# A SCIENCE POLICY FOR CANADA

## Report of the Senate Special Committee on Science Policy

Chairman: The Honourable Maurice Lamontagne, P.C.

Volume 1

A CRITICAL REVIEW: PAST AND PRESENT

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*The following Senators also served on the Committee: The Honourable Hazen ARGUE (replaced on the Committee on September 9, 1969); The Honourable T. D'Arcy LEONARD (retired from the Senate on April 4, 1970); The Honourable Norman A. M. MacKENZIE (retired from the Senate on January 5, 1969); The Honourable M. Wallace McCUTCHEON (retired from the Senate on May 5, 1968).

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## THE SENATE INQUIRY:

## ITS NEED, SCOPE AND METHOD

In November 1967 the Senate adopted a resolution setting up a special committee to review the science policy of Canada. The terms of reference were broad. They specified:

> That a special Committee of the Senate be appointed to consider and report on the science policy of the Federal Government with the object of appraising its priorities, its budget and its efficiency in the light of the experience of other industrialized countries and of the requirements of the new scientific age and, without restricting the generality of the foregoing, to inquire into and report upon the following:
>
> (a) recent trends in research and development expenditures in Canada as compared with those in other industrialized countries;
>
> (b) research and development activities carried out by the Federal Government in the fields of physical, life and human sciences;
>
> (c) federal assistance to research and development activities carried out by individuals, universities, industry and other groups in the three scientific fields mentioned above; and
>
> (d) the broad principles, the long-term financial requirements and the structural organization of a dynamic and efficient science policy for Canada.

### THE NEED FOR THE INQUIRY

Several reasons justified this inquiry. The growing dimensions and the increasing speed of the international scientific and technological race had become evident. It was important for us to appraise Canada's participation in what may well be one of the predominant phenomena of the remaining portion of this century. As the race developed, so did the perception of the importance of science policy at the international level. (For the reader interested in exploring this new subject further, *Annex A* of Volume II contains a short bibliography.)

This increased perception was reflected in Canada by the creation of the Science Secretariat in 1964 and the Science Council in 1966. When the Senate Committee was set up the Science Council was preparing its own assessment of the Canadian situation. Its report, entitled *Toward a National Science Policy,* was published in October 1968. The Organization for Economic Co-operation and Development (OECD), which had initiated national science policy reviews in 1963, had begun its inquiry on Canada. Its report was published in December 1969, under the title of *Reviews of National Science Policy "Canada"*. Other more specialized studies had been undertaken on such topics as federal support to academic research, medical research, and scientific manpower.[1] At the government level, the Hon. C. M. Drury, Minister of Industry until 1968 and Chairman of the Cabinet Committee on Scientific and Industrial Research, was also showing a renewed interest in science policy.

However, no one had conducted a detailed public review of government science activities that offered government agencies, universities, industry, and professional organizations an opportunity to be heard. There was a growing need for such a forum, and an obvious reason for providing it through a committee of parliamentarians, for it is Parliament that must appropriate the money needed to support government science activities.

## THE SCOPE OF THE INQUIRY

The committee did not interpret its terms of reference restrictively. It adopted definitions that are now used internationally. UNESCO has defined science policy as "the sum of the legislative and executive measures taken to increase, organize and use the national scientific and technological potential, with the object of achieving the country's overall development needs and enhancing its position in the world."[2]

*Government science activities constitute the object of science policy.* This simple statement, however, deserves further explanation. It is obvious from UNESCO's definition that science policy is not restricted to activities related to pure and applied science but extends also to technology and to the different phases of the invention and innovation processes, including design, testing, and the building of prototypes. These various activities, from fundamental research to innovation, are usually called "research and development" (more briefly, R&D).

Curiously enough, the social sciences were not included until recently in the realm of science policy. This exclusion was unjustified and governments are at last becoming more and more interested in the behavioural sciences. They are specifically mentioned in the Committee's terms of reference and they were covered by our inquiry to the extent that data were available.

Science policy is not limited to government intramural R&D activities. It covers government measures, such as grants and contracts to support R&D programs carried out by industry, universities, and other organizations. It also extends to other government programs and services required by the national R&D effort, such as technical surveys, the gathering and diffusion of scientific and technological information, and scholarships and fellowships for the training of scientists and technologists. All these government activities and programs have been covered by the Committee's inquiry.

We will not attempt here to give detailed definitions of the research and development activities that are the subject of science policy considerations. *Annex A* contains some definitions that have been found useful by many policy makers. But the Committee wishes to emphasize at the outset of this report that science activities form a very diversified world. The purpose, requirements, and social impact of science, technology, and innovation differ widely. A clear understanding of their nature and their relationship is necessary to visualize the scope of the Committee's inquiry and to appreciate the substance of its report.

Science can be defined as the rational and systematic understanding of man and nature. Its goal is to explain human and natural phenomena as they are and to formulate empirically verifiable laws accounting for their behaviour. Basic scientific research is essentially a passive and contemplative activity attempting to discover what already exists. It produces knowledge, not tangible results. This natural fruit of science is always good and its impact on society can only be beneficial.

Technology, as defined by Emmanuel G. Mesthene, is "the organization of knowledge for the achievement of practical purposes".[3] The search for new technology is aimed at changing man and his environment through the development of new products, new processes, and new ways of doing things. It is essentially active and creative. A scientific theory is true or false according to whether it *accounts* for reality or not. A new technology is good or bad according to whether it can *improve* reality or not. Innovation is the first utilization of new technology—the introduction for the first time of a new product, a new process, or a new way of doing things, such as a new government policy.



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These distinctions are not always as clear-cut in real life, for science and technology are practised by people. A scientist can produce inventions; a technologist can make scientific discoveries or be an innovator. However, a true scientist is not usually interested in becoming an inventor; a technologist is seldom a good innovator, for that requires management skills; and a competent manager who knows how to innovate is not often capable of making scientific discoveries or inventions, or interested in doing so. Rarely do these specialists share the same aspirations, the same mentality and background, the same habits, and the same lines of communication. Recent empirical studies show that the relationship between science and technology is far from being as direct and immediate as is sometimes asserted.[4]

On the basis of numerous studies on the subject, Derek de Solla Price of Yale concludes that science forms "a cumulating, close-knit structure; that is, new knowledge seems to flow from highly related and rather recent pieces of old knowledge". He goes on to say that "new technology will flow from old technology .... It may have a similar, cumulating, close-knit structure to that of science, but of the state of the art rather than of the literature".[5] He also notes that "it is evident to any historian of technology that almost all innovations are produced from previous innovations rather than from any injection of any new scientific knowledge".[6]

While the relationship between science and technology does not appear to be close, technology and innovation are much more directly related, although a great number of inventions are never utilized. There is evidence to suggest that the average time for the transfer of science to technology has been about twenty to thirty years and from technology to innovation about nine years. On the whole, it seems more realistic to consider science and technology as separate streams loosely connected than as sections of the same river.

These considerations are important for the orientation of science policy. They have been inserted here to explain the wide scope of the Committee's inquiry. Their implications for a realistic policy strategy are drawn in subsequent sections of the report.

## METHOD OF THE INQUIRY

The Committee began to plan its work early in 1968. We were soon impressed by the scope and complexity of the problems we had been asked to investigate. The inquiry was divided into four successive phases and we decided to hear first a number of experts from Canada and abroad to learn about the broad issues of science policy.

### *First phase*

This began in March 1968. The Canada Council, the Science Council, the Medical Research Council, and the Science Secretariat, all government central agencies with no R&D activities of their own, gave us their overall assessment of the Canadian situation. Some distinguished Canadians who had extensive experience with the national science effort or with one of its important aspects were also interviewed. These included Dr. C. J. Mackenzie, a former President of the National Research Council, who has devoted all his life to the promotion of science in Canada; Dr. Hans Selye, Director of the Institute of Experimental Medicine and Surgery at the University of Montreal; Dr. Vincent Bladen of the Department of Political Economy at the University of Toronto; Professor Arthur Porter, Acting Director of the Centre for Culture and Technology at the same university; and Maxwell W. McKenzie, member of the Economic Council of Canada and former President of the Canadian Chemical and Cellulose Company Limited. Thus some of the broad issues of Canadian science policy were defined by experts from the government establishment, universities, and industry.

Distinguished experts from abroad were also invited, including Lord Blackett, Nobel prize winner for Physics in 1948, advisor to the British Ministry of Technology, and President of the Royal Society; Dr. Christopher Wright, Director of the Institute for the Study of Science in Human Affairs, Columbia University; Dr. James Killian, Jr., Chairman of the Corporation of the Massachusetts Institute of Technology, and science advisor to President Eisenhower; Dr. Richard R. Nelson, economist and author, formerly of the Rand Corporation; Dr. Alexander King, Director for Scientific Affairs at the OECD in Paris; Dr. Jacques Spaey, Secretary-General of the National Council of Science Policy and Chairman of the Interministerial Commission on Science Policy in Belgium; Dr. Saburo Okita, President of the Japanese Economic Research Centre; Mr. Pierre Piganiol, Manager of the St. Gobain Chemical Company and formerly General Delegate of Scientific and Technological Research in France; and finally, Mr. Maurice Goldsmith, President of the Science of Science Foundation in London.

This first phase of the inquiry proved most useful. It allowed the Committee to meet eminent scientists of various backgrounds and from different countries and to become more familiar with the complex problems raised by science policy.

*Second phase*

The Committee then reviewed the R&D activities of the main federal departments and agencies involved in science and technology. This second stage began only in October 1968 because the Committee went out of existence in April as a result of the dissolution of Parliament and was not reconstituted until September.

The summer months of 1968 were devoted to the preparation of detailed guidelines for federal research agencies, indicating the kind of information the Committee wished to receive with respect to their scientific activities. The guidelines were designed to standardize examination of all the relevant agencies. They are reproduced in *Annex B*.

Some 79 federal departments and Crown corporations were contacted and provided with the guidelines. Fifty-three briefs were received from government agencies, many of them containing 100 or more pages, including one of more than 800 pages. Thirty-eight of them were heard, including the Canada Council, the Medical Research Council, the Science Council of Canada, the Science Secretariat, the National Research Council, Atomic Energy of Canada Limited, the Defence Research Board, the Bank of Canada, the Canadian National Railways, and such departments as Agriculture; Energy, Mines and Resources; Fisheries and Forestry; National Health and Welfare; Finance; Treasury Board; Industry; Trade and Commerce; Labour; and Immigration and Manpower. These departments and agencies represented a cross-section of scientific activities ranging from the physical to life and social sciences, from pure and fundamental research to technology and development.

Some of these agencies appeared before the Committee more than once and for more than one day. The Committee completed the second phase of its inquiry at the end of April 1969. For the first time in Canada the inquiry provided a detailed description and a valuable inventory of most of the government's science activities. Many questions raised by the guidelines had never been examined by the agencies; in some cases they were forced to look at their own science activities for the first time. The Committee was thus in a position to obtain valuable information on the scientific manpower, research and development expenditures, formal organization of research activities, and specific science and technology responsibilities of these agencies and departments.

*Third phase*

The final stage of our formal hearings began in May 1969. It covered the university sector, interested provincial agencies, professional associations and learned societies, the industrial sector including some private companies, and a number of private individuals who had submitted briefs. The Committee felt that the relationship between science, technology, and society required a debate in a public forum and that it should ensure that any Canadian who had an interest in this problem would be given the opportunity to submit a brief.

The Committee first received the views of 44 universities and colleges, including individual faculties, and actually heard 36 of them. After having met with members of the Macdonald Group, which had just completed a report on federal support to research in universities, and the executive of the Association of Universities and Colleges of Canada, the Committee organized a "University Week" to hear the representations of the academic community on a regional basis. Groups from the Atlantic to the Pacific were given the opportunity, which they had never had before, to discuss science policy in a parliamentary forum.

Following this, the Committee heard the representations of 63 organizations, including provincial research agencies, learned societies, labour and industrial associations, 35 manufacturing and commercial enterprises, and private individuals. In total the Committee had representations from 272 groups, associations, and individuals from the provincial, the university, and the private sectors.

