Contributions of Science and Technology

—Increasing effectiveness of foreign aid by bringing a complete range of scientific techniques to bear on the problems of specific developing areas.

—Increased understanding of the dietary needs of people in different areas of the world, linked to improved methods of producing the right kinds of food for the hungry of the world.

—Increased understanding of the problems and aspirations of other peoples of the world, through the increasing links in the scientific community such as the international agencies, societies and "International Years" for study of specific problems.

There are undoubtedly many contributions which science and technology can make to these goals which are not listed here, and there are some contributions which affect all of the goals. Among this latter group, one would include contributions to the understanding of population growth and of individual and group behaviour. Given this framework of goals and the need to apply science and technology to their realization, Canada needs an appropriate scientific infrastructure or environment. The Science Council believes that some of the basic prerequisites for success in achieving these goals are:

—an increasing awareness, on the part of the public, government and industry, of the value to society of science and technology, as important means of attacking economic and social problems;

—the effective application of existing scientific knowledge;

—a high level and standard of scientific and technological education as a precondition for upgrading the technical competence of all levels of the Canadian workforce;

—effective participation in the international scientific community, as a means of tapping a vast supply of knowledge;

—effective use of modern information technology and systems.

Having set out a list of Canadian goals and having noted a number of the prerequisites for establishing the kind of scientific environment in which Canada could hope to realize these objectives, the Science Council must add

a note of economic caution. The resources necessary to realize these goals will be substantial and there will be competition between the goals for both manpower and funds in the foreseeable future. The maintenance of a prudent balance of the resources assigned to the various goals will be important. For example, if the allocation of money outstrips the available trained manpower in a particular area, money will be wasted. The reverse is also true. In addition, if health services are developed at the expense of education, the supply of trained minds to support all of the goals would be truncated. However, education must not only be a consumer of resources but must, on the long term, be an investment in the training of the kinds of manpower which will be needed. The Science Council will be considering this problem of resource allocation on a continuing basis.

Section 4

PAST TRENDS IN FUNDING R&D IN CANADA

Much work has been done by various Federal departments and agencies, including the Dominion Bureau of Statistics, the National Research Council, the Department of Industry and the Science Secretariat, in an attempt to provide a picture over time of the way in which funds for research and development are expended by the principal sectors of the Canadian economy. To provide background information for this report the Science Secretariat has produced a compilation of the principal statistics for the perioid beginning in the fiscal year 1957-58, and ending with the most recently published data. The important trends emerging from this compilation are depicted in Figure 1.

Considering first the expenditures by sector of performance of R&D, the effect on gross industrial expenditures of the cancellation of the Arrow program on February 20, 1959, is obvious. Expenditures on R&D in the "transportation" segment of Canadian industry, which contains virtually all activity associated with aircraft development, made up some 51 per cent of all industrial R&D expenditures in the fiscal year 1958-59. In 1961-62 this share had plunged to 9.9 per cent and the latest data, for 1966-67, show that it has recovered somewhat, to become 21.2 per cent of the total. In contrast, the sum of R&D expenditures by all other segments of industry showed increases, of varying proportions, in every succeeding fiscal year subsequent to 1957-58, but these were insufficient to compensate for the drastic cutbacks in R&D in the aircraft industry in the years immediately following the Arrow cancellation.

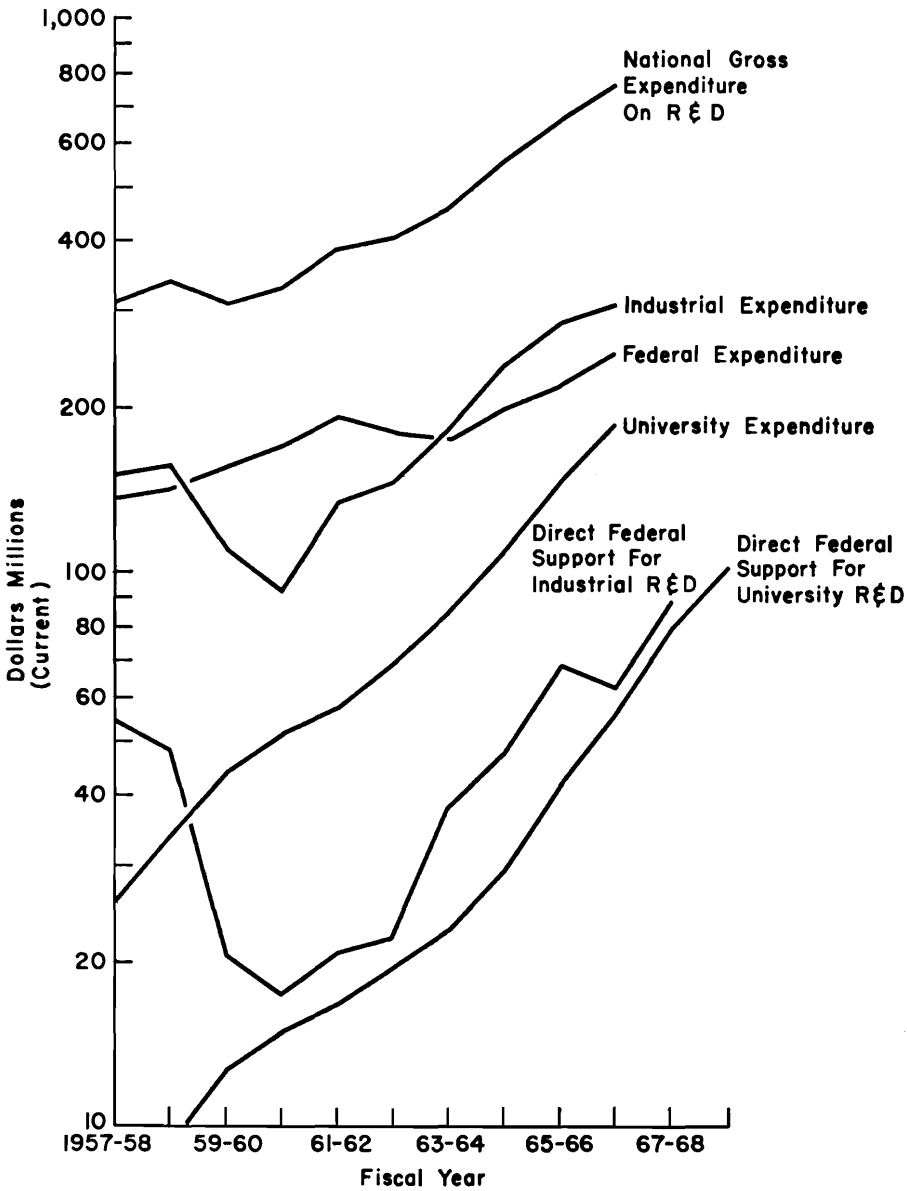
In contrast to the picture presented by the industrial expenditures, the Federal Government's expenditure on its own programs did not show an absolute decline until the days of austerity, starting in 1962. Concern has been expressed that data, presented as in Figure 1, fail to take account of some important contributions by government organizations to industrial R&D, in that some major government procurement contracts, charged as "in-house" expenditures, may well stimulate R&D within the contractor's organization An example would be the fixed-price purchase by Atomic Energy of Canada Limited from Canadian industry of the WR-1 Reactor for the Whiteshell Nuclear Research Establishment in Manitoba which, under the present system, would be labelled an "in-house" capital expenditure. Insufficient information is at present available to permit the identification of all such expenditures which appear to fall in a category which is neither "federal in-house" nor "direct federal support" as this latter category is currently defined.

The "Direct Federal Support for Industrial R&D," consists of grants and contracts to perform specific programs of R&D, provided by the departments and agencies of the Federal Government. No estimate is made of the cost to

the Federal Government of the various tax-exemption programs of the early 1960s which were used as incentives to promote industrial R&D. Once again the cancellation of the Arrow program was the single biggest factor which influenced the total Federal support program. In the fiscal year 1966-67 a cut-back by the Department of National Defence in its R&D procurement

Figure 1

GROSS EXPENDITURE (CURRENT PLUS CAPITAL) ON R & D BY SECTOR OF PERFORMANCE AND DIRECT FEDERAL SUPPORT FOR R & D IN INDUSTRY AND THE UNIVERSITIES[6]



program accounts for the drop in the total, while the upsurge in the following year is in part due to the effects of the conversion of the Industrial Research and Development Incentives Act (I.R.D.I.A.) program from being a tax exemption to a granting program.