In this revealing third phase of its investigation the Committee learned about the research needs and problems of the Canadian private scientific community. It heard the assessment, criticisms, and suggestions that these important groups had to make about Canadian science policy. The Committee was also concerned by the isolation of the segments of the Canadian scientific community. Here were three solitudes—the government research sector, the university world, and industry—and within them, additional barriers between one agency and another in government, between one university and another, between one industry or one firm and another. This isolation also pervaded the scientific and engineering disciplines, manifesting itself in the proliferation of learned and professional societies interested in science policy. There were then nearly 100 such associations in Canada.

*Fourth phase: visits abroad*

The public hearings of the third phase were concluded in June 1969. Early in May, however, the Committee had decided to accept the invitation to visit Washington received earlier from Congressman Emelio Daddario, Chairman of the US House Sub-Committee on Science, Research and Development. We felt that it would be most useful to see how the Americans had organized their science effort, to which the Federal Government annually devotes about $25 billion, or approximately half of what is being spent in the whole world for this purpose.

While in Washington the Committee attended a meeting of the sub-committee when it was discussing the International Biological Program and heard Dr. Lee DuBridge, who was then the newly appointed science advisor to President Nixon, and Dr. Norman Gibbons of the National Research Council of Canada. We also met privately with Dr. DuBridge and his assistants, who are responsible for the central co-ordination of science activities in Washington; Dr. DuBridge was also Director of the Office of Science and Technology, Chairman of the President's Science Advisory Committee, and Chairman of the Federal Council for Science and Technology. The Committee held a joint executive session with Congressman Miller's Committee on Science and Astronautics and were told how the American parliamentarians were approaching the issue of science policy. Meetings were also held with Mr. Secor Browne, Assistant Secretary for Research and Technology in the Department of Transport; Mr. William D. Carey, who had recently left the post of Assistant Director for Science and Technology in the Bureau of the Budget and who is one of the most experienced experts on American science policy; Dr. Dael Wolfle, Executive Director of the American Association for the Advancement of Science; and Dr. Philip Abelson, Editor of AAAS's weekly journal *Science*.

In Boston, the Committee held meetings at the Massachusetts Institute of Technology with Professor Richard S. Morse, and Professor Donald Marquis of the Sloan School of Management, two widely recognized experts in the field of research management and methodology; Dr. James Killian, Jr., former science advisor to President Eisenhower; and Professor Joseph Licklider, Director of the Project for Multiple Access Computers. The Committee also held a meeting with General Doriot, President of the American Research and Development Corporation, a private company that specializes in financing new ventures exploiting advanced technology.

At Harvard University we interviewed Dr. Emmanuel G. Mesthene, Director of the Center on Technology and Society; Dr. Harvey Brooks, Dean of Engineering and Applied Physics and Chairman of the National Academy of Sciences Committee on Science and Public Policy; and Dr. Juergen Schmandt, research associate in the John F. Kennedy School of Government. The Committee also had a session with Mr. Howard McMann, a former Canadian and now President of Arthur D. Little Company, and two of his Vice-Presidents, Mr. William A. Krebs and Dr. Bruce S. Old. The firm under-takes research assignments for governments and private industry across the world.

This visit to the United States was most fruitful and provided a much better understanding of the American scientific scene that could be had by reading published material. On the basis of this experience, the Committee came to the conclusion that it would also be valuable to visit some countries of Western Europe before beginning to prepare its report.

The European tour lasted three weeks and began during the last week of August 1969.

SWEDEN. In Sweden we first met the Minister of Industry, Mr. Krister Wickman; Mr. Bo Aler, Section Head for Technical Research and Development, and other officials with whom we discussed the general science and technology role of the Swedish government and the mechanisms responsible for policy making and administration. Meetings were also held with Mr. Sven Moberg, Minister without Portfolio of the Ministry of Education; Dr. Hans Löwbeer, Chancellor of Swedish Universities; Professor Arne Engström, General Secretary of the Science Advisory Council; and Dr. Hans Palmstierna, Executive Secretary of the Environmental Co-ordination Ministerial Council, when we heard a description of the various programs of the Swedish government designed to meet the problems of pollution of the natural environment.

We discussed government incentive programs and financial assistance to encourage industrial research and innovation. Present at these discussions were Dr. E. M. Fehrm, Director General of the Board of Technical Development, and Mr. L. H. Brising, Managing Director of the Swedish National Development Corporation.

The Committee also discussed industrial research and development from the point of view of the industrialist with Professor Sven Brohult and his colleagues, including representatives from seven of the most important private companies interested in R&D and officials of the Royal Academy of Engineers. Finally meetings were held with the representatives of the RIFO (Riksdagsmän och Forsake), an association grouping about 200 scientists and 220 parliamentarians.

WEST GERMANY. From Sweden the Committee went to Bonn, where we had meetings with the Minister of the West German Federal Department of Scientific Research, Dr. Gerhard Stoltenberg, his Deputy Minister, Dr. Hans von Heppe, and about ten other top officials of the Ministry of Scientific Research. We discussed broad issues of science policy in West Germany including organization, budget, and priorities. The Committee then visited

Professor Karl Winnacker of Hoechst, an expert in industrial research and nuclear science who happened to be in Julich, where the Atomic Research Institute is located. We also had the opportunity of obtaining an account of German progress in the nuclear power field. The Committee held a series of discussions with Dr. Kurt Frey, Secretary-General of the Standing Committee of Ministers for Education and Culture, which is also responsible for the participation of Länder, the West German equivalent of provinces, in the national science effort and policy. With Dr. Helmut Krauch and Dr. Horst Rittel of the Heidelberg Systems Research Institute we discussed new research methodology that this institution is developing for the social sciences.

The Committee met Professor Edwin Hoelzler, Assistant Research Director of the Siemens Company, and discussed industrial research. Talks were held with Dr. Karl Gottart Hasemann, General Secretary of the Science Council, with senior officials of the Max Planck Institute, and with representatives of the German Research Association, an important body supporting academic research in Germany.

FRANCE. The Committee then proceeded to France where we had a meeting with M. François Xavier Ortoli, Minister of Industrial and Scientific Development, then acting as Chairman of the Ministerial Committee on Scientific Research. We discussed the role of French parliamentarians in the formulation and control of science policy with a group of French Senators and members of the National Assembly led by Senator Etienne Dailly, Vice-President of the Senate, and M. Maurice Herzog, a deputy, economic and social councillor, and former minister. We visited the Atomic Energy Commission and the European Enterprise Development Corporation, which specializes in financing innovation. Discussions were held with a number of research directors and advisors of different industries on the problems of industrial research in France.

The Committee met with M. Jacques Aigrain, the General Delegate of Scientific and Technological Research, and the top official in charge of the central mechanism for the planning and control of science policy in France. We visited the National Centre for Scientific Research, the National Centre of Space Research, and the National Centre of Oceanography. Finally, while in Paris, the Committee met with Dr. Alexander King, Director for Scientific Affairs at the OECD, who was then completing the organization's report on Canadian science policy with his two colleagues, M. Pierre Piganiol and Dr. Saburo Okita, who had appeared before us in Ottawa.

SWITZERLAND. In Geneva a day long session took place with representatives of government, universities, and industry interested in research and development in Switzerland. They included Dr. V. Hockstrasser, Director of the science division of the Federal Department of the Interior; Dr. F. Walthard, who is responsible for questions of industrial policy in the Department of Economic Affairs; Professor D. R. A. Labhardt, Chairman of the Swiss Science Council; and Dr. P. Aebi, Director of the Vorort, a scientific and research organization of the Swiss Union for Commerce and Industry.

THE NETHERLANDS. From Switzerland the Committee went to The Hague where we first received a briefing on the organization of science policy in the Netherlands from Dr. C. J. F. Böttcher and Professor H. W. Lambers, Chairman and Vice-Chairman of the Science Policy Council. We interviewed a group of parliamentarians interested in science policy representing four different political parties. The Committee also met the research directors of the "Big Five" industrial corporations of the Netherlands—Royal/Dutch Shell, Philips, Unilever, AKU (Algemene Kunstzijde Unie) and States Mines. These companies are responsible for 75 per cent of the research and development carried out in the Netherlands, and discussion concentrated on industrial research and development programs. Meetings were held with Mr. V. Nittel and Dr. C. H. Stefels of the Ministry of Science and Education, who have special responsibilities for central co-ordination of science policy. We discussed agricultural research with Dr. G. de Bakker. A review of the government incentive program for industrial research was given by Mr. A. A.T.T. Van Rhijn, Director of Industrial Research and Industrial and Structural Policies in the Ministry of Economic Affairs. Subsequently, meetings were held with Dr. H. W. Julius, Chairman of the Central Organization for Applied Scientific Research (TNO) (Toegepast Natuurwetenschappelijk Onderzoek), and some of his colleagues, and with Dr. Bannier, Director of the Netherlands Organization for the Advancement of Pure Research (ZWO) (Zuiver Wetenschappelijk Onderzoek), a foundation dispensing funds for basic research.

BELGIUM. In Brussels we were received by the Minister for Science Policy and Planning, M. Théo Lefèvre, who was Prime Minister of Belgium from 1961 to 1965, and who is one of the leaders of the European community, M. Lefèvre was accompanied by more than a dozen of his top advisors, including Dr. Jacques Spaey, Secretary-General of the National Council for Science Policy, who had already appeared before the Committee in Ottawa. The broad issues of Belgian science policy were discussed.

At the headquarters of the European Economic Community the Committee was briefed by Dr. Hans Michaelis, Director General for Research and Technology, on scientific co-operation in the European Economic Community, and by Dr. Robert Toulemon, Director General of Industrial Affairs, on E.E.C. industrial policy in the field of nuclear energy, advanced technology, and the development of innovation in industry. These discussions were concluded by a talk from the Vice-President, Mr. Fritz Hellwig, on the programs and future of the organization.

UNITED KINGDOM. In the United Kingdom we met with Mr. J. Embling, Deputy Under-Secretary of the Department of Education and Science, and his colleagues; Lord Jackson, representing the Council for Science Policy; and Mr. K. Berrill, Chairman of the University Grants Committee. We discussed the organization and science functions of the department, the role of the Council for Science Policy, the support of research in universities, scientific manpower problems, and the system of scientific information being developed by that department.

Meetings were held with Dr. J. A. B. Gray, Secretary of the Medical Research Council, and with Professor V. C. Wynne-Edwards, Chairman of the Natural Environment Research Council. A luncheon meeting was held with representatives of the learned societies; Lord Blackett, President of the Royal Society, was the main speaker. The role of the British learned societies in the national science effort was described.

Interviews were held with Sir Gordon Cox, Secretary of the Agricultural Research Council; Mr. H. C. Rackham, Secretary of the Social Science Research Council; Mr. B. T. Price, chief scientific advisor in the Ministry of Transport; Mr. E. C. Williams, chief scientist of the Ministry of Power; and Mr. John Duckworth, Managing Director of the National Research and Development Corporation.

The Committee held meetings with Mr. J. P. W. Mallalieu, Minister of State for Technology; Dr. G. G. MacFarlane, Controller of Research; and other senior officials of the Ministry of Technology. They reviewed the general organization and functions of the ministry, the policies and programs of the research establishments that come under the responsibility of the Minister, means of encouraging innovation, the activities of the technical information and productivity services, and the major programs in the fields of aviation, electronics, space, and atomic energy.

A luncheon meeting was held with British parliamentarians especially interested in science policy. They were led by Mr. Arthur Palmer, M.P., Chairman of the Select Committee on Science and Technology in the House of Commons.

We discussed defence research and development with Sir William Cook, Chief Advisor for Projects and Research in the Ministry of Defence; technical innovation and industrial development with representatives of the Confederation of British Industries; technological forecasting and project evaluation with experts of Imperial Chemical Industries; the activities of the Science Research Council with its Chairman, Sir Brian Flowers; and central co-ordination of government science policy with Sir Solly Zuckerman, Chief Scientific Advisor to the Cabinet and Chairman of the Central Advisory Council for Science and Technology.

In November 1969 the Committee held a two-day meeting with Dr. J. L. Gray, President of AECL, to review in greater detail the Canadian nuclear program. Formal and public hearings were concluded in February 1970 when the Committee held a return joint meeting in Ottawa with Congressman Daddario and other members of the Committee on Science and Astronautics of the U.S. House of Representatives.