Two factors have strongly influenced the growth of university expenditures on research. Enrolments in Canadian universities have been increasing rapidly and the proportion of undergraduates who subsequently enter graduate school has also been rising. This combination of factors has led to the rapid expansion of the research activities of the graduate schools that is reflected in the data on university research expenditures in Figure 1. The Federal Government contributes to the support of this activity in two distinct ways. The direct support, shown in Figure 1, is provided as grants or contracts by the National Research Council, the Medical Research Council and the departments of government with scientific interests. Indirect Federal support, through the fiscal transfer to the Provinces of amounts equal to Provincial expenditures on education, must already pay for a significant fraction of the costs not met by the direct support system.

Figure 1 shows how Canada's Gross Expenditures on Research and Development (GERD) have risen over the period 1957-67. Table 1 records these expenditures as a percentage of the Gross National Product (GNP).

While much attention is often paid to the division of activities among the sectors of the economy, relatively less attention is paid to the way in

Table 1.—GERD as a Percentage of GNP for Canada[e], 1957-67

Item	Fiscal Year									
	1957–58	58–59	59–60	60–61	61–62	62–63	63–64	64–65	65–66	66–67
GERD as a Percentage of GNP	0.95	1.00	0.89	0.89	1.05	1.00	1.08	1.19	1.30	1.33

Table 2.—Current Expenditures on R&D, by Sector of Performance and by Type of R&D Activity
(Percentage Distribution)[r]

Sector of Performance	Type of Activity			
	Basic Research	Applied Research	Development	Total
Government (All levels)	7	23	6	36
Industry	2	12	30	44
Higher Education	13	5	1	19
Private Non-Profit	—	1	—	1
Total	22	41	37	100

which the national expenditures on R&D are divided between basic research, applied research and development. In 1965-66, Canada's *current* expenditures on R&D amounted to some $524.4 million, or 1.01 per cent of the G.N.P. The percentage distribution of these funds, by sector of performance and by type of activity is shown in Table 2. For fiscal 1964-65, the current expenditures in the United States on basic research, applied research and development were respectively 12 per cent, 22 per cent and 66 per cent of that country's total.

While Table 2 is subject to considerable uncertainties in the allocation of expenditures to the different types of activity, it is nevertheless sufficiently accurate to support the argument that Canada has in the past tended to support research but to neglect development and innovation. It is acknowledged that development is the most expensive part of the R&D spectrum; but it is development and innovation which generate benefits. Knowing how to solve a problem is a poor substitute for solving it in practice. In the opinion of the Science Council much more of Canada's future investment in scientific activities must be channelled into development and innovation.

Section 5

GENERAL CONSIDERATION OF THE ORGANIZATION OF SCIENCE AND FEDERAL SUPPORT PROGAMS

A major past failing in Canadian science has been the performance of too much basic research remote from the training of new scientists and the performance of too much applied research far from the point of innovation. This latter shortcoming has been aggravated by a recurrent tendency in Canada to terminate research programs short of the point of innovation, thereby preventing the reaping of any substantial benefits from investments in research.

> **It is recommended that in future every new research or development activity be critically examined at its outset to identify the appropriate organization to carry through the project to its final conclusion. For extensive programs that encompass many individual projects, the distribution of these projects among the sectors of the economy must be carefully considered. Such a procedure may well lead to the universities and industry performing a larger share of the research and development in Canada than has occurred in the past.**

A major aim of the policy being proposed is not to establish more research programs, simply for the sake of doing research, but is rather to choose programs directed to the long-term needs of society and to ensure that those programs which are undertaken, whether new or existing, are carried through to the point of innovation and application in practice. It is recognized that the final stages of development and innovation may involve heavy investment in prototypes or pilot schemes, but the benefits of a program come only from the fulfilment of objectives and the application of results. To reap the benefits that have been missed in the past, Canada must first be prepared to increase its expenditure on innovation. The Science Council is convinced that emphasis on innovation will be a wise investment, and that Canada should be prepared to see the proportion of the nation's total resources allocated to scientific activities increase steadily. However, the allocation of this or that percentage of GNP to research, development and innovation will not, on its own, bring about the answer to all problems or ensure future prosperity. Money invested in research, development and innovation must be wisely spent, and new activities must be established in the appropriate sector of the scientific community. Success in realizing economic returns or social improvements by innovation based on active research and development will depend in large measure on the participation of Canada's primary, manufacturing and service industries.

Throughout this report, emphasis is given to economically-oriented science and technology, especially that related to secondary industry, but this does not mean that other areas, because less extensively discussed, are less important. Science and technology in support of Canada's resource industries, or oriented towards problems in health or welfare, or related to national and international security must be maintained and fostered. They, too, need detailed consideration within any realistic policy.

Canadian industry should give the greatest possible attention to creating for itself a position of comparative advantage over its competitors by imaginative innovation and exploitation of the results of research. By innovation, new markets, particularly export markets, may be captured, productivity can be increased and more advantage may be derived from natural resources. If industry is to do all of this on an appropriate scale, it will require the active assistance of the Federal Government, which must create and stimulate an environment in which commercial initiative can flourish.

It is recommended that the Federal Government

(a) support Canadian industrial enterprise by improvement and expansion of existing R&D incentive programs, by simplifying where possible the administration of the programs, and by deliberately increasing the share of management responsibility placed on the companies involved;

(b) further encourage industrial involvement by contracting out Federal programs where participation is likely to increase the technological or innovative capacities of the companies concerned. The underlying objectives should be to upgrade the overall capabilities of those involved, and ultimately to develop self-supporting research organizations in Canadian industry;

(c) through its mission-oriented departments actively seek to promote industrial and university work in support of each mission as well as responding to initiatives from the private sector;

(d) use government procurement contracts as an additional means of upgrading the technological level of Canadian industry. The provision of modest sums of money, in addition to the cost of the item procured, to be used for either the upgrading of the contractor's productive capability or the funding of continued development of the product being purchased, could be a significant assistance to industry.

There will certainly arise cases where 100 per cent funding by the Federal Government of research programs carried out by industry will be necessary, especially where Canada's competitors for world markets are so funded by their own governments. However, two cautions must be added. **Firstly, the Federal Government cannot be expected to be the sole source of funding for all research and development;**

if industry is to profit from this scientific activity then there is an obligation on industry to make substantial investments of its own funds in research, development and innovation. Secondly, the incentives and contract programs proposed are intended as spurs to the successful, not as crutches for the failing.

The Science Council is anxious to ensure that all important areas of scientific activity are considered for support, so that available funds are used as wisely as possible. As the mission-oriented programs, proposed later in this report, develop they will require the services of and thus provide support for many elements in the scientific community, in the universities, industry and government. However, the mission-oriented agencies will not cover the entire field of science. Complementary sources of funding will be needed to ensure that science as a whole is being developed in a balanced way and that spontaneous originality is encouraged.

The Science Council and Canada Council have together established a committee to review a report on the support of research in the universities which is in preparation. When this report has been studied, the Science Council will be in a position to make more specific recommendations on the co-ordination of mission-oriented and general support for science.

Yet another problem in the development of science in Canada is the tendency of organizations whose missions have been realized, or which have demonstrably failed to reach their objectives, to follow programs which are diffuse and self-perpetuating. There is often a marked reluctance to terminate such programs, even when they are of little priority, as long as the least justification can be found. On the larger scale there is almost inevitable reluctance to close down institutions which are no longer needed, or even to provide them with some new goal which is of real significance. This problem is by no means unique to Canada. A. M. Weinberg, the Director of the Oak Ridge National Laboratory in the United States recently summed up his opinion in the words:

> "What happens to the laboratory when the job of the agency is no longer as important as it was when the laboratory was established? If the government makes a commitment of support to its laboratories as institutions and delegates to the management the responsibility of allocating resources within the institution, it is natural that as the laboratory loses its sense of mission, the management will ensure survival of the institution by drifting into basic research. I believe that this is a phenomenon which one can see in government laboratories in many parts of the world. This drift toward basic research in a mission-oriented laboratory, if allowed to proceed unchecked, could destroy the laboratory's taste and capacity for getting on with practical missions".[8]

This is not attack on the value of fundamental research, which has an important and growing role to play in the universities and as a component of comprehensive mission-oriented programs, but is a criticism of applied research that is labelled as "basic" either because it was initiated with inadequate consideration of its ultimate application, or because circumstances have changed and left its application pointless without bringing an end to the program.

The Science Council has considered the particular status of research and development within government, in the light of the foregoing general criticisms, and *recommends some general principles for the future.*

(1) All Federal Government scientific organizations should be mission-oriented and should be engaged principally in applied research and development, but any development based on government programs which is likely to give rise to marketable products should be transferred to industry at the earliest possible stage. This general principle should apply equally to departmental organizations and to non-departmental agencies. Where this is not the present case, the department or agency should be given a specific long-term mission in which its particular competence can be brought to bear on a problem of economic or social significance.

(2) Federal scientific organizations should have a particular responsibility for fostering the growth of the scientific community within the fields encompassed by their respective missions. They should actively seek to collaborate with industrial and university groups and to an increasing extent should be the initiators and co-ordinators rather than the performers of R&D.

(3) All of the scientific programs of government should be subject to a regular "technical audit" by an appropriate body which should include the users of the information generated by the program. These users will come from government departments, universities and industry. In dealing with departments of government the "auditors" could form an Advisory Committee to the Minister, while for the non-departmental agency they could form either a Board or Council. Irrespective of the organizational structure chosen for any particular case, all of the scientific programs of government should have the benefit of such informed scrutiny.

(4) All scientific organizations, and particularly those with applied missions, must possess an internal flexibility which allows for the easy reallocation of resources in the face of changing program requirements. Each must be capable of maintaining a continuing review of the way in which its allocation of resources matches its goals. Full exploitation of the advantages of the program budgeting system recently introduced by the Federal Government should facilitate this continuing review of internal needs and priorities.

(5) A good mission-oriented program will certainly contain an element of fundamental research in fields closely related to the mission, but there is no formula that can provide the precise proportions in which all mission-oriented programs should be divided between fundamental and applied studies. In many cases the allocation of a few percentage points of the total effort to fundamental science will suffice while in a few special areas, such as nuclear energy, where the frontiers of knowledge are rapidly advancing, a larger allocation can be justified.

(6) The future of all government laboratories at present devoted principally or entirely to fundamental research must be carefully considered, since they constitute a national resource that must not be destroyed by precipitate action. It is the belief of the Science Council that fundamental science must continue to flourish at an appropriate level in Canada.

The Science Council has instructed each of its Special Committees to give particular attention to the role and organization of government scientific activities in its area of interest, in the light of these general principles.

The expectation that industry and the universities will in future perform an increasing proportion of all research and development in Canada in no way denies the need of government departments to perform research and to maintain a scientific expertise. Departments must retain the competence to guide and evaluate scientific programs being carried out by others on their behalf and to perform those tasks which are unsuited to the other sectors. However, it must be recognized that traditional government departmental structures and procedures were not designed to accommodate scientific activities, and that there are administrative complications inherent in operating a research establishment within a public service environment. Policy changes are needed to permit easy redeployment of resources, both of money and staff, in the face of changing program objectives and requirements. The difficulties which at present can be encountered in moving men and funds from old to new programs have only served to stiffen the resistance to change which has been mentioned.

In government, just as in industry and the universities, the quality of R&D programs depend on the quality of leadership and staff involved, and on the freedom for good leaders to pursue their objectives. In the past, semi-antonomous agencies within government, such as Boards or Crown Companies, have had a good record in providing the environment in which these leaders could flourish but no form of organization can be guaranteed to provide the right environment and every form tried in government has had some successes and some failures. There exists a real need for close study of the factors which tend to create the necessary environment.

The Economic Council of Canada has observed, in a comparison of the economies of Canada and the United States, that a significant relationship exists between the level of productivity and the national average level of education. It is suggested that an increasing average level of education in Canada could contribute to narrowing the "productivity gap" between Canada and the United States. Canada must make a concerted effort to encourage the training of her manpower to the highest levels.

The Federal Government already makes a significant direct contribution to university research, which is closely linked to the training of graduate and professional students, and the trends in this funding over the past decade are shown in Figure 1. This particular Federal support program is highly impor-

tant to the development of science and technology in Canada. At present the Science Council and the Canada Council are jointly sponsoring a study of the mechanisms of support of research in Canadian universities. This study is nearing completion and detailed recommendations will be published in the near future.

While the supply of university-trained manpower is important, it does not represent the sole need of science and technology. The Science Council is happy to note the rapid growth of post-secondary Institutes of Technology and vocational centres across Canada, for these bodies have valuable contributions to make to the development of the technological infrastructure which the nation needs.

As research in the universities expands, two factors must be considered. First, the universities must be selective in their efforts to expand their research programs. It would be disastrous if every campus were to attempt to plunge into every new area of research which opens up. The joint consultations held by the universities, both of Ontario and of the Atlantic Provinces, respecting the future development of research on their campuses are a welcome indication that this problem has already been recognized. Second, basic research is not the only form of scientific activity suited to the universities and to the training of new scientists. The increasing emphasis on application in research and development programs outside the universities would argue for a greater emphasis on applied research in graduate schools, and in particular in the professional faculties.

Section 6

THE CONCEPT OF MAJOR PROGRAMS

The greatest concern of the Science Council is to see that the growth of science and technology in Canada is channelled in appropriate degree towards specific broad objectives as they are defined.

> **To permit this channelling it is proposed that most new undertakings in Canadian science be organized as large, multidisciplinary, mission-oriented projects having as a goal the solution of some important economic or social problem and in which all sectors of the scientific community must participate on an equal footing. This report refers to these initiatives as major programs.**

Research and development will naturally play leading roles in these major programs, but it always must be remembered that the objectives will be the implementation of solutions to problems or the fulfilling of needs and that the programs will be concerned with the production of new goods and the initiation of new services.

Major programs are not new to Canada and some successful examples, such as the atomic energy program, have contributed notable achievements in their field. What is new in this policy is that these programs are envisaged as the principal instrument for the growth and development of Canadian science and technology.

A most important, but by no means sole, reason for the major program approach to organization is that it seeks to provide a national focus for efforts aimed at solving national problems. Ideally each program will give cohesion to the efforts of all levels of government, of industry and of the universities as they work towards a common goal.

Many other arguments can be advanced in favour of the major program approach. First, a concerted, co-ordinated and co-operative program is the most efficient way to make progress toward the solution of large-scale practical problems where many technical disciplines are involved. Traditionally, research and development for the needs of national defence has been carried out on a national scale, and no one would suggest that it would be effectively accomplished by leaving it to small-scale efforts by local units. The example makes it plain that the massive, centrally guided and funded approach may be called for, either because of shared interest, an overriding social goal, or because an effective solution to the problem requires a scale of funding beyond the resources of small jurisdictions. Today it should be a measure of a nation's maturity that it can apply its problem-solving resources on the national scale to progress on matters affecting the public interest other than the defence of sovereignty by military means.

A major program approach is also called for by the increasing degree of organization that technological advance brings to society. In the past, problem-solving could be piecemeal, the goals of society were those of the individual, and the more government stayed aloof the better. Nowadays, with the gathering of people into urban concentrations, with the high degree of interdependence created by technology and with increasing demands for efficiency in transportation, communications, energy supply, manufacturing, distribution of food and goods, waste disposal, etc., society has closed in upon itself. One man's effluent is another man's intake. It has become clear that there is a public interest which is not always coincident with or optimized by the pursuit of private interests. The problems which stand in the way of realizing the optimum conditions for life in contemporary society, as a society, will not necessarily be solved in an optimum way, or may not even be soluble at all by private or piecemeal approaches. A total "systems approach" may be essential.

Frequent references are made in many sections of this report to the need for "a systems approach". The Science Council considers such an approach to involve the systematic and rational analysis and design of an object or policy, in which every possible effort is made to ensure consideration of all reasonable alternatives and in which attempts are made to provide objective quantitative measures of the consequences of alternate courses of action as a basis for decision. It is in effect an optimization technique.