Between March 1968 and February 1970 the Committee held 102 public meetings and more than 20 *in camera* meetings to plan and prepare its work in addition to its visits abroad. It received the views of 325 groups and individuals in Canada. Well over 1,000 scientists and science administrators attended the hearings, either as witnesses or members of the audience. More than 10,000 pages of evidence were accumulated. As the inquiry proceeded, the Chairman and other members of the Steering Committee spoke at about 30 special symposia and annual meetings of Canadian associations across the country on science policy issues.

## THE IMPACT OF THE INQUIRY

Already the Committee's inquiry has had a useful impact. It has certainly helped to initiate the first real national debate on science policy in Canada.

As a result of this debate and of the Committee's discussions with individual organizations on the extreme compartmentalization of the scientific community, a new association called SCITEC (The Association of the Scientific Engineering and Technological Community of Canada) was founded in January 1970 to provide a multidisciplinary basis for the discussion of science policy issues and to enable the Canadian scientific community as a whole to develop its own views on these matters. The Committee will have more to say later about this new organization and the essential role it ought to play in the formulation and implementation of a dynamic science policy.

The Committee's inquiry has already had some influence in government. Individual departments and agencies have told us that the guidelines circulated by the Committee for the preparation of briefs gave them an opportunity to examine their research operations critically and to make improvements that would not have been initiated without such an examination. The Committee believes that its public hearings and the strong and valid criticisms that industry voiced about the Program of Assistance to Industrial Technology (PAIT) influenced the decision of the Department of Industry, Trade and Commerce to make it more effective.

The impact of the inquiry on the government central machinery for coordination has also been obvious. At an early stage of our investigation, it became widely known that the Cabinet Committee on Industrial and Scientific Research had been meeting infrequently, if at all, to examine government science activities. In July 1969 we were told that the Committee had begun to meet every week under the chairmanship of the Hon. Mr. Drury, President of Treasury Board.

When our inquiry began, the Science Secretariat was playing a dual role: privately advising the Prime Minister on science matters, and servicing the Science Council, which had no staff and which advised the Prime Minister on the same subjects mainly through the publication of reports. Our hearings showed that these two functions of the secretariat were hardly compatible and imposed a heavy burden on its small staff. In November 1968 the government decided to separate the two organizations completely and in April 1969 the council became a crown corporation allowed to hire its own staff. In addition, in May 1969 the new director of the Science Secretariat was appointed Chief Science Advisor to the Cabinet.

## NATURE OF THE REPORT

VOLUME I. The first volume is devoted to a critical review of Canadian science policy. This assessment has three perspectives. The first is historical; it describes how science policy developed in Canada and purposely emphasizes the weaknesses which have appeared at different periods since 1916. The second is international; it attempts to perceive how the Canadian science effort and its main components compare with those of other OECD countries, so as to expose weaknesses in Canadian participation in the international scientific and technological race. The third perspective is current and national; it summarizes the critical views on present conditions and the main suggestions presented to the Committee by Canadian representatives of the public and private sectors. This volume ends with the Committee's views on the need for an overall science policy.

VOLUME II. The second volume attempts to build a coherent policy for Canada. It begins by outlining the challenges and opportunities that the present and the future hold for science and technology. This introduction is contained in Chapter 11.

The first part of this volume, Chapters 11-16, recommends a basis for formulating overall policy. It also suggests a general framework, targets, and strategies for that policy, and its main components: the support of basic research, of industrial research and development, and of social R&D.

The second part, Chapters 17-21, deals with re-organization of the administrative science policy structures. It suggests new duties and powers for the central machinery of planning and control. It recommends a new allocation of functions and responsibilities in several existing organizations and the creation of new ones in the three main areas of government support for science activities.

The report ends with a review of the interfaces of science policy, of the network of relations that should exist between the Canadian government on the one hand, and, on the other, the provinces and the municipalities, Parliament, the Canadian scientific community, international institutions, and other countries.

It is also important to indicate what the report does not do.

It is not designed to provide a detailed or even a broad picture of the science activities and programs of government departments and agencies. A detailed description of these operations is contained in the Committee's proceedings. *Annex C* of this report indexes the agencies and organizations that submitted briefs to the Committee and *Annex D* indexes the individuals who appeared before the Committee or submitted briefs to us. As to the broader picure, it has been provided by the OECD report on Canada, and that is still valid.

The report does not present a systematic study and appraisal of the science policies of individual government departments and agencies. In other words, it does not attempt to appraise in a systematic way the rules, methods, and strategies used by each of these organizations to determine and conduct their own science activities. For instance, it does not contain a detailed appraisal of the way Atomic Energy of Canada Limited, the Department of Agriculture, or any other agency carries out its science and technology responsibilities. The Committee did not consider such assessments part of its main assignment.

It is a basic theme of the report, however, that a system that relies exclusively on such individual policies is bound to produce an inadequate national science effort and that a proper overall science policy is much more than the sum of isolated policies. Once this overall policy has developed, it will be much easier to appraise specific policies.

The decision to exclude assessment of the policies of individual departments and agencies makes parts of the report more abstract and academic than they would have been if concrete examples had been given to substantiate arguments. We believe that our decision was wise, that our main arguments stand on their own, and that the academic character of a few sections of the report is fully justified because certain important issues raised by science policy really are academic in the true sense of the word.

The Committee would be naïve not to state that its report is far from providing complete and final answers to the problems that science policy ought to solve. After prolonged hearings and discussions with the leading experts in this field in the Western world we know that no individual, no group, and no country has yet found such answers.

The world of science and technology, of research and development, and of innovation is still largely unknown. And yet these activities are changing more rapidly than any other sector of human endeavour. If science has an "endless frontier", how could it be otherwise for science policy. All that can really be hoped for at any given moment is to provide a better understanding and organization of that complex and changing world in the immediate future than in the recent past.

Within this less demanding context, the Committee is convinced that it has proposed new avenues, new strategies, and new institutions that could help the Canadian people and its public leaders understand and master this mysterious world. To that extent, we are satisfied with the job done. But we are much more impressed by the unfinished business. Indeed, unless the societies of tomorrow want to suffer from a widening technological gap or to be dominated by technology, they will have to devote much more serious and continuing attention to their overall science effort than they have done up to now.

## A SENATE STANDING COMMITTEE ON SCIENCE POLICY

This vigilance is a responsibility that belongs to all individuals and groups. Let us hope that their failure to fulfil it in the past will soon be corrected. But parliamentarians have an obvious and special obligation in this respect which has not always been recognised.

This neglect was brought to our attention on many occasions. Indeed, so many distinguished experts who appeared before us congratulated the

Senate for setting up our Committee that it sounded almost like a criticism of the past. Many witnesses said they hoped the interest of the Senate in Canadian science policy would continue after publication of this report, when our Committee ceases to exist.[7]

All the members of the Committee are convinced that this suggestion is sound and should be accepted. It is impossible to provide adequate answers to the problems raised by science policy at any given time, just as it is necessary to re-define that policy endlessly; and this indicates the need to provide a permanent forum easily accessible to the public and at the same time offering an opportunity for parliamentarians to express their views on these important issues.

If this suggestion is accepted, the new permanent committee should undertake an inquiry every five years and present a report on the general state of science, technology, and innovation in Canada and on the major changes that appear to be needed in overall science policy. Between these general reviews, the proposed committee could select a specific area or problem of science policy each year and study it in depth. There are several such areas or problems that deserve special attention and detailed consideration: scientific and engineering manpower requirements, atomic energy, food technology, communications, scientific and technological information, research methodology, and research management are given here merely as illustrations. Other new major issues requiring quick but careful attention will undoubtedly arise.

**The Committee therefore recommends that the Senate appoint a standing committee on science policy to make a general review of major policy issues every five years and to undertake special investigations each intervening year on specific areas or problems of particular interest within the scope of science policy.**

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# 2

# THE EARLY DAYS:
# THE FIRST ATTEMPT TO BUILD A SCIENCE POLICY

## INTRODUCTION:
## THE NEED FOR AN HISTORICAL REVIEW

This chapter and the three that follow review the development of science policy in Canada, emphasizing the Canadian government's response to the challenge of science and technology. They describe how major research and development programs were initiated and new institutions established to deal with that challenge. They analyze the successive attempts that were made to co-ordinate the science activities of public agencies, why they failed, and how the absence of a global strategy affected the government's involvement with science and technology.

The Committee has found that the present state of Canadian science policy is largely a result of the past and cannot be really understood without reference to its historical background. Any consideration of the development of science policy in Canada must necessarily focus on the history of the principal government institutions, such as the National Research Council, the departments concerned with science and technology, the Science Secretariat, and the Science Council. It is useful to review the history of these agencies, for this provides a perspective for some of the Committee's conclusions. It is true that one risks being unfair in criticizing institutions that were set up to contend with the problems and opportunities of the past. Nevertheless, their failure to transform themselves to meet new challenges must be pointed out to show that changes have become necessary. But it must also be recognized that transformations of this kind are a major world problem that has nowhere been solved satisfactorily.

The danger arising from the re-constitution of an historical record has been described by Fischer as the *pragmatic fallacy*; one can fall into this trap by selecting facts in the service of a cause. In choosing its material, the Committee may have had its perception coloured by its preoccupation with the problems of present-day science policy. To guard against such bias, the Committee has asked some knowledgeable persons to read and comment on these historical chapters.

## SCIENCE AND TECHNOLOGY IN CANADA: THE BEGINNINGS

In the latter part of the 18th century and the early 19th century the pace of technological development and application in Europe began to accelerate. This development has come to be known as the "Industrial Revolution". In time this revolution swamped the whole of Western society and changed its social fabric in a most dramatic manner.

As Karl Polanyi wrote, "The nineteenth century, as cannot be over-emphasized, was England's century. The Industrial Revolution was an English event."[1] The men responsible for technological innovations in England during the beginning of the Industrial Revolution were nonconformists who had been excluded from the universities and learned their science indirectly while pursuing their trade. In other words, the coupling between science and technology was very loose and did not rely on the established system of higher education. The new discoveries that created this revolution at the end of the 17th century in England "were made by men outside the Royal Society and the universities. The many-sided, inventive men who founded the Royal Society in 1660 still existed. . . . But they were no longer to be found in the respectable circles of the professional scientists. Instead, they were found in the manufacturing towns, and in the academies of the dissenters, to which manufacturers sent their sons because they gave a more realistic education than the universities."[2]

During the early part of the 19th century, Great Britain and to a lesser extent France were fast developing industrial technology and finding ways of fruitfully exploiting science. Later on the United States moved from technical backwardness to such a level that it could begin exporting to the "advanced" European countries manufacturing techniques and machine tools so different that the whole approach became known as the "American system". An English productivity team that visited the United States in 1853 to study this "system" concluded that "Men served God in America, in all seriousness and sincerity, through striving for economic efficiency."[3]

Meanwhile, in Canada a small population was struggling to open up a large land and to extend the region of habitation. Although from the beginning Canada had people who were knowledgeable about science and technology and aware of its future importance, Canadian activity in these fields and the development of Canadian industry both lagged behind the progress of Europe and the U.S.A. On the whole, the growth of Canadian science before World War I was a slow and cautious process.

Canadians are probably backed by more natural resource wealth per capita than the citizens of any other land. It is not surprising that some of the first scientific interest in Canada was focused on these resources. For example, the transactions of the Quebec Literary and Historical Society, founded in 1824, contain the first works on geology published in Canada, and in 1856 the Natural History Society of Montreal began publication of the *Canadian Naturalist and Geologist*. It is also not surprising that the oldest scientific organization of the Government of Canada is the Geological Survey of Canada, the present-day descendant of the Geological Survey of the Province of Canada, which was created in 1841.[4] It is one of the oldest survey groups in the world; the survey in the United States, for example, was founded in 1879. The challenge of vastness is still with us: Dr. J. M. Harrison, writing in 1960, could state that "not more than 15 to 20 percent of Canada is now geologically mapped in adequate detail."[5]

The founding of the Geological Survey and the publication in 1863 of the *Geology of Canada* laid the foundation for the Canadian mining industry,[6] which did not become prominent until the 1890s in British Columbia and the early years of this century in northern Ontario when rich deposits of gold and silver were discovered.

The first study of astronomy in Canada, too, was in response to practical problems. The Jesuits in Quebec studied partial solar eclipses as early as 1670 as an aid to determining longitude.[7] Federal government support of astronomy dates back to 1885 when the first longitude surveys were begun in order to define tracts of land needed for the construction of railways in British Columbia. But astronomy seems to have been the first pure science in Canada. The first astronomical observatory in this country was founded at Fredericton, N.B. in 1851, and was followed by other small observatories: Quebec City in 1854, Kingston in 1875, and McGill University in 1879. The completion of the Dominion Observatory's 15-inch telescope in Ottawa in 1905 allowed Canada to start the research that rapidly won a respected standing in international science.

When the Dominion Astrophysical Observatory was completed in Victoria in April 1918, its 72-inch telescope was the largest in the world.[8] Dr. J. S. Plaskett directed the observatory from its beginning until 1935; his studies of the motion of the Milky Way and its stars and the rotation of galaxies were respected contributions to science.[9] In 1922, he discovered a twin star now called the Plaskett twins.[10] The field is as exciting today as it has ever been. How best may Canadian scientists continue to share in the opportunities for discovery? The circumstances surrounding the federal government's cancelling of the Mount Kobu telescope illustrates the difficulty of science policy decision making.

In 1852 the government of Canada appointed Pierre Fortin to head an expedition to inquire into the protection of the fisheries of the Gulf of St. Lawrence. Fortin initiated the scientific study of the fisheries by listing the species found in the area and by developing a system of fishery statistics that has provided basic data for much later research.[11] He was summoned to the Senate in 1887.

The present Fisheries Research Board is a direct descendant of the Board of Management of the Biological Stations established in 1898 by the Department of Marine and Fisheries. Parliament formalized this organization in 1912 by establishing the Biological Board of Canada. In 1937 the responsibilities of the Board were increased and the Board was renamed the Fisheries Research Board of Canada. The first full-time chairman was appointed in 1953. He was named as "the chief executive officer of the Board and has supervision over and direction of the work of the Board." Thus for the first time both policy guidance and full-time executive authority and responsibility were placed in the hands of a person always available to the minister and to the field establishments.[12]

The oldest scientific journals that have been continuously published in Canada are two that began in 1868: *Le Naturaliste,* founded by L'Abbé Léon Provencher, and *The Canadian Entomologist,* founded by William Saunders who, in 1863, created the Entomological Society of Canada.

It was around this time that experimental farms were being developed in the United States. The improvement of agriculture there had been accelerated by the land grant colleges, the "cow colleges" as they were known by some, and by the middle of the 1870s states began to set up experimental stations designed to give these colleges both outdoor and indoor facilities. Many observers thought more effective co-ordination between state experimental stations and the U.S. Federal Department of Agriculture—and more federal money—would be a further improvement. In 1887, Congress passed the

Hatch Act which made the experimental stations purely state institutions aided by federal land grants; A. Hunter Dupree writes:

> The passage of the Hatch Act changed the Department of Agriculture from a single central agency into a nexus of a system of semi-autonomous research institutions permanently established in every state. No other scientific activity of the government had attained such a spread.[13]

In Canada, in 1884, a select committee of the House of Commons looked at the problems of agriculture and recommended, among other things, the establishment of an experimental farm. A year later Professor William Saunders was sent to tour the experimental farm stations in the United States. He recommended a similar experimental station project in Canada.[14] Four months later Parliament passed a bill establishing five experimental farms, of which the principal or central farm was to be in Ottawa and to serve Ontario and Quebec.[15]

The courses followed by Canada and the United States in setting up experimental farms indicate what the situation has been over the years in several other fields. The United States would innovate institutional responses to problems or opportunities earlier than Canada; some years later Canadians would study the U.S. system and then initiate a solution compatible with the Canadian political, social, and economic environment. Because of its earlier development and larger population, the United States has been used from time to time as an "early warning line" for problem identification and as a model for organizational solutions.

The name of William Saunders is connected with one of the most striking innovations in Canadian history: the introduction of Marquis wheat. The opening of the West and the increasing grain export trade had revealed the need for earlier-ripening, good quality wheats, and in 1892 Saunders crossed an early ripening wheat from India and the popular Red Fife. This led to the famous Marquis wheat. Saunders' son, Charles, made the final selection and is generally regarded as the father of Marquis.[16] This wheat was introduced in 1907, and ten years later it accounted for nearly 90% of wheat grown in Canada.

Nevertheless, wheat rust still caused repeated and disastrous crop losses. Representatives of federal and provincial departments and experts from the United States held a conference in Winnipeg in 1924 and mapped out a series of experimental projects for a central Rust Research Laboratory on the grounds of the Manitoba Agricultural College at Winnipeg. This laboratory opened in 1925 and after exhaustive tests Renown, the first new wheat variety, combining disease resistance, high quality, and satisfactory yield, was released to farmers for seeding in 1937. Many other varieties followed. An eastern Canadian paper commented on the battle against wheat rust:

> Nothing that the politicians have done or are doing, nor anything they may do towards strengthening the position of the wheat producer, can, in the long run, compare with what has been accomplished by departmental scientists in developing wheat that is not infected by rust.[17]

Forestry research[18] was slow to develop in Canada. From 1875 to 1905 federal forestry seems to have been largely involved with the disposal of timber from federal reserves, though some informal experimental research in nursery research was conducted by the Department of Agriculture and later by the Forestry Branch of the Department of the Interior. The first formal forest experimental station was established by the Forestry Branch at Petawawa in 1917.

The importance of forestry research was understood by some but it was many years before the federal government began conducting research. As early as 1884, J. H. Morgan, Forestry Commissioner, submitted a report to the Minister of the Interior in which he recommended the use of a system of forest management and the establishment of forest experimental stations. In various forms this recommendation recurred for more than 30 years. Yet the annual report of the Department of the Interior for 1916-17 noted that an advisory committee had submitted a memorandum pointing out the great need for forest research in Canada:

> Ignorance, lack of definite information, opinions rather than knowledge of facts have characterized, and still to a large extent continue to characterize, the methods of handling the forest resources of the Dominion to their detriment and loss . . . We have in Canada not yet undertaken the first systematic study of the biology of any of our species, a knowledge fundamental to its silviculture . . . As regards increment, the rate of production that may be expected from our species under varying conditions, we are also lacking in knowledge. There are neither volume tables as aids for timber estimating nor growth or yield tables as bases for calculating the results of our silviculture in existence. Meanwhile, truly foolish ideas prevail regarding the rate of growth of forest trees and forest acres.[19]

Not until 1921, did the federal government at last establish a Division of Forest Research in the Forestry Branch.

There was little basic research in the sciences before World War I. Nevertheless one important episode is worth mentioning here.

Around the turn of the century, three young scientists were working at McGill University who later went on to win Nobel prizes, the ultimate symbol of scientific accomplishment. One of the three was a young New

Zealander, Ernest Rutherford, who has been called "one of the greatest scientists of all time."[20] In 1902, Rutherford and his McGill associate, Frederick Soddy, put forward a theory of radioactivity that brought order into the chaos of many newly discovered elements. At the beginning of their McGill days Rutherford was 27 and Soddy 22.

In 1905 a young German chemist, Otto Hahn, went all the way to Montreal to become a student of Ernest Rutherford. This was the first demonstration of Rutherford's amazing ability to attract and train scientists of the first rank. Hahn subsequently described Rutherford's tin-can apparatus and basement laboratory at McGill and remarked: "It was in our favour that this whole area of research was so new that one could have the pleasures of discovery even with primitive equipment." Back in Germany, Hahn received the Nobel prize for chemistry in 1944. Frederick Soddy, in England, had received this prize in 1921 for his work on isotopes (the physics Nobelist that year was Albert Einstein), while Rutherford himself had received the Nobel prize in chemistry in 1908, the year after he left McGill for Manchester.

Until World War I, the Canadian government concentrated its science activities on natural resources. That policy was sensible. For a large country with a small population that had to face the unfavourable impact of coal and steel technology, the normal avenue to rapid growth lay in the exploitation of natural resources. It was wise, therefore, to survey their potential and prepare to use them more effectively.

## WORLD WAR I AND THE BIRTH OF NRC

World War I challenged the government to extend its involvement with science and technology. For the first time the government concerned itself with what is now called science policy, as opposed to its previous practice of trying to solve practical problems as and when they arose. The stimuli came from Canadian industrialists, the British government, and Canadian universities.

In 1915, a group of businessmen urged the government to encourage industrial research.[22] It was suggested that the government should cooperate with the universities to improve industrial techniques and to finance the work. A meeting was held in the office of the Minister of Trade and Commerce, but nothing concrete resulted.[23]

Later that year the British Government created a Department of Scientific and Industrial Research (DSIR).[24] Parliamentary responsibility for this department was vested in the Lord President acting with the consent of a committee for scientific and industrial research attached to the Privy Council. The main source of scientific knowledge was supplied to this committee by an advisory council drawn from members of the Royal Society.[25] In 1916 a British cabinet minister seems to have recommended a similar plan to the governments of the Dominions,[26] and the U.K. Ministry of Munitions added a Canadian university to the list of British universities to which it sent a circular inviting co-operation in research and development. According to Mel Thistle, the historian of the National Research Council, the letter requested that a Canadian government department co-ordinate university research activity. This exhortation, occurring in the midst of a war in which Canada was aiding its "mother country", brought results. In May 1916 the principal of McGill University told the Minister of Trade and Commerce, Sir George Foster, that at the annual conference of Canadian university presidents he would propose that the universities associate themselves with the DSIR, unless the minister had more definite proposals for co-operation between the Dominion government and the universities.[27] The minister replied:

> I have not yet abandoned my idea of co-operative work with the Universities along the line of research. The scheme of Imperial authorities is wide and comprehensive, but it seems to me that first and foremost each Dominion should organize itself and through that organization, work with the Imperial scheme.[28]

Before leaving for England, the Minister of Trade and Commerce asked for the appointment of a committee of six cabinet ministers to be responsible for the expenditure of funds provided by Parliament for scientific and industrial research. He also recommended the establishment of a council of unpaid advisers to be responsible for co-ordinating research in the universities and suggesting projects for their attention. These recommendations were approved by Order-in-Council in June 1916. Thus was born the National Research Council, as the Honorary Advisory Council came later to be called.

It was not an auspicious birth. It is apparent that the government's hand was to some extent forced by the spectre of Canadian universities becoming linked with Britain's DSIR. The Minister of Trade & Commerce recorded in his diary "Got my Advisory Council though most members of [Privy] Council utterly indifferent or antagonistic."[29] The council was not born out of a deep, strongly held conviction of the need for a science policy machinery. But it was a start.

Dr. C. J. Mackenzie describes the sitution this way: "It was from Britain in 1915 that Canada's attention was first drawn to the fact that science had become a major force and that government should recognize this and set up the necessary machinery to insure the best use of this new element."[30]

The British influence did not stop there; as late as 1963 Dr. Mackenzie commented to the Prime Minister:

> While detailed government organizations in Canada will naturally differ from those in Britain, it is from the country that our systems of government and organization have stemmed that we can draw our most useful lessons. Information from other western countries about general objectives is interesting, but to guide us in regard to organizational details an examination of the experience of Britain is the most helpful.[31]

The Order-in-Council setting up the Honorary Advisory Council (or, as it became popularly known, the National Research Council) laid down the following reference:

(a) To consult with all responsible bodies and persons carrying on scientific and industrial research work in Canada with a view to bringing about united effort and mutual co-operation in solving the various problems and industrial research which, from time to time, present themselves;

(b) To co-ordinate as far as possible the work so carried on so as to avoid overlapping of effort and to direct the various problems requiring solution into the hands of those whose equipment and ability are best adapted thereto;

(c) To select the most practical and pressing problems indicated by industrial necessities and present them, when approved by the Committee, to the research bodies for earliest possible solution;

(d) To report, from time to time, the progress and results of their work to the Minister of Trade and Commerce as Chairman of the Committee of Council.

Later, according to the chairman of the National Research Council, Dr. A. B. Macallum, it was found that "to make things stable, to give a certain amount of security and definitiveness to its work, it was necessary to have a statute enacted." This statute was assented to on August 29, 1917.