Major national programs of scientific research and technological development could provide a powerful stimulus to industrial innovation, not only of new products and processes, but also of new types of industry and new forms of industrial organization. This has been amply demonstrated both by defence and space programs in the United States, and by past Canadian programs of geological survey, railroad building, agricultural research, and atomic energy. Public funding of research with an industrial payoff, particularly when the payoffs are long-term or diffuse, has its justification in the uncertainties of research, the spreading of risk, and the capture of many and various benefits. The probabilities of capturing and keeping to oneself the benefits of one's own research improve with the size and diversity of one's organization. Thus the largest science-based industrial corporations support research laboratories of their own. The argument extends to society as a whole. The benefits of research often accrue to industry in total, and thus to the health of the economy, even when the results do not find their best or eventual use in the company in which the research was done.

For Canada major national programs are particularly desirable in relation to industry because they will result in the shaping and stimulation of new industrial growth in directions determined by national needs and related to Canadian goals. This problem is of special importance to Canada because of the extensive foreign ownership of our manufacturing industry. Some of the foreign-owned subsidiaries are leaders in doing R&D and applying new technology but many merely operate branch plants, manufacturing familiar

products for the Canadian market. Obviously in many cases industries of this kind are very useful but it is hoped that well-conceived long-range major programs will add to Canada's existing industrial base new industries which will have evolved through the finding of unique new solutions to unique Canadian problems. Past experience indicates that novel products of this kind are quite likely to find markets in less-developed countries where similar problems are encountered but where the resources for finding solutions are not as good as they are in Canada.

The problem of establishing priorities for new major programs is complex: the priorities must take account of many and sometimes conflicting factors. The goal of a major program must be of social or economic significance; it must aim to advance significantly the current state of knowledge, but in so doing the choice of objective must be influenced by the opportunities afforded by present knowledge; it must aim to exploit efficiently the available resources of manpower and money, but again the availability or shortage of manpower with particular specialized training will affect the timeliness of the program. Despite these complexities, *a number of criteria can be established which must be met.*

(1) The objective selected for each major program must be of real importance to Canada, and perhaps even peculiar to Canada. Each should be such that the solutions would cope with problems posed by Canadian conditions—of climate, of organizational structure, or of availability of resources—and some of them should offer prospects of being more generally applicable in other areas of the world.

(2) No major program should duplicate work already under way in other developed nations. Rediscovering technology is expensive and pointless. If a problem for example is of great importance to another nation which has already set out to find a solution, Canada should attempt to learn from the other efforts by importing the technology being developed rather than squander much-needed resources by repeating work already done elsewhere.

(3) There must be some demonstrable prospect of direct social or economic benefit which in an overall view would be commensurate with the resources invested. The concept of social needs can be extended to encompass Canada's obligation to contribute usefully to the progress of the world's developing nations.

(4) The scientific and technological challenges must be fundamental and far-reaching enough, that they will not be quickly exhausted, and yet in general not so far-out that there is little hope of tangible progress with time spans of ten or twenty years. The challenge must stimulate genuine innovation, and it must be sustained consistently over a long enough period that manpower training sources respond and adapt, and new industries both come into being and get established on a viable footing.

(5) The unpredictable quality of research and the openendedness of the future must be clearly recognized. The programs should be regarded as campaigns to open up new opportunities. They should therefore challenge technologies over a broad, varied and open frontier rather than proceeding down a narrow and confining lane. Skills, capabilities, and organizations will thus be brought into existence in readiness to exploit breakthroughs and inventions, made in Canada or elsewhere, in the most opportune ways. Particular projects within the broad program areas should be chosen more as stepping stones to future positions of advantage or readiness, than as fixed goals not subject to revision.

(6) Not only does a program need to be sufficiently sustained in time, if it is to be effective in building new industry and in supporting new ideas through the complete cycle to practical innovation, but it must be mounted on a sufficiently large financial scale that the various R&D groups formed to attack the special problems will be of above-critical or viable size, and will have reasonable prospects of a steady diet of challenging projects within their range of competence.

(7) The choice of a program should be based on a conjunction of need, and of scientific or technological opportunity. Thus a major program to develop atomic energy for power generation would have been premature in 1920, when there was no felt shortage of power from hydro plants or coal, and before the necessary basic discoveries in nuclear physics had been made. Further, the potential innovative fertility of the program area must be considered, since the benefits from the unexpected and unpredicted discoveries and opportunities may well exceed the benefits from those outcomes that could be predicted at the start.

The major programs will flourish or perish depending on the level of co-operation which is achieved in running them. All elements in the scientific community—in government, industry and the universities—must be integrated in each program, efforts in different laboratories must be co-ordinated and a truly multidisciplinary approach must be taken, for only when all these elements are present will there be real progress towards the program objectives.

For each major program which receives substantial levels of Federal funding it will be necessary to designate or create a body which will be made responsible for co-ordinating the program, for actively promoting the involvement of all of the scientific community in all phases of the program, from initial planning through to execution and for administering the Federal support for the university and industrial components of the program.

When the objective of a given major program is clearly the responsibility of a single department of the Federal Government, the

appropriate body could be a widely representative Advisory Committee, established to advise the Minister involved. In cases in which the objective is of equal interest to a number of departments, a central agency should be established to perform this co-ordinating role.

These recommendations are developed more fully in Section 7.

Section 7

SPECIFIC AREAS FOR ACTION

Many of the programs required for Canada's scientific and technological development are already under way in one form or another, although not always on the necessary scale, with the most effective organization or in the best environment. A rational and systematic consideration of priorities will have the effect of strengthening the important programs of existing organizations, as well as co-ordinating or integrating their activities where necessary. Much of the work being done in these "de facto" major programs is of high quality and can serve as a nucleus for increased and better co-ordinated efforts in the future.

Canada's nuclear power program is one existing major program which has been particularly successful and which has secured for Canada a prominent position in the world market in this highly-competitive field. It is vital that this program receive continuing generous support. The future for Canada in nuclear power looks bright provided that this support is given and that basic research, applied research, development and innovation in this field continue to be closely coupled.

The arrangements being proposed are so large in scale and so new in type for Canada that they should be approached experimentally and pragmatically, though energetically. It is recommended that three categories of fields of interest be distinguished. These three categories represent a time priority (although there is no priority established within each category), partly determined by circumstance, and partly by present importance. The first category contains two fields in which specific plans for major programs are now in existence and which will provide very useful proving grounds for the concepts to be applied in later programs. The second category consists of four fields of indisputable primary importance to Canada, in which it is very likely that the need for a major program will be identified, and in which detailed study should begin immediately so that concrete proposals for specific action can be advanced at an early date. The third group consists of a larger number of areas of importance, each very little different in level of significance from those in the second group, but with their immediate appropriateness and limits less clearly determined. These last areas can be regarded as forming a list within which the necessity of starting additional major programs may be identified within a short span of years as planning and implementation of the first two groups of major programs proceed. The list of the third group of program-areas should not be considered as exclusive. Further, the limits of any program defined within the second or third group of areas should not necessarily be bound by the discussion in the present report.

Here, it must be pointed out that individual major programs, like any program, must not last indefinitely. As time passes there will be a continuing shifting of priorities and programs started soon will eventually fulfill their objectives and come to a natural end or will lose their priority and be terminated.

A.—Prototype Major Programs

The Science Council recommends that two prototype programs be set in motion immediately, to test the systems of organization and co-ordination which have been proposed. The two programs should cover:

(1) Canada's Interests in Space, and

(2) Water Resources Management and Development.

A Space Program for Canada

The scientific and technological aspects of space have drawn increasing attention in Canada over the last few years. The extent of the present effort was examined in a report issued under the title of "Science Secretariat Special Study No. 1, *Upper Atmosphere and Space Programs in Canada*" (February, 1967). In turn the Science Council Report No. 1, *A Space Program for Canada* (July, 1967), called for:

> "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".

In March 1968, the Minister of Industry issued a "White Paper on a Domestic Satellite Communications System for Canada", and the Federal Government has since proposed the formation of a Department of Communications which would, among other tasks, assume responsibility for co-ordinating the design and construction of a satellite communications system.

The Science Council feels that these new developments have not reduced the need for the establishment of a Space Agency to deal not only with scientific and technological matters concerned with a satellite communications system, but also with all other areas of research of concern to Canada involving the upper atmosphere and space. Two of the latter might involve weather survey satellites and resources survey satellites, which are of potentially great importance to other Federal departments, particularly the Department of Transport and Department of Energy, Mines and Resources. The work under the direction and control of the proposed Space Agency would constitute a major program. The various existing functions in government concerned with upper atmosphere and space might be gradually transferred to the Space Agency, but the policy direction and control for all aspects of the major program, wherever located, should come from the agency from the outset.

Water Resources Management and Development

The Science Council has conducted a study of water resources research in Canada and published its findings in Science Council of Canada Report No. 3[9], in which the Council recommends that water resources research be organized as a major program.

Water resources research exhibits all the desirable characteristics of a major program. It is multidisciplinary, requiring the skills of hydrologists, meteorologists, engineers, physicists, chemists, economists, social scientists and life scientists and no doubt of other disciplines as the program takes shape. It is mission-oriented, aimed at making efficient use of our water resource, at the development of methods for managing and controlling water pollution, and at the development of techniques for efficient, minimum-cost design, construction, and operation of engineering works required to implement the water resources development program. It is important from both the economic, and social point of view. The economic significance may be judged by the two billion dollar estimated yearly expenditures on construction and repair of water control, treatment and conveyance structures by the mid-1970s, while the social significance relates to the problems caused by water pollution, particularly as they affect recreational facilities dependent upon water. It finally is a field in which all sectors of the scientific community, government, universities, and the private sector, must take part.

The Science Council has suggested that the main co-ordinating and advisory function be delegated to the National Advisory Committee on Water Resources Research which has already been established to advise the Minister of Energy, Mines and Resources. This committee should be broadly representative of all sectors of the economy, Federal and provincial public services, universities and industry, and should reflect the range of disciplines contributing to water resources research. The present terms of reference of the National Advisory Committee on Water Resources Research call for it:

1. to provide continuing advice to the Minister of Energy, Mines and Resources on needs and priorities for research on water resources in Canada, including water pollution research;
2. to assist in the co-ordination of water resources research;
3. to review and make recommendations on applications for grants-in-aid of research from the Department of Energy, Mines and Resources.

The Science Council recommends that the mandate of the Committee be expanded by requiring it

4. to provide continuing advice to the Minister of Energy, Mines and Resources on the use and application of science to water resources management and development.

With this change in its terms of reference and with some increase in its responsibility for the allocation of Federal funds to industry and to the universities, as outlined in the Science Council's report, the National Advisory

Committee could become the effective co-ordinating body for the major program.

While research on the problems associated with Canada's water resources is important, the need to apply science to the management of these resources is urgent. The Federal Government, as a sponsor of the research in this area, should also be concerned with assisting the Provinces in bringing up-to-date technology and science to bear on water management. One positive move recommended by the Council is the designation of the National Advisory Committee on Water Resources Research as the scientific arm of the proposed Canada Water Advisory Board, whose creation is soon to be discussed by Parliament, one of those principal roles is envisaged as being the co-ordination of all aspects of water management in Canada.

B.—Areas for Immediate Planning

The second category of important fields referred to consists of:
Transportation
Urban Development
Computer Applications, and
Scientific and Technological Aid to developing areas of the world

At the present time, the detailed information required to make specific recommendations for action on programs in these areas has not been prepared and considered in the manner used in arriving at proposals in the case of both the space and water resources programs. In order to develop this information and to prepare detailed proposals on organizational structures and specific objectives for each of these programs, *the Science Council is now setting up a task force of appropriate experts for each of the proposed areas; once each task force has reported, the Science Council will make public the detailed recommendations developed.* At present the Council can only give a broad picture of the scope envisaged in these new ventures.

Transportation

Canada's large land mass and its peculiar population distribution make the problems of transportation in this country quite different from those experienced elsewhere. The needs and expectations of a modern society require rapid and efficient transfer of goods and people between urban centres as well as access to remote areas. For Canada, this means meeting the challenges created by a varied terrain and a wide range of climatic conditions. As the population and the prosperity of the country increase, the transfer of goods will tend to grow. Further, the population of the world's industrial nations is becoming more mobile, and this means, for Canada, that the transportation needs of its people will tend to increase more rapidly than the population. It seems apparent that this country, with its particular geographic and demographic structure, can reasonably expect to find only some of the solutions to its transportation problems abroad. The rest will have to be worked out in Canada.

Transportation research has had a chequered history in Canada. As indicated earlier, in the fiscal year 1958-59 it made up 51 per cent of all of Canada's industrial R&D expenditures, at a time when aircraft development was at its peak in Canada. Today transportation research is fragmented. While different groups are involved in the development of specific pieces of hardware, few if any are looking at Canada's total needs.

A co-ordinated major program on transportation would aim at developing a rational, national system. Setting up such a system would involve consideration of all of the necessary subsystems, of the inter-faces between subsystems (e.g. what is the best way of linking an interurban passenger airline service with an efficient urban transportation system?) and would consider specific hardware development where the demands of the Canadian situation indicate that such is needed.

The two principal features which will determine many of the constraints on a Canadian transportation system are geography and climate. Canada must consider the problems of transportation across Arctic terrain since this will be one of the important factors which determines the extent of the economic future of the North of this country. Canada's size poses other problems. The costs of transportation represent a sizable portion of the costs of manufactured goods whether distributed in Canada for domestic consumption or shipped abroad as exports. Any lowering of transportation costs would be advantageous from the view point both of the internal standard of living and of the nation's competitive position in export markets. Thus it would appear essential to Canada to improve the efficiency and convenience of transportation on a large scale basis through the implementation of a major program in this field.

The urban aspects of transportation are also important, since most Canadians are city-dwellers. The growing problems of urban transportation in the United States have contributed significantly to the decay of their city centres and, to a lesser extent, some of the same problems are already apparent in the large urban centres in Canada. These problems, if not properly attended to, could become equally critical.

In Canada, as in many industrial nations, many of the transportation utility companies are publicly-owned and operate as monopolies. This situation, although often necessary, tends to create inefficiencies and conservative attitudes towards innovation. In view of this, it might be necessary and reasonable for the Federal Government, in conjunction with the provincial and municipal governments, to play a strong entrepreneurial role in this field through a major program in transportation, in order to encourage increased efficiency and innovative approaches to problem-solving. This does not mean that the Federal Government will directly carry out a major portion of the entire program or of the R&D part of the program. Some of the R&D side of the program should be carried out in government organizations, largely to provide the government with the expertise necessary to evaluate the progress of the entire program, but the central role of the Federal Government should

be as a director, co-ordinator and provider of funds for much of the major program. The universities must perform some of the research, to provide a mechanism for producing an adequate number of scientists and engineers with a strong interest in transportation problems. However, the largest proportion of the R&D part of a major program in transportation should be located in industry where it would be closest to the most direct and efficient mechanism of innovation. The producers of transportation hardware and the operators of transportation systems must be deeply committed to the realization of the aims of this major program.

Urban Planning and Human Environment

Two important, problem-creating trends in Canada are the growth of population and the increasing urbanization of that population. Canada's population at the 1941 census was little more than 11.5 millions; in the census of 1961 it had grown to 18.2 millions[10] and it has been estimated[11] that the population will reach 21.5 millions by 1970. In 1961 some 70 per cent of all Canadians lived in urban areas with populations of more than 1,000, while about 25 per cent lived in three major metropolitan areas—Montreal, Toronto and Vancouver. While this in itself has given rise to many problems, the future holds prospects of much greater ones. In its *Fourth Annual Review*[12] the Economic Council clearly demonstrated what the future holds for Canada's cities:

> "The projected *increase* of some 5.8 million people in total urban population by 1980—and more particularly the 60 per cent rise anticipated for the largest centres—provides a broad measure of the urban growth problem ahead. Clearly, however, it is a minimum measure only. Even if these major cities were already functioning models of urban efficiency and attractiveness, growth of this magnitude would itself involve substantial new investment and threaten severe strain and potential social cost. In reality, of course, there has long been widespread concern about the mounting deficiencies of our cities and the heavy backlogs of essential improvements. Shortages and inadequacy of urban housing, traffic and transport problems, air and water pollution, the confused jumble of conflicting land uses, decaying neighbourhoods and monotonous suburbs, urban poverty and social disturbance, steadily rising property tax burdens, and the frustrations of municipal administration—these are familiar problems to the average Canadian city dweller today. Yet it is against this background that our larger cities must face up to the continuous pressures of accommodating and fulfilling the wide-ranging needs of a further period of rapid expansion".