Thus the Canadian government decided more than 50 years ago to establish a central machinery to plan and co-ordinate the national science effort. It is worth underlining some features of this first attempt to develop a general science policy for Canada. The new central organization was copied from the British model. Its responsibility was to plan and co-ordinate, but it could not carry on any scientific work itself. Its objectives were clearly mission-oriented and aimed at "the most practical and pressing problems indicated by industrial necessities."



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## THE CRONYN COMMITTEE: A FIRST EXPRESSION OF CANADIAN CONVENTIONAL WISDOM

As its first task and according to its terms of reference, the National Research Council undertook a review of scientific and industrial research in Canada. The situation was bleak. Questionnaires were sent out to about 8,000 firms, replies were received from 2,800, and only 37 firms were found to have research laboratories. The majority employed only one research man, four employed two or three, and seven or eight employed four or more. Dr. Macallum said that some of the work could hardly be called research and concluded that "in this country, there are not many more than fifty pure research men all told."[32]

At the conclusion of its review, the council presented its recommendations to the Privy Council sub-committee on scientific and industrial research. At the centre of this proposal was a two-part plan:

> The government should build a research laboratory complex, primarily to develop the new technology Canada needed if it was to join in the post-war progress of the more advanced nations.
>
> Industry should be encouraged to expand its research facilities and to join forces in setting up "industrial guilds" to consider the common research needs of a particular industry sector. It was proposed that instead of the government helping to fund laboratories for these guilds, the staff of the guilds would conduct research in the proposed new government laboratories under the supervision of the laboratory staff.

In April 1919, five months after the end of World War I, these proposals were submitted to a special committee of the House of Commons. The chairman was Hume Cronyn. The committee called witnesses from the government, universities, and the private sector and from the United States. This was the first public forum provided by Canadian parliamentarians for the discussion of science policy issues.

We quote extensively from the evidence presented before that committee because the prevailing views it contains represent the first expression of the Canadian conventional wisdom on science matters and because they had a significant impact on subsequent developments.

Looking back today with the advantages (and disadvantages) of more than half a century of experience of government involvement in science and technology, one can only marvel, on the one hand, at the primitive state of Canadian industry and, on the other, at how similar were the basic problems the men of those days had to cope with; at the subtlety with which they foresaw problems of our own times that were then only faintly visible; and at the patience and pertinacity the council members brought to their pioneering task.

The end of World War I had left Canada gloomy and uncertain of the future. One brief the House of Commons committee received went so far as to propose an optimism campaign:

> That the Publicity Department of the Government start at once an optimism campaign, and that in this the press of the country be requested to co-operate. The country is drifting into a pessimistic state of mind as regards the immediate future which might easily bring about far-reaching depression unless it is quickly checked.[33]

It was thought that scientific research was one instrument that could help revive the country's hope. One witness appearing before the Cronyn committee, Prof. A. L. Clark of Queen's University, put it this way:

> If we go in for this research—and we surely must do so—we should not be content with scratching the surface with imitations. We should begin by establishing a system of training workers and create a scientific atmosphere as it has never been done in any country. This country is rich, a few millions spent on research will yield untold millions and prestige beyond our dreams.[34]

This romantic view of science and technology was far from the reality of 1919.

The development of natural resources was lagging, according to Prof. R. D. McLaurin of Saskatchewan, who called it "one of the most vital problems which is facing Canada at the present time."[35] He added that Canada was importing 98 per cent of its oil and large amounts of iron ore and coal.

Professor McLaurin stated that:

> In Canada the only national industry, we might say, is agriculture. The Canadian people recognize that. Everyone recognizes the importance of agriculture. We should have the same thing in science. It is necessary to create a national industrial consciousness.[36]

There were also difficulties in the pulp and paper industry. Dr. R. F. Ruttan of McGill said that although enormous capital was invested in the pulp and paper industry from Labrador to British Columbia, there were only two men "in charge of the expert work in connection with these mills. . . .We have not trained the men, with the result that those in charge of the technical work, especially the chemists in the larger mills throughout Canada, come from Norway, Sweden, and the United States. We have only one, perhaps two, who are Canadian graduates."[37]

Professor Ruttan said that Canada, a country of eight million people, was probably the only country of that size in the world "that has no adequate university or Government research facilities. Therefore, as a nation we have very little to be proud of with regard to our standing in what might be called the most advanced regions of educational work, in which I include, naturally, research. . . . The whole problem has to be undertaken from the beginning in Canada where there are no universities properly equipped for research nor any institutions worth speaking of devoted to research in the larger sense. . . ."[38]

The representative of the Canadian Manufacturers Association, noting that thoughtless people proposed to rely on research imported from other countries, pointed out that many resources were unique to this country and that Canada must do research on those.[39]

Even basic services were lacking. For example, Professor Clark stated:

> At present, if I wish a thermometer calibrated or a set of weights standardized or some electrical instruments tested, I must send them to Washington. That should not be. We should have a place here in Ottawa where such instruments could be sent and taken care of at once.[40]

In the opinions expressed by the council's members we can spot one of the problems that continue to confuse research policy to this day. They could see that industry had to be supported by research, but most of them suffered from what the well-known scientist René Dubos calls "the snobbery of scientists toward inventors."[41] Dr. Macallum himself cautioned that "a training in industrial research alone gives only limited powers and the researcher so trained is ineffective except on very special points"; furthermore, "from the nature of things," industrial science was "only of ephemeral value".[42]

He gave an example:

> There are a large number of experts engaged in the flotation process of separation who do not even recognize that surface tension is involved and in consequence any improvement that they seek to find is sought for only empirically . . . while fundamental research, if carried on in surface tension, may, in one discovery, affect the whole industrial field ultimately.[43]

This attitude undoubtedly stemmed in part from the quality of fundamental or basic scientific research then being done in universities. Dr. Macallum pointed out that only two Canadian universities gave the Ph.D. degree, a necessary prerequisite for a research worker—Toronto (from 1896) and McGill (from 1904). Dr. Macallum claimed that in all that time the two

Canadian universities had granted only 11 Ph.D. degrees in pure science whereas he supposed that U.S. universities turned out 350 to 500 Ph.D.'s in the field each year.

Dr. Macallum thought that the trouble lay in the tradition of Canadian universities. He suggested that the universities were controlled, not by men of science, but by men whose education was on classical or literary lines. He said:

> I recall that when I first began to advocate the promotion of research in the University of Toronto, both inside and outside of the university I met with ridicule. All the staff on the Literary side were pointing to Oxford as the model for the university to follow, not an American university, and contempt was poured on the word "research". What was research, they asked. We had to meet that attitude.[45]

Professor W. Lash Miller of the University of Toronto told the Committee that he had asked a number of professors at Toronto whether they would like to see an institute for industrial research set up at the university and had found "they would not." He explained:

> I think they feel they would not like bargaining with manufacturers, because in the long run the university would lose more than it would gain.[46]

Dr. Macallum shared the view of the Toronto academics:

> If you bring an industrial research problem into a laboratory it monopolizes all the attention of the place. Its importance is enhanced, because it is going to have immediate results, if successfully solved. The students themselves form a wrong estimate of the value of it, and in consequence they are inclined to disregard fundamental research . . . Research in fundamental science should be their function which is a part of education . . . The council . . . would not make any provision in its recommendations for forcing industrial research on the universities.[47]

Not many witnesses contested the council's view that university research should be pure; of the few who did, two made particularly damaging comments, for they were senior officers of the institutions on which the council's proposal for a central laboratory complex in Ottawa was patterned, the Mellon Institute of Pittsburgh and the National Bureau of Standards in Washington. Dr. S. W. Stratton, director of the National Bureau of Standards, said that although researchers for industry should be well grounded in mathematics and the fundamental sciences of physics and chemistry, technical courses had to be added at the graduate level. Universities should turn out men trained in cellulose chemistry or in the chemistry of rubber, for example, because those were the types of researchers industry wanted. W. A. Hamor, assistant director of the Mellon Institute, also thought universities could carry out industrial research: "You would not only be training men there for the institute, but you would be actually doing something and getting the work under way."[49]

For the parliamentarians and the National Research Council members, one of the most delicate areas was existing government research. One witness said hopefully that since Canada's problem lay in the need to create *industry*, the council's activities would presumably not come into conflict or even contact with federal departments already operating laboratories and carrying out research. This observation did not convince the Commons committee and they called as witnesses a number of federal government scientists.

One who must have reassured them that they were right to look into government research was the Dominion Cerealist, Dr. C. E. Saunders (of Marquis wheat fame). He was critical of the experimental farm program that had been set up following his father's report 30 years earlier. He said at the outset that "it would seem to me desirable that the purely scientific part of agricultural investigations should be separated from the present experimental farm system."[50]

He contrasted the control of research exercised by universities and government departments. Governments looked for immediate success, "for obvious reasons. Governments wish to please the people. They wish to be re-elected, and the ordinary voter wants results right now, just the very time when they cannot be had. At any cost therefore he must be convinced that success is being attained . . . The proper method is to look not for immediate success, because immediate success often means permanent failure, but to look for light. Those two words, success and light, express the contrast between the two methods . . . to seek not immediate success but light—a very much finer and more important aim."[51]

Dr. Saunders presented a long exposé of the problems of research in the Department of Agriculture. The neglect of research might make Canada permanently dependent on the rest of the world for its basic agricultural science. "Petty details prevent work being done," he said, and "laws and regulations are steadily increasing in number and red tape has become a tragedy rather than a joke." Researchers who needed freedom and "an undisturbed mind" were "harassed by all sorts of annoying regulations and demands." Researchers on the farms who tried to pursue scientific research found that "scientific papers are refused publication. The Printing Committee will not pass them. . . .We have been warned that the Committee will only publish such articles as they consider of practical value such as will increase the supply of bread and butter, I suppose."[52]

He could see only one way out:

> There is no hope for scientific research in its best form unless an institute be established which is not under direct, daily, departmental control. . . . If an institute for scientific research could be established under the control of an independent board of scientists, it might accomplish a great deal both in pure and in applied science. Such an institute could, I think, very well take over the study of the great basic problems of scientific agriculture, while the experimental farms might continue to be demonstration farms, teaching institutions and propaganda centres for good farming.[53]

Another problem was brought to the committee's attention by Professor Edward E. Prince, chairman of the Biological Board, Naval Department, Ottawa:

> I know I am on controversial ground but official heads like to have big departments and the more officials they have the more credit they think attaches to themselves. So that each department wants its own lawyer, architect, biologist, and medical officer, and all duplication goes on in order to enlarge the staff and make the department important. The idea is duplication and waste of money.[54]

The advisory council saw itself co-ordinating science policy and becoming involved "with all phases of scientific and technical problems affecting the economic and industrial life of the country." Would the government support and encourage it in this direction? Even at the risk of blocking the growth plans of a particular department? These were the questions underlying the discussions before the Commons Committee in May and June 1919.

The council agreed that industrial development must depend in part upon an army of Ph.D.'s trained in fundamental science and believed that universities would be subverting their role by training engineers and industrial researchers. As Professor Ruttan, a member of the council, put it, universities would provide the money and facilities for training in basic research, and the council would supply the incentives to students to get that training.

> The universities must receive money from somewhere. . . . The universities must get special endowment in connection with research, and it would with much better grace come from the public, from those who support the universities, or from the provinces, than it would from the Federal Government. There are so many universities, eighteen or twenty as Dr. Macallum has pointed out, that would apply for this grant. . . . With the view of assisting in this research and graduate work we have established fellowships, scholarships, studentships, and recently bursaries, the object being to help the universities to get the men. But the universities must supply the money for the training.[55]

Another problem raised before the Commons Committee was the seriousness of the brain drain. Professor Miller said that the University of Toronto undergraduate honours chemistry courses fitted students for research but



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that there had never been many students. The yearly average for the previous 27 years had been about half a dozen graduates. He said steps had never been taken to increase that number because their best men had always gone south of the border.

He said the same was true of graduates who had gone into industry.