What are the demands which this growth will place upon Canada's economy? In 1965 Canada devoted 19 per cent of her GNP, some 9.9 billion dollars, to building and engineering construction, of which nearly 2.8 billion dollars went on the construction and repair of residential housing[13]. The proportion of GNP so spent has remained fairly constant in the decade up to 1965; if it remains at this level in the decade 1968-1979 and if the Economic Council's projections of GNP hold good, then Canada will spend about 184 billion dollars on new building and engineering construction over that period. This then is some measure, however inadequate, of the magnitude of one of the tasks ahead, though it still gives no indication of the costs of resolving the existing social problems of the cities.

An important cause of the social and physical decay in urban areas is the great congestion in city centres, which has induced the middle and high income groups to move out to suburban areas, thus further aggravating the decay through the loss of tax dollars and leaving the poor trapped in slums. This congestion has emphasized other problems which reflect on the quality of life within urban society—those of air pollution, noise, waste disposal, urban transportation and traffic control, crime, the shortage of educational and recreational facilities and so on. The fragmented efforts of the past to alleviate our basic environmental problems have not been successful, simply because the complex nature of the total human ecology requires a co-ordinated approach to the solution of its problems. Congestion is far from the only cause of our environmental problems—and decongestion alone will not solve the basic problems (and it may create new ones).

It is recommended that a systems approach to community planning and human environment, applying the techniques of science, technology and the social sciences to the total ecology, be undertaken as soon as possible. This might best be done through a major program in this area.

To any observer the problems of the cities in the United States are far more serious at present than the problems of the cities in Canada. With this in mind one can reasonably ask why does Canada not wait to see what solutions to various urban problems are adopted in the United States and follow this lead—why should a major program in community planning and human environment receive high priority in Canada? The answer to this, in part, lies in the lesser state of decay of the Canadian cities on one hand, and in the more rapid growth of the Canadian population on the other. The problems besetting the cities in the United States are so urgent and so immediate that the United States has little choice but to tackle the problems at the pressure points—to attempt to stop the urban decay and social unrest through urban renewal and social programs, through tearing down and rebuilding. This approach is not only very expensive, it is extremely difficult because it will tend to get entangled by the existing bureaucratic procedures and jurisdictions that are found in most urban centres. Canada, on the other hand, can afford to work initially to a larger extent with the margin of growth, since the nation's cities are in a lesser state of decay physically and socially, thereby avoiding some of the many complications and lowering the initial costs of such a program.

Canada must start now on a concerted effort to build a new future for Canadians and the attack on the problems must be bold. Many possible and intriguing solutions are already talked about. Should Canada build new cities instead of creating a vast megalopolis around each of the already sprawling major cities? Can the population of the North be expanded on an economic basis or are most Canadians to be forever found in a narrow belt close to our southern border? And finally, what more can be done to cope with Canada's winter?

Many diverse efforts are presently being made in the urban centres in Canada in order to improve them as places for people to live and work, and it is acknowledged that the practical solution of today's problems should serve as guide posts to the future. However, these efforts are often diffuse and unco-ordinated and often insufficiently imaginative. A major program in community planning and human environment would have the advantage of co-ordinating and augmenting these efforts effectively to the benefit of the cities and of all levels of government in Canada.

Obviously such a complex major program could only be carried out successfully through the mutual co-operation and involvement of industry, the universities, and Federal, provincial and municipal governments. However, it seems apparent that the various levels of government, and the Federal Government in particular, must take a leading role in directing and financing the program in order to provide both impetus and appropriate management. The Science Council is encouraged by the decision of the Federal Government to take the initiative in this vital area, by setting up a task force under the Minister of Transport to advise on early legislation. The Council has offered its assistance in mobilising the scientific community to participate in the attack on Canada's pressing urban problems.

Computer Applications

In his widely-publicised book, *Le défi américain,* Servan-Schreiber summed up the position of the computer in today's industrial age by saying "dans la guerre industrielle, la bataille centrale est celle des calculateurs électroniques, dits ordinateurs".[14]

The electronic computer may well be the basis in the 1970s of the world's third largest industry, after petroleum and automobiles, and just as these existing industrial complexes have wrought innumerable changes in contemporary society, so the computer industry will play a major role in shaping the society of tomorrow. The computer is already bringing about a revolution in industrial processes and management. Its influence is being felt in education. It offers a potential solution to some of the problems arising out of the increasing flood of information, particularly scientific and technical, and its use in the storage, manipulation, and retrieval of data promises better opportunity for mastering the complex problems of our society in the future.

The present state of Canada's indigenous computer industry stands as a monument to the nation's lack of entrepreneurial initiative and to the past failure to turn successful research into successful innovation. Canada has repeatedly demonstrated great competence in the design of digital computers but for every successful development there has been a corresponding failure to capitalize on the opportunity provided. Even today, large Canadian corporations still show no faith in Canada's ability to design computer systems.

A Canadian program on computer applications should not now set out to challenge the position of the huge international corporations which design

and manufacture successive generations of general purpose digital computers. While the program might well lead to the development of some peripheral hardware needed for a particular application, or even to the development of specialised computers, the primary aim should be the promotion of the intelligent use and application of computers throughout Canada's economic framework.

There are many ideas already being put forward, and one question which must receive early study is that of the feasibility and desirability of establishing nation-wide computer communication utilities. It has been suggested that such a utility would provide the foundation for an information transfer system, that it would permit the extensive introduction of computers into education and that it would make available powerful computer systems to individual users in scattered areas, providing them with facilities whose cost they alone could not justify. This far-reaching question must be examined carefully and critically.

The combination of computers and the techniques of systems science can be applied to many previously intractable problems. The provision of health care and of education have been two segments of the service industry where past pressure has always been directed towards upgrading the quality of the service being provided. The absence of the pressures of a competitive market has meant that there has been little attention paid to the efficiency with which these vital services have been provided. The spiralling costs of hospital care and the swelling numbers of students in our educational system both demand that serious effort be made to improve the productivity of these services.

The attempts to improve the quality of these services will naturally continue and the application of computers to medical diagnostics and to the provision of educational aids both seem to be potentially rewarding.

It has earlier been emphasized that a basic requirement of modern society is a highly developed information system, and this is one sphere where computers have already made spectacular contributions. The masses of data and information which now are generated and which must be retrieved demand that the speed and reliability of the electronic computer be harnessed as a vital part of modern information services.

Because of the pervasive and national importance of computers a major program is required to give focus and body to the many interests in industry, universities and government. The action must be commensurate with the economic and social implications of the topic. Such a program should be designed to encourage individual research, innovative and entrepreneurial initiative, and to provide a system within which policy, co-operation and co-ordination may develop.

One must ask why the Federal Government should become involved in a major program in this field. Two reasons are particularly important. First, the scope of such a program should be vast. The use of computers, as an aid to increasing productivity, should permeate all of Canadian industry. It is in

the national interest to encourage the rapid application of computerized techniques in industry, but such a large undertaking should not proceed in a random fashion. There must be concerted leadership, and the Federal Government should seek to provide it. Second, the Federal Government itself invests large sums annually in the purchase, rental and maintenance of computers, either for its own use or for use by the universities, and it must be concerned that this investment be wisely used.

Scientific and Technological Aid to Developing Areas

Widespread poverty and hunger, the lot of the underprivileged millions throughout the world, demand that the developed nations of the world make a concerted effort to better the conditions of life for all mankind. Failure to respond could condemn the world to complete ruin and universal misery.

The scientific community in all nations must meet the challenge posed by the plight of the starving poor. Full use of the enormous growth potential of the tropics, watering of arid lands, and on a less dramatic scale the development of economically marginal or depressed areas in general, could aid immeasurably in alleviating problems of overpopulation, of poverty, famine and dwindling world resources, and of national and regional disparities in economic advantages. The problems are closely akin to those of colonizing uninhabited regions, though they are less extreme. In each case the objective is to develop a prosperous community in the absence of or inadequate local supply of one or several of the necessities of economically developed life. The problem is in part social, but it depends in large part on providing locally an adequate source of the missing factors or of developing economical transportation links with complementary regions. Science and technology may contribute also to the intelligent choice and effective development of specializations that will stimulate such regional economies. Some such areas exist in Canada. There are many more in the developing countries, where the solution of population problems, the development of productive economies and the reduction of tensions would be highly beneficial to Canada.