> As in the case of those who have gone into academic work, the greater number, and the best paid, are south of the border, in rubber works, oil, gas, soap, salt, abrasives, explosives, electrochemical works, etc., not doing routine work under somebody else's direction, but in responsible well paid positions. . . I think these illustrations will help to make it clear why we did not try to get more men into the chemistry department. We were turning out half a dozen men a year and Canada did not need that number. If we sent out more men they would simply leave Canada. . . . The universities did supply the men, but we could not place them here, and the reason was not that the men were no good, for they have made a great success of their work in the United States . . . .We saw these things a long time ago, as far back as 1902 we were just as clear about this subject as we are now.[56]

The council concluded that two things had to be done simultaneously if Canada was to increase the level of scientific research. Job opportunities had to be created for the graduates, and more research-trained students had to be graduated. But it was easier said than done.

Turning to what was regarded as the major problem, Dr. Macallum said Canada had between 40 and 50 firms whose operations would benefit greatly by research but that their annual sales were not sufficient to meet the expenses involved. He contrasted the research budget of the few Canadian firms that did conduct research, such as Imperial Oil, which spent $240,000 a year, and Consolidated Rubber, which spent $40,000 to $50,000 with the numerous American firms that spent "several hundred thousand dollars each year on research.[57] In looking at this problem, Dr. Macallum said, the council "took a leaf out of the book of the British Research Council" and advocated the formation of industrial guilds for joint research for firms in a particular industrial sector. The firms would pool their research funds and hire research men to investigate their problems.[58]

In Britain the government funded laboratories, equipment, and staff for several such research associations. The Canadian council could not give any substantial funds for these purposes, "but," Dr. Macallum said, "we hoped to give these guilds . . . advantages which would equal that which the British Research Council provides for the trade associations for research. These advantages would be free accommodation, light, and heat in a national research institute.[59]

The national research institute, Dr. Macallum said would parallel "in a modest way for the next few years the Bureau of Standards in Washington, and in the building which is to house this institute there would be free accommodation for the staffs of various guilds of research. This, with supervision that the staff of such an institute would exercise over the work carried on by the staffs of the guilds housed in the institute, would greatly promote the success of the researches carried on by such guilds. There is great urgency in the need of such an institute in Canada. We must give our industries such advantages as the American industries possess."[60]

The council's recommendation for a laboratory complex (the National Research Institute) was elaborated before the Commons Committee by Dr. Macallum. One part dealt with what he called "the Bureau of Standards side":

The institute shall have charge of:—

(a) the investigation and determination of standards of length, volume, weight, mass, capacity, energy, and time, and of the fundamental properties of matter.

(b) the standardization of the scientific and technical apparatus and instruments for Government service and for use in the industries of Canada and of the materials used in the construction of public works.

(c) the investigation and standardization of the materials which are or may be used in the industries, and of the products of the industries.

(d) researches undertaken with the object of improving the technical processes and methods used in the industries and of discovering new processes and methods which may promote the expansion of the existing industries or the development of new Canadian industries.

(e) Researches undertaken to promote the utilization of the natural resources of Canada.

The second part, he said, dealt with "the industrial side":

The Institute shall have charge, direction or supervision of the researches which may be undertaken by or for single industrial firms under conditions to be determined in each case or by such organizations, to be known as Trade Guilds for Research, which may be formed in the various industries with the view of improving the processes of production or the products of these industries, as may desire to avail themselves of the facilities offered for this purpose by the Institute.

Thus all roads led to the creation of a laboratory complex, the National Research Council Laboratories as it was called when it was finally built many years later.



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Commencing on this recommendation Professor Ruttan said:

> Probably one of the greatest authorities, Dr. Stratton, the head of the Bureau of Standards, stated that if they could begin again they would have the one central organization instead of having a geophysical laboratory, a chemical bureau, and numerous other laboratories, as well as the Bureau of Standards and research institutions in connection with the Department of Agriculture and the Department of Food, all doing research in an independent way. One national organization for research in addition to the departments of the United States Government, doing routine scientific work, would lead to the best results. We found that this was confirmed by a number of others at the various discussions that we carried on.[61]

The central research institute would also help to absorb the increasing number of graduates which it was hoped the universities would produce, aided by scholarships from the National Research Council.

This large stream of researchers was to go to the institute, where they would work on standards and supervise the researchers coming from the industrial research guilds. Presumably some of this flow would leave the institute to work in industry but there was no discussion of how that would come about.

Council members pushed for generous funding for their institute. Professor J. C. McLennan, for instance, said the cost of the institute had been estimated at half a million dollars but that was insufficient, "a mere bagatelle"—an understandable comment in light of evidence given by A. W. Hamor of the Mellon Institute: "At the present time, gentlemen, manufacturers in the United States are spending annually ten million dollars in chemical research, and perhaps an equivalent amount in physical and mechanical investigation. The chemical research relates largely to the discovery of new processes, the improvement of existing processes, the cheapening of products, standardization work, and a certain amount of research applied to the public service."[62]

There were critics who disliked the idea of a central institute and would have preferred a number of decentralized institutions. There were also supporters of the central institute who had reservations about some of its features. The Canadian Manufacturers' Association urged two points on the government. The research council should include "manufacturers in representative industries ... on a basis equal numerically to the academic representation now thereon," the manufacturers said; and they also thought the government should, under the supervision of the research council and "in co-operation with the industries on terms to be agreed upon, establish, equip and maintain a laboratory for conducting scientific industrial research and furnishing information relative to new processes, properties, inventions, improvements, and materials discovered there *as may seem capable of use* by interested manufacturers."[63] Even that early, it is seen, industry was concerned about academic control of the research council and about the paternalism implicit in the proposal that the central research institute should have "charge, direction or supervision of the researches which may be undertaken for industry."

Yet although the research council representatives and other Canadian scientists were seeking to increase the number of pure scientists, the examples they cited to the parliamentarians as problems to be investigated by the institute were very pragmatic. They included:[64]

Use of straw for producing gas for Western farmers.
Development of signalling methods for foggy weather.
Utilization of low-grade iron ore.
Development of a wheat superior to Marquis.
Exploitation of the Western tar sands.
Certain problems of pollution.
Development of the enormous supplies of lignite in the West.
Manufacture of ethyl alcohol from waste sulphite liquor from pulp mills.
Methods of extracting helium from Alberta natural gas.
Methods of utilizing fish waste.
Development of navigational aids based on anti-submarine technology.
Economic use of coal and fuel supplies.

Although the witnesses proposed many investigations of a practical nature, Professor Ruttan reported that when the research council put out a call for problems requiring research assistance "we were rather disappointed at the number of men who came forward in answer to our request for problems. There were very few. It was one of the most disappointing features in connection with our work. . . . We expect to have more applications in the future."[65] The need to develop an atmosphere in which industrial research was normal rather than exceptional could hardly have been demonstrated better.

## CONCLUSION

Before World War I, the emphasis had been on surveying and using Canada's natural resources. During and after the war, the main preoccupation was with the needs of industry and university training to meet these industrial requirements. The diagnosis presented to the Cronyn committee by Canadian scientists in 1919 was accurate but, as we can see today, the remedies proposed were impractical.

The scheme rested on two premises: that Canadian industry was clearly incapable of carrying out enough research of good quality to satisfy its needs and that there were not enough scientists in Canada to investigate and solve industrial problems. The conventional wisdom was also strongly opposed to the idea that universities should carry out industrial research.

With such premises the solution seemed very simple. The National Research Council would use financial incentives to induce young Canadians to get a scientific training. Universities would produce more and better pure scientists. A government research institute would hire them to work on standards and other technological problems faced by primary and secondary industries and to direct or supervise research done by industry in government laboratories. Thus the deficiencies of supply and demand would be corrected.

This first formulation of a Canadian science policy was not the work of Cabinet ministers who were "utterly indifferent or antagonistic" but of a small group of dedicated scientists. Its success, however, depended largely on generous government funding. Moreover, it clearly created a conflict of interest between the co-ordination and research functions of the council. Individual firms were not considered the ideal location for industrial research aimed at market innovations, and the limitations of cooperative arrangements for research within an industry when secrecy is essential were under estimated. Finally, the policy ignored the fact that pure scientists are trained to carry out pure research and that they are not usually motivated or equipped to do testing work and to solve engineering problems.

It is easy today to make these criticisms. But some of these points were presented to the Cronyn Committee in 1919, mainly by American experts. It is regrettable that they were not given more weight and attention.

The first Canadian attempt to plan and co-ordinate science activities ended in confusion. Canada adopted the British model for planning, co-ordination, and execution of science activities as well as for university training, but the objectives and goals that were selected, namely the emphasis on industrial research and standardization, were inspired by the American experience. This dual focus of science policy should not surprise us today. It merely reflected the general Canadian ambivalence during a transitional period of our history.

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# 3

# BETWEEN THE WARS: THE FAILURE OF SCIENCE POLICY

Once formed, the National Research Council had to give meaning and reality to the function formally defined for it in the Act. This was not an easy task. In C.J. Mackenzie's words, "By terms of reference the NRC was instructed to co-ordinate and promote scientific and industrial research in Canada. The NRC soon found that there was little or nothing to co-ordinate."[1] From 1912 to 1915, it was estimated, the total expenditure on university research by government departments amounted to $277,000. The NRC study begun in 1917 showed that less than $100,000 was expended annually by government laboratories for scientific research, and apart from salaries the total amount spent in 1916 in industry was probably less than $135,000.[2] This, plus the mere trickle of Ph.D. graduates in the physical sciences and the lack of interest by the Privy Council, must have made the situation appear bleak to members of the National Research Council, especially at a time when the British and American governments were much more deeply involved in science.

## THE COUNCIL'S MODEL

For the council, *research* was the key word, the path to success; *development* and *innovation* or even *engineering* do not appear to have been in the Canadian science policy vocabulary of the day. It was the role of the universities to train "the new army of researchers who are to assist in the application of science to Canadian industry."[3] The universities should not attempt to train researchers in industrial research but should concentrate on pure and applied science, "which is held by all who have experience in research to be the best field in which to prepare students for a career in industrial research."[4] Implicitly basic science was associated with timeless values, industrial research with the ephemeral affairs of commercial life.

The persistence and stability of this view is noteworthy. A decade later NRC's President, Dr. H. M. Tory, stressed the point:

> It is very seldom that the pure scientist is willing to put aside his own work and undertake a special piece of industrial work. The man willing to do so is usually one who . . . generally does not succeed in doing work after it is given to him. I would never permit a university over which I presided being made a fifth wheel to an industrial coach. Our work after all is teaching and research.[5]

When some council members suggested the government should fund universities to carry out industrial research, others argued that this would deflect universities from their true goals and overburden their already meagre capacity to train research scientists. The council's response was to begin a program of scholarships and grants.

The council members wished to build a strong basic science capability in Canada—where virtually none existed—and to see that it did not bog down in short range industrial research objectives. Nevertheless, they realized that if basic science was to maintain its financial support it had to deal successfully with practical problems of national significance. That led the council to propose a co-ordinating machinery for each new technical problem as it arose. By 1920 the council had created its system of appointed advisory committees, but they were not successful. Seven years later Dr. Tory claimed that all the major research projects then in progress were "the results of study and persistent effort on my part to get them going."[6] The problem of co-ordination proved persistent.

The council's other major objective was to develop government laboratories to undertake long-range industrial research that no one else would do. This seemed the obvious way to put science and industry together. Many firms would never be able to afford the luxury of their own laboratory: they could combine their resources as "Trade Guilds for Research" for particular industries for the purpose of financing research in the central complex of government laboratories.

The council's model foresaw the necessarily loose relationship of science, technology, and practical development. Science would be confined principally to the universities; technology and advancements in the "state of the art" would be found in government laboratories and in the laboratories of the few large firms with trained researchers; development would presumably be carried out by industry, although this was not too clearly spelled out.

### NRC'S BATTLE WITH THE CIVIL SERVICE ESTABLISHMENT

The council was the first science policy machinery to be set up in the environment of government departments and political realities, and like all innovations it was resisted. When the council was set up to co-ordinate research and then sought to build its own laboratories, the government departments understandably became very conscious of the fact that they were "here first". Several had a long and distinguished career of scientific achievement, and from their point of view the council, the new enthusiast for science, was simply hoping to rediscover what they had known for years. It was inevitable that there would be a clash between the established bureaucrats who knew how the system worked and a new council of, to them, innocent enthusiasts.

On the other hand, there was no reason why the university professors and others on the council should have had an undue respect for civil servants —and they hadn't. The Civil Service Commission, they said, was not capable of selecting scientists. The process of selection was too slow and the salary scales offered were low. Speaking of the council's proposed laboratory, its chairman predicted: "If it is put under the Civil Service Commission it will die prematurely or be ineffective as so many Departments of the Government are."[7] Eventually the council managed to obtain its independence from the Civil Service Commission. But the council still reported to a Cabinet subcommittee whose members were ministers of the main departments conducting research, who would therefore be briefed by their senior officials. The grounds for internecine battle were well laid.

Government departments were understandably cool toward the council's attempt to co-ordinate their work, set up associate committees, or fund research in what they might well have considered their fields of activity and to attempt to obtain laboratories, which might extend the council into direct competition with them.

The early days were scarred heavily by institutional friction. When the council tried to obtain information about pulverized coal for a public report, "difficulties arose, chiefly through the curious psychology that develops in government departments. The jealousy that was manifested in this connection was beyond any expectation of mine."[8] NRC felt that the Department of the Interior was "busily concealing the fact that it was the Council who initiated forestry research at Petawawa",[9] and later the council president wrote that the Deputy Minister of the Interior instructed members of his department "not to give us information, not to mention us in the literature, etc."[10] Dr. Tory wrote the chairman of a Commons committee that the Interior Department had committed "a deliberate action to steal some of the work which otherwise would be done by our National Research Laboratories".[11] Another department was also in the fray with Dr. Tory: "Things are as I expected. Department of Defence wants everything and our co-operation was only asked because we were in ahead." A senior NRC staff member said: "Personally I have many times felt that some of the Department were more concerned with preventing encroachment on what they consider to be their preserves than with the importance of getting the work done. This situation is thoroughly recognized by those who have had any considerable experience with the Public Service . . ."[12]

In 1927, according to Thistle, the NRC historian, "relations with the Department of Mines, tense as they were, constituted a model to be envied in comparison with the relations between the Research Council and the Departments of Agriculture and the Interior." Nevertheless the Deputy Ministers of Mines and Agriculture had been placed on the council and the president was resisting the appointment of the Deputy Minister of the Interior. The council had won its independence from the civil service but it ran the risk of being dominated by those whom it was supposed to co-ordinate.

The Senate Committee has often been told that co-ordination of scientific and technological activity in government organizations can only be achieved when people from the various organizations are in day-to-day contact or sitting together in committees. To believe this of NRC's early days would be credulous beyond reason; to believe that it would work any better today would be naive. Friction is inevitable when issues are important and when enthusiasm and ambition run high, especially if there is little policy direction and review from above.

Even the Senate for a time frustrated the council's ambition to obtain its own laboratories. In 1921 the Meighen government determined to give NRC the authority to establish laboratories—a National Research Institute. The bill also stipulated that the council would come directly under the Department of Trade and Commerce. After much debate the amending bill was passed in the House, but it was defeated in the Senate. The president of Dalhousie University, a member of the council, was moved to write, "It seems a pity to allow a lot of old blathering idiots in the Senate to stampede us. I read the debates, if they can be called such, in the Hansard, and I think that I never had the opportunity of reading such unadulterated twaddle."[13]

Six years later the council's president claimed he had subsequently learned that the bill did not pass because "the hostility to the Research Institute organization was deep-seated in the minds of members of the Government", and that inquiry had shown him that the bill's proposal to set up a "completely separate organization, known as the Research Institute, under a separate set of officers" and divorced from the council "was the real reason why the Bill had failed to pass the Senate."[14]

Another attempt was made to obtain the laboratories in 1924, at the same time as the council was seeking the greater autonomy of what would now be called a crown corporation. This time the council chairman, Dr. Tory, rewrote the NRC Act of 1917 in such a way that authorization for the "research institute" could easily be struck out, so that opposition to the laboratories would not cost him an improvement in NRC's status. Struck out it promptly was, but the revised act passed. (The definition of NRC's work in the Research Council Act of 1924 is reproduced in Appendix 1.)

In 1928 the Minister of Trade and Commerce announced the government's decision to proceed with the laboratories. But should they be separate or part of the council? Despite the hot debates of earlier years, Dr. Tory (whose title had been changed from chairman to president by the Act of 1924) won his case that they should be part of NRC and should in fact be called the National Research Laboratories. From 1919 on, the council had pressed hard to obtain laboratories. It was not until eleven years later, in February 1930, that construction began.

The minister's announcement in 1928 was accompanied by a declaration of intent "to gradually co-ordinate research work of government departments under one controlling organization."[15] But how this was to be done was not spelled out.

## CO-ORDINATION: THE FORGOTTEN FUNCTION

While the council was fighting with government departments to get its own laboratories it had little time and energy left to accomplish the mission for which it had been originally established, co-ordination of the national science effort.

The Cabinet sub-committee, which was the other element of central co-ordination machinery, could not be very effective when its advisory council was fully occupied on another front. In 1921 Sir George Foster, the Minister of Trade and Commerce and chairman of the sub-committee, remarked that it had been "impractical". He stated further: "You can get meetings of the Cabinet with reasonable regularity of attendance, where you have the interests of the whole to be looked after; but when you make a sub-committee stand in the place of the minister with reference to a branch of work being carried on under him, practical difficulties arise. It works out in the end to this—the chairman of the sub-committee must take the responsibility and in the main must carry on the work. So much delay is caused in getting together the members of the sub-committee that it keeps back all the work of the department, and if you adhere to that method absolutely it is very difficult to make progress or to have satisfactory administration."[16]

It must be said, however, that the sub-committee could work when it had something concrete to do. For three years, 1927-30, it met monthly to discuss the research council, mainly because of problems connected with the founding of the new laboratory. Then it reverted to its former habit of indifference, leaving matters in the hands of the chairman. (Time did not much change traditional apathy, however: the sub-committee held no meetings between 1950 and 1958.)

In those early days there was not much research to co-ordinate in industry. NRC's opportunity to co-ordinate its *future* plans with those of industry was weakened by the absence of contacts and the insignificant representation of industry on the council and its associate committees, as it is still, 40 years later.

There were difficulties too with the universities. The council thought the universities should concentrate on pure research but had to "contend . . . against two universities because their Presidents held that all the research work required to advance the industries should be carried on in the Universities."[17] Other universities regarded the budding council simply as an unwelcome rival. Dr. Macallum reported "the authorities of Queen's are opposed to the creation of a National Research Institute simply because they want to get the money for Queen's University."[18]

The council, fighting for its own autonomy and its laboratories, was hardly in a position to co-ordinate the activities of its rivals in government departments. The conflict of interest that the council itself created was too obvious for them to miss, and they refused to be co-ordinated.

The reasons why the central co-ordination machinery established in 1916 could not work were obvious. Yet in the 1930s the government was still declaring its interest in co-ordination. Prime Minister Bennett stated that "all government scientific services should be centrally co-ordinated and controlled."[19] NRC's president took up the Prime Minister's idea and offered to bring federal research programs under review and control by the council. He described his proposal in a memorandum he wrote to the Deputy Minister of Trade and Commerce, J. G. Parmelee, in April 1932. (It is worth reading in full for the feeling its gives of the problems of that time, many of which persist to this day; the document is printed as Appendix II.) Dr. Tory knew by then that co-ordination could not work. What he proposed was integration or amalgamation of government in-house science activities within the council, as a substitute for "co-ordination". For example, he stated:

> The Public Works Laboratories without question would find their natural home in the National Research Building. . . . Such work would ultimately be done under a testing division of the National Research Laboratories. . . . Without question the bringing under the control of one body of all the analytic work done for the Government Services in the various small departmental laboratories would be a tremendous advantage.[20]

NRC staff estimated that the proposed amalgamation of government research would reduce the costs by about one third. Yet for all the stated interest, for all Dr. Tory's efforts, for all the potential savings, nothing was done. Government departments that had rejected co-ordination were certainly not prepared to accept amalgamation, which in many cases would have meant the transfer of their research services to the council.

The council also failed to accomplish another mission that it had proposed for itself in 1919. Dr. Macallum had suggested that "the universities ought to produce a large number of scientific research men" who would work in NRC's laboratories if not required by universities. However, 13 years later, when the laboratories were formally opened in 1932, "it was impossible to obtain the required number of scientists to staff the Council laboratories."[21] By June 1935 there were only 54 professionals on the council's staff. Lack of funds certainly had something to do with this situation. Whatever the reasons, the slowness of response was not commensurate with the fast pace of international developments in science.

The picture of the situation on the eve of World War II painted by Thistle shows the complete failure of "co-ordination" and of the first attempt initiated in 1916 to formulate and implement a science policy for Canada:

> Government scientific services for agriculture, mining, forestry and fisheries continued as before. Even the smaller laboratories, for example in the health field, went on with their business as usual. Agricultural research remained scattered, and uncoordinated by anybody—not even by the Department of Agriculture. The Minister of Agriculture . . . refused to name anyone from his department to . . . [the council's] Committee on Agriculture, and set up a rival committee of its own to which . . . the director of NRC's Division of

Biology and Agriculture was appointed. The Council, of course, continued to co-ordinate a portion of Canada's scientific effort by way of the Associate Committee mechanism. This brought together all parts of the scientific community from universities, industries, and government. However, this committee device was largely restricted to national problems, in which all three components had an interest. It left untouched and unco-ordinated most of the 'in-house' scientific activities—pure science in the universities, the private affairs of private industries, and even the private affairs of public institutions such as government departments.[22]

### A POST-MORTEM ON SCIENCE POLICY: NRC's PLAN IN 1938

In 1938, 19 years after the council presented its review to the Cronyn Committee of the House of Commons in 1919, the National Research Council submitted a brief[23] to the Rowell-Sirois Commission (the Royal Commission on Dominion-Provincial Relations). General A. G. L. McNaughton was then NRC's president and had been since 1935. The similarities between the 1919 and 1938 presentations were striking, and they deserve to be underlined.

In 1938 the key word was still "research"; in fact the report ended with the statement, "Countries neglect research at their peril." The introduction implied that the research situation in Canada had not greatly changed in two decades: "Even now, organized research may be said to be in its infancy."[24]

Nor had the years done much to bring about the long-sought co-ordination of science activities. The report stated: "In any expansion of [research] activities special consideration should be given to the formulation of a national plan of research, and to arrangements for close co-operation between all research workers and research organizations throughout the country."[25] Obviously the established machinery was not doing the job.

The NRC submission specified three requirements for a national research plan:

(1) A survey of the country's natural resources, industries, and facilities for research . . . A national survey of the natural resources and industries of Canada from a technical point of view has not yet been made . . . Several years ago the National Research Council proposed taking preliminary steps in such a survey, with particular reference to the natural resources of the country, but the facilities for carrying it out were not obtainable.

(2) An estimate of domestic needs and of the part which Canada might play in world economy . . . [this] would involve a detailed study of imports and exports . . . related to the country's natural resources and

manufacturing facilities . . . . It would also be surprising if it did not disclose the existence of research problems which alone stand in the way of the utilization of raw materials or waste products already available.

(3) A study of the means which should be adopted in order to attain the desired ends.[26]

These proposals represented almost exactly what the council had been asked to do in 1916 and what it had been specifically authorized to do by the Act of 1924.

NRC repeated its claim of 1919 that pure science was the keystone of research and industrial development:

> . . . The solution of practical problems by research depends on the new facts brought to light and made available by fundamental research; . . . the long-range research of today carried forward without immediate utilitarian objectives is the basis of the practical investigations of the future. . . .[27] Recognizing this truth, the National Research Council . . . has undertaken as a component part of its duties under its charter to support university investigations in pure science.[28]

Again in 1938, as it had in 1919, the research council insisted that the vital function of research must be conducted by Ph.D. graduates in the pure sciences and warned of the dangers of conducting industrial research in the universities. University professors, the council said, must be accomplished researchers like Rutherford and Osler in order to train and motivate students.

One of the conclusions of NRC's submission to the Rowell-Sirois Commission was as follows:

> Fundamental scientific research is the basis of industrial research, and the chief responsibility for it rests on the universities and national research organizations. The selection and training of research workers is a continuing task of the first importance.[29]

Since 1919 the council had set up a system of post-graduate scholarships to complement its university research grants. While this had been an important factor in building up postgraduate schools, the council thought these facilities still inadequate, "and in consequence much more effort in this direction will be necessary."[30] The council was still, in 1938 as in 1921, providing about 40 scholarships a year at an annual cost of about $30,000; in the 20 years of the program more than 400 persons had been assisted. NRC had a total staff of around 300 employees and it was estimated that about a third were people who had received these scholarships at university.

NRC, in 1938 as in 1919, was critical of what industry was doing. Research carried out by corporations still mainly related "almost directly to their own operations . . . and even yet a very large proportion of industrial research is intended to solve specific problems"—a far step from the important part of the research spectrum, basic research. NRC's brief contrasted this with the practice of some U.S. companies, which undertook "many researches where no immediate commercial objective was in view."[31]

The 1938 submission contained the same complaint about the brain drain. "Many of our best men have been and are being drawn away to these organizations from service in their own country, and thereby . . . we suffer a heavy loss, both in money to pay for imports and culturally in the slowing up of our progress."[32] There was a new danger, too:

> In Canada, many companies are subsidiaries of larger companies in Great Britain or the United States. . . . In such cases, all, or a great part, of the research is usually carried out by the parent company.[33]

The NRC brief did not discuss any means for increasing the research conducted in industry, but contented itself with the following observation:

> Industrial research will, in general, be carried out by industry itself. In appropriate circumstances it is practicable and of advantage for industry to have research on special problems carried out for it and at its expense by the National Research Council.[34]

It seems that the large welcome mat for industry had gone from the door of NRC's laboratories, but that some headway had been made in co-operating with researchers in departments of the federal government. NRC's submission to the Rowell-Sirois Commission recalled what difficulties had been experienced earlier:

> Some years ago fears were expressed in Parliament and elsewhere that the activities of the Research Council might overlap those of the Department of Agriculture. Actually, nothing of this sort has taken place; the working arrangements between the two bodies are quite as harmonious as if they were a single organization.[35]

As a matter of fact, only four years earlier NRC's president, Dr. Tory, himself had been worried that Agriculture's chemistry branch was being further expanded when the research it was undertaking could more advantageously have been undertaken by his own organization.[36] The brief itself had previously emphasized the need for "close co-operation".

As Dr. Macallum had in 1919, General McNaughton in 1938 justified the council's laboratories by emphasizing the council's practical researches.

NRC's Division of Biology and Agriculture was working on grain research, paying special attention to the problems of growing wheat and barley in western Canada. The Division of Chemistry was placing its main emphasis on industrial research: asbestos, laundering and dry cleaning, leather, and rubber were mentioned. Work on the streamlining of locomotives, the design of ship's hulls and windmills, and tests on domestic oil burners were among the activities of the Division of Mechanical Engineering. The Division of Physics and Electrical Engineering conducted routine tests and standardization on such items as thermometers, air cameras, and surveying instruments along with research on sound and heat insulation, radio and X-rays. The Division of Research Information, collected, collated, and distributed scientific information, built up a library, published the *Canadian Journal of Research*, and was working on a comprehensive national building code as a guide to Canadian cities and municipalities.[37]

The associate committees too, to judge from their titles, were mainly concerned with pragmatic problems: asbestos, coal classification and analysis, field crop diseases, forestry, grain research, laundry research, leather, market poultry, oceanography, potato research, storage and transport of food, Trail smelter smoke, tuberculosis, weeds and wool.[38]

Yet over the years the council in its public statements had placed great stress on pure research and belittled utilitarian research or termed it of "ephemeral" value. This dichotomy was not restricted to the National Research Council nor to Canada. In commenting on this problem the scientist René Dubos has written:

> The ambiguity of social attitudes toward science may account in part for some disconcerting behavioral traits of the scientific community. Scientists are prone to teach their students that science is a great intellectual adventure to be pursued without regard for practical utility. But they encourage technologists and popularizers to convey a different message to the public because they realize that science for science's sake does not have enough general appeal to secure large financial support. The very same scientists who affirm in academic circles that they are primarily concerned with eternal truths publicize the practical potentialities of their work when they testify before congressional committees. This conflict between the pure science ideal and the exigencies of democratic processes has profound and unhealthy consequences.[39]

## CONCLUSION

NRC's 1938 brief to the Rowell-Sirois Commission was a post-mortem on Canada's science policy as it had been organized and formulated in 1916 and 1919. Neither the initial function of co-ordination nor the original objective of fostering industrial research had been satisfied. The model proposed in 1919 had not become a reality. But NRC had succeeded in obtaining its own laboratories and in establishing a good relationship with the most important Canadian universities through its financial support. This was undoubtedly the major development that occurred on the scientific front in Canada between the two world wars.

It appears, however, that when NRC obtained its laboratories the effectiveness of the council as an overall science policy agency was seriously weakened. The council could hardly perform its advisory role effectively when its president was responsible for operating laboratories in competition with not only government departments but the universities and industry too.

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29. NRC Submission, *op. cit.* p. 49.
30. NRC Submission, *op. cit.* pp. 21-22.
31. NRC Submission, *op. cit.* p. 45.
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33. NRC Submission, *op. cit.* pp. 45-46.
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## APPENDIX I

The scope of the council's work is set out in the Research Council Act of 1924, Sections 6 and 10:

6. The Council shall have charge of all matters affecting scientific and industrial research in Canada which may be assigned to it by the Committee, and shall also have the duty of advising the Committee on questions of scientific and technological methods affecting the expansion of Canadian industries or the utilization of the natural resources of Canada.

10. Without thereby limiting the general powers of the Council conferred upon or vested in it by this Act, it is hereby declared that the Council may exercise the following powers, namely:—

. . .

(c) to undertake in such way as may be deemed advisable:

- (i) To promote the utilization of the natural resources of Canada;
- (ii) Researches with the object of improving the technical processes and methods used in the industries of Canada, and of discovering processes and methods which may promote the expansion of existing or the development of new industries;
- (iii) Researches with the view of utilizing the waste products of said industries;
- (iv) The investigation and determination of standards and methods of measurements, including length, volume, weight, mass, capacity, time, heat, light, electricity, magnetism and other forms of energy; and the determination of physical constants and the fundamental properties of matter;
- (v) The standardization and certification of the scientific and technical apparatus and instruments for the Government service and for use in the industries of Canada; and the determination of the standards of quality of the materials used in the construction of public works and of the supplies used in the various branches of the Government service;
- (vi) The investigation and standardization, at the request of any of the industries of Canada, of the materials which are or may be used in, or of the products of, the industries making such a request.
- (vii) Researches, the object of which is to improve conditions in agriculture; . . .

(d) To have charge of, and direction or supervision over, the researches which may be undertaken, under conditions to be determined in each case, by or for single industrial firms, or by such organizations or persons, as may desire to avail themselves of the facilities offered for this purpose.

(g) Subject to the approval of the Chairman, to publish, from time to time, such scientific and technical information as the Council may deem necessary.

## APPENDIX II

### TO J. G. PARMELEE* FROM H. M. TORY, OTTAWA, 16 APRIL 1932

I enclose herewith a memorandum on the laboratory situation, as requested by you. I have not signed it, as I thought you would put in your own name. I have, of course, no objection to the Minister knowing that I drafted it.

### MEMORANDUM REGARDING LABORATORIES

It is rather difficult to get a reasonable estimate of what laboratories might be advantageously brought under a common system without having had the privilege of going over the laboratories in detail, determining exactly the kind of work being undertaken in them and the amount of time that is devoted to administrative work outside of such efforts at research as are being made.

*Types of Laboratories under the Federal Government*

Laboratories under the Federal Government may be divided broadly into two classes—

A. Laboratories the work of which involves a greater or less amount of research or which could to advantage be developed definitely along research lines.

B. Laboratories the work of which is concerned primarily with the administration of Acts of Parliament or with testing of a somewhat routine character.

A. *Laboratories the work of which involves research*

Of the laboratories of the first sort, the main laboratories outside of agriculture are the laboratories in the Mines Branch, the Forestry Branch and the Dominion Observatories in Ottawa and Victoria.

1. The Geological Survey may be considered as being concerned with the *location* of mineral resources in Canada, and stands pretty much in a position by itself, except in the use of geophysical methods of prospecting, which is in the strictest sense a problem for physicists to solve, as is shown by the fact that the Geological Survey has been using professors of McGill and Toronto in assisting them in a solution of this problem.

*Deputy Minister, Department of Trade and Commerce.

2. The Mines Branch laboratories may be regarded as concerned with the *character* of the mineral resources located by the Geological Survey. Here is a distinctive branch of service which, properly co-ordinated, would be working in closest liaison with the central research organization. This liaison has been effected in the United States and in Great Britain, where complete coordination of effort has been brought about.

3. Under the Mines Branch the Divisions of Ore Dressing and Metallurgy, Fuels, etc. may be regarded broadly as being concerned with the *utilization* of mineral resources, the Ore Dressing and Metallurgical Division being concerned more particularly with the winning of metals from the ores. Here again, especially in relation to the analytical work involved, a close relation and coordination should be brought about in relation to the National Research Laboratories, especially in the planning of programs and in interchange of information.

In none of these three instances is it intended to suggest that the personnel should necessarily be under the control of the Research Council, but coordination of work to avoid duplication ought to be brought about.

4. With regard to the Forest Products Laboratories, they could be brought into intimate relationship, preferably, as in England, under the control of the National Research Council. A considerable part of the work of these laboratories is of a chemical nature, for example, wood preservation, fireproofing, gluing, wood utilization; part of the work bears on physics and engineering, for example, timber testing, strength of materials, etc.; some of it is biological in character, for example, wood preservation, timber pathology etc.

The National Research Laboratories now have a Chemical Division specially fitted to undertake all types of chemical work. Its plans could easily be extended to include varnishes, paints, wood distillation, and the study of wood by-products generally. The Division of Physics and Engineering will be fully equipped for testing all sorts of building material, including strength of materials, machines capable of caring for work now being sent to the United States because of lack of facilities in Canada. The work of this division could easily be adjusted to care for all the physics and engineering work of the Forest Products Laboratories. A similar adjustment could take place with regard to biological problems.

The work of the pulp and paper division is almost entirely research. This laboratory is at Montreal, and could with great advantage be related to the work of the Research Council. The Council is already interested in the use of waste pulping liquor for the manufacture of tanning extracts, and its work on straw has a direct relation to the problem of making paper and board for agricultural wastes. The tying of these interests together with common programs would greatly increase the efficiency of the staffs already at work.

5. The Public Works Laboratories without question would find their natural home in the National Research building, where essential equipment for doing all the work they are now doing must be set up to meet the growing demands that

are being made for testing and standardization. Such work would ultimately be done under a testing division of the National Research Laboratories. A good deal of work of this nature is already being done under the Division of Physics and Engineering.

6. In the Department of Trade and Commerce the Electrical Inspection Laboratories under Mr. Stiver are being brought into the new laboratories of the National Research Council. The standardizing work for this branch will be done by the National Research Council, as authorized under the new Electricity Inspection Act. The liaison here has been completely established and the plan of cooperation worked out.

7. Similar arrangements could be made in connection with the Weights and Measures Branch. Here there is a clear distinction between the standardizing work, for which the Research Council is responsible under the Research Council Act, and the administrative work which is done by officers operating under Mr. Way.

8. So far as research work under the Department of National Defence is concerned, complete coordination has already taken place, and all the work that could be considered as of a research character is now being turned over to the National Research Laboratories. It can be stated without fear of contradiction that not only is more work being done of a real research character than was possible under the arrangement of a small laboratory directed by the National Defence authorities, but the work is of higher quality.

9. The Physical Testing Laboratories heretofore conducted by the Department of the Interior were transferred last year to the National Research Council, and the work has already been completely absorbed into the Council's organization. The old laboratories on Cliff Street are being abandoned, and the equipment is being set up in the new National Research Laboratories, where the Division of Physics will give supervision and control.

10. With regard to the Biological Laboratories, complete liaison between the Biological Board and the National Research Council has never been established. Most of the researches undertaken by the Biological Division under the Research Council has been of an agricultural character. The Council has, however, undertaken