Foreign aid will always be primarily motivated by the simple charitable urge to lessen the suffering of the less privileged, but the modern view recognizes that too simple an approach can be misguided; true charity in the long run consists not in leading the poor to depend on free bread, but in teaching them how to make bread for themselves. Dealing with the short-run emergency must be backed up by a long-range program designed to solve the root problem.

In the field of foreign aid, Canada has particular reasons for enlarging its activities and for bringing research and development to bear to improve their efficacy.

Canada has made a pledge to match the performance of other advanced nations in contributing one per cent of national income to foreign aid. The total net flow of official and private financial resources from Canada to the

less developed countries has risen from 0.38 per cent of national income in 1962 to 0.66 per cent in 1966. Assuming that Canada reaches and maintains its annual target through the 1970s, the annual financial flow to foreign aid may exceed $900 million by 1978. Such a magnitude of financial allocation justifies a significant expenditure for research and development related to the problem which the foreign aid is trying to solve.

Canada has much to offer to the less developed countries, since in comparison its own scientific, technological, and industrial establishment is well developed while, at the same time, it has its own problems of regional development. As those problems are overcome, valuable experience will be gained for application elsewhere.

Canada, through its foreign policy, is finding its own role to play in world affairs. As an intermediate power without imperial design, Canada can often play a more effective role in assisting the less developed countries than can the larger powers, whose motives are suspect or whose freedom to act is compromised by their involvement in complicated manoeuvres for political power.

To contribute usefully to the solution of the problems of the developing nations, it appears to the Science Council that Canada should decide that it can do most by bringing a wide range of aid to a small number of areas, rather than making token efforts all over the globe.

A major program in this field would have as its aim the development of a specific area of the world. Given the size of the resources Canada has for this program, the area selected will necessarily be small. However, having chosen an area, Canada should offer to share all her scientific and technological expertise. The program should set about improving education to create the infrastructure for a developed economy. It should set about establishing efficient industry to capitalize on whatever resources offer most advantage to the nation being helped, and to employ those being educated—an education alone does not fill empty stomachs. It must emphasize developments in agriculture to make the recipient nation as self-sufficient for food as possible and, finally, Canada must be willing to serve as a good market for the produce of the area supported.

The Science Council is convinced that Canada's scientific community is anxious to become deeply involved in the nation's foreign aid program and that a major program of assistance to a specific area is the way to make best use of the aid available.

Discussions are currently in progress within the Government, concerned with the proposal to set up a Canadian Center for International Development, to support and carry out research and development for just the purposes set out above. The Science Council is encouraged by the proposal and awaits with interest the details of the policies and programs, and form of organization proposed for the Center. Pending the results of this work in progress, the Science Council will be happy to offer its advice and services wherever they may be useful.

C.—Areas for Continuing Consideration

Setting up the two protoypte major programs and identifying programs in the four areas in which immediate action is recommended will constitute the beginning of a continuing program of investigating problems, highlighting objectives and initiating new action.

Once the first programs are successfully launched the Science Council proposes to give serious consideration to the need for action in a number of areas, including the following.

Health Care Delivery Systems

The entire health care system, involving general practitioners, nurses, specialists, clinics, hospitals, sanitoria, has evolved over the years in essentially a random way. One result of this is the rapidly increasing cost per day of keeping a patient in hospital. The application of the techniques of systems science and of computer technology hold out the promise of increasing the efficiency of the whole service and this could at least prevent costs from rising any further. The total expenditures on health care in Canada (about $4 billion annually) are so large that any increase in the "productivity" of the service could yield large dollar savings.

Economic Development of Canada's North

Most Canadians live in a narrow strip of territory close to the United States border, leaving the vast expanse of land to the North sparsely populated. If this vast area is to be developed and its resources fully tapped, much more has to be done. Science has much to offer in the quest to make sure that the full economic potential of Canada's North is realized and that the cultural life of the population of this area is enriched.

The Development of Energy Sources

Low cost energy is a fundamental requirement of this industrial age. To obtain it, Canada has made substantial investments in the exploitation of hydro-electric power and has become one of the world's leaders in the development of nuclear power. A major program would seek to build on the successes of the past and to exploit the systems which have already been developed, while at the same time branching out into new fields to keep Canada abreast of emerging technologies such as those associated with power reactor development.

Integrated Resource Management

Canada's development has been tied to the exploitation of its resources, and the R&D programs with the longest histories here have been associated with agriculture and mining. The time has now arrived when a piecemeal approach to the development of the nation's resources is no longer adequate and when science should be applied to the problems of resource management.

Oceanography, and Marine and Undersea Technology

Canada has thousands of miles of coastline, touching on three oceans, and the resources which could be tapped on the continental shelf may be vast. However, science and technology have many problems to solve before this potential wealth can be exploited.

Weather Prediction, Modification and Control

To the wheat farmer on the Prairies who sees his crop ravaged by hail and to the municipal treasurer who sees Canada's cities spend about a quarter of a billion dollars annually on snow removal, the attractions of weather control are great. There are however major scientific problems to be solved in the development of the necessary skills. There is ample scope and need for a major program first to improve our understanding of the mechanisms which determine our weather and then to improve our ability to predict, modify and control it. The objective should be to maximize the advantages which Canada's climate offers and to minimize its deleterious effects.

Two important topics, one of great public concern and the other of much current scientific interest, do not appear as items in their own right in three categories presented. These are Pollution and Materials Science. Research seeking the causes of and cures for the pollution of Canada's waters is already an important part of the proposed program on Water Resources Management and Development, while the proposed program on Urban Development will naturally be the place where work on air pollution and noise abatement receive most attention. As for Materials Science, the Science Council believes that this will be the subject of intense activity in many of the major programs and that it must be closely linked with the mission of each program. The needs of each major program will define the important questions in materials science which must be resolved.

In all attempts to organize major programs, efforts must be made to co-ordinate and build upon existing successful programs. Canada's atomic energy activities would be a leading component of a program on Energy Sources, while existing programs in Agriculture, Fisheries and Forestry will necessarily be major segments in a program of Renewable Resource Management. The Science Council is planning to consider Canada's current Medical Research program, to see the extent to which it requires support to develop as a successful and expanding major program.

Section 8

MANPOWER

A perennial cause of concern in Canadian science has been the "shortage of qualified manpower". However, this concern in general has not distinguished between a "shortage in the manpower which would permit every organization to embark on all of the programs of interest to it" and the much more serious problem of a "shortage in the manpower required to tackle all of the problems which Canada must solve".

The Science Secretariat has conducted a study[15] of the expected supply of scientists and engineers in Canada up to 1978. The starting point was the data available up to 1963 and an estimate was then made of the net annual input from university graduations, from the upgrading of people already in the workforce and from immigration, less an attrition rate due to deaths, retirements, and job changes. An attempt was made to take into account, as far as possible, shifts which might occur in demand, in student motivations and in immigration patterns. The results of the study—given all the many necessary qualifications—indicate that the total number of qualified scientists and engineers in Canada's work force will rise from a level of slightly over 104,000 in 1965 to a little more than 304,000 in 1978. In gross numbers this supply seems entirely adequate to meet the needs of the major programs which are recommended.

However, one important limitation on the usefulness of this projection does exist in that the study gives no information on the supply within specific disciplines and cases are already known where supply and demand are seriously mismatched. If shortages exist in some disciplines, then in a situation where total numbers appear adequate, there must be oversupplies in others. The study was concerned only with university trained manpower, but it is to be feared that similar problems may well exist or be forming in the new and expanding Institutes of Technology.

The Science Council is now consulting the appropriate authorities to organize detailed studies by discipline of the manpower now in training and to have realistic forecasts made of the expected supplies of the various specialists. The results of such efforts should provide the basis for any corrective measures—preferably in the form of incentives—which may have to be applied as a step towards ensuring that Canada will have the appropriate talents available to carry out the essential programs. The traditional effects of the market place are diminishing and the long lags in the education system hinder the supply from keeping pace with rapidly changing demands; other means must be employed to balance supply and demand. It is important that the universities, colleges, technical institutes and the student bodies become aware of and understand the problems to be faced.

While supply by discipline is important, it is not the only concern. Special attention must be given to creating the scientifically stimulating environment which will attract and retain the relatively small percentage of top-level people—the scientists and engineers, the managers and entrepreneurs, who can lead, perform and link up Canada's efforts in research, development and innovation—for they make up the nucleus around which a sophisticated and dynamic scientific or technological enterprise can develop.

Section 9

EXPENDITURES

In the preceeding sections of this report it has been proposed that Canada embark on a number of major programs and it has been asserted that the manpower appears to be available to staff them. This leaves one last and important question—that of the cost of these programs.

The only real way of obtaining an estimate of the annual costs of these programs would be to take each individually and, by laying out detailed plans and estimates for each project within the program, compute an aggregate annual cost. The major programs being recommended are in general in too early a stage of organization to permit this to be done, hence some other way of coping with this vital question must be found.

The Science Council first sought an indication of an appropriate level of investment in R&D for Canada by searching for some quantitative economic theory which would relate the level of investment in R&D to some corresponding rate of economic growth. The Council has found no such theory. The effects of science, both positive and negative, are extremely difficult to quantify and often do not come in an orderly progression starting from any given program of R&D. As indicated earlier, the Council is continuing its studies of this important question.

A second attempt to find some guidelines was made by comparing Canada's record of performance of R&D with those of other nations, particularly those within the OECD. However the Council could find no good reason to believe that the past record of any other country, given that country's goals, aspirations, problems and conditions, should be of particular value as an indicator of what Canada should do in the future.

The Council has had two exercises carried out to see what the results of particular policy decisions, if made now, would be within the next decade. The first of these[16], carried out as part of the evaluation of the then proposed Intense Neutron Generator project, postulated a series of large programs, many of which appear in the Council's present recommendations for major programs, and sought to evaluate the proportion of the nation's resources which would be required to permit each of them to receive substantial levels of funding. The second exercise, whose results are reported[17] in a companion volume to this present report, sought to relate the growth of expenditures on R&D in Canada over the next decade to the growth of the manpower involved in R&D, and was based on the manpower projections discussed earlier.[15]

The limitations on the value of the results of these two exercises must be clearly understood. They provide complementary views of what might

happen in future provided that certain policy decisions are followed and provided that the assumptions used in each case turn out to be valid. While they provide interesting pictures of a "surprise-free" future they do not give prescriptions for desirable, adequate or necessary levels of future expenditure, nor can they be used as justifications for any particular level of expenditure.

At this point it should be plainly stated that the Science Council does not believe that there exists any particular proportion of the Gross National Product which, a priori, should always be allocated to R&D. Canada should not fall into the trap of allocating this or that percentage of GNP to R&D and than dividing up this "budget for R&D" between the contenders for funds. The funds which are allocated to scientific activities annually should be granted, program by program, in face of competition from other potential uses of these funds, with each program justifying its expenditures on economic, social or cultural grounds. The "R&D budget" would then become the sum of the allocations of funds to individual programs and activities.

Given this reservation on the budget for R&D, the Science Council does firmly believe that annual expenditures should and will rise rapidly in future and that the popularly discussed target level of around 2 per cent of GNP will prove to be over cautious and will be surpassed. The justification for these foreseen increases in expenditure will come in large measure from the major programs which are undertaken. These programs will be justified on economic and social grounds and their costs will not be thought of as expenditures on R&D but as economic investments or as social expenditures.

The Science Council has argued in this report that much more effort in future must be devoted to development and innovation than has been the case in the past. Whether the end-product is a product or service, the costs of prototypes, pilot-plants, the installation of new productive capacity, or the testing and introduction of new services—the costs of all these will mean that total expenditures on the major programs will be high. It is therefore to be expected that expenditures on these activities will constitute a growing share of the Gross National Product.

While much of the increase in future expenditures will be due to the costs of innovation there is another observable factor which causes escalation of R&D costs. The rising costs of scientific programs, due to the increased sophistication of the equipment used, are of much concern to all organizations which support research and development. The "sophistication factor" has been the subject of studies in the United Kingdom and the United States; the Science Secretariat paper[18] on this factor reviews experience in these countries and has reached the conclusion that, in Canada, the best estimate of the combined effects of sophistication plus inflation, implies an annual 6 per cent escalation in costs. This means that to maintain any given level of manpower effort in a research and development program, the budget of the program, over a number of years, would have to increase by an average of 6 per cent per annum. In these present

days, when attempts are being made to hold the line on expenditures, many programs will find that their level of effort is diminishing over time. When budgets are tight, those responsible for research and development within mission-oriented agencies should be wary of applying across the board cuts in efforts to reduced expenditures, but rather should decide which programs are most vital to the objectives of their organizations and recognize the need of these programs to have access to increasing levels of funding. To make the best use of available resources, important programs must take precedence in questions of funding. An extension of this principle leads to consideration of the fate of new, proposed program in days of financial stringency. When decisions are made on the programs to receive the funding available, the importance of all programs, new and old, must be considered. The expediency of adopting the attitude that "no new programs will be undertaken" fails to take account of the fact that some new programs may be more urgently needed than many of the older, on-going ones. In cases like this, resources should be reassigned so that the program of each organization reflects the priorities of the tasks assigned to it.

APPENDIX

REFERENCES AND NOTES

[1] Science Council of Canada, *First Annual Report* (Ottawa: Queen's Printer, June 1967) page 19.

[2] Special Study No. 6, *Background Studies in Science Policy: Projections of R&D Manpower and Expenditure* (being published as a companion document to this report).

[3] *See* Keesing, *The Journal of Political Economy, 73,* 38 (1967) *or* Gruber, Mehta and Vernon, *ibid., 75,* 20 (1967).

[4] Kaliski, *ibid.,* 75, No. 5, page 761 (1967), "The R&D Factor in U.S. Trade, a comment".

[5] The first five of the "elements" are the economic goals for Canada postulated by the Economic Council. *See* Economic Council of Canada, *First Annual Review* (Ottawa: Queen's Printer, December 1964, $3.50), page 1.

[6] Figure 1 and Table 1 are derived from data taken from DBS, DOI and NRC and other sources in an exercise undertaken by M. Eliesen of DOI and G. T. McColm of the Science Secretariat. The figures for the R&D expenditures in universities were arrived at by estimates based on NRC publication No. 9196 and other material. Those for industry include an estimate for intramural research not regularly reported.

[7] Table 2 is taken from a document "Statistical Data on Industrial R&D in Canada", by J. L. Orr, presented to the Science Council by the Department of Industry in March, 1967. The comparison with the United States is taken from the same source.

[8] A. M. Weinberg, "The philosophy and practice of national science policy", in *Decision Making in National Science Policy: A Ciba Foundation and Science of Science Foundation Symposium,* edited by de Reuck, Goldsmith and Knight: J. A. Churchill Ltd., London, 1968.

[9] Science Council of Canada, Report No. 3, *A Major Program of Water Resources Research in Canada* (Ottawa: Queen's Printer, Sept. 1968, 75 cents).

[10] Dominion Bureau of Statistic, *Canada Year Book, 1966* (Ottawa: Queen's Printer, 1966, $5.00) pages 177 and 188.

[11] *OECD Observer,* No. 24, October 1966, page 20.

[12] Economic Council of Canada, *Fourth Annual Review* (Ottawa: Queen's Printer, 1967, $2.75), page 191.

[13] DBS, *Canada Year Book, 1967, op. cit.,* pages 713 and 715.

[14] *Le défi américain,* by J. J. Servan-Schreiber (Denoël, 1967), page 151.

[15] Special Study No. 6, Paper 1, "The projected supply of scientists and engineers in Canada". (In press).

[16] Special Study No. 4, *The Proposal for an Intense Neutron Generator, Scientific and Economic Evaluation* (Ottawa: Queen's Printer, 1967, $2.00).

[17] Special Study No. 6, Paper 2, "Gross Expenditures on R&D in Canada projected to 1978". (In press).

[18] *Ibid.,* Paper 3, "The Inflation-Sophistication Factor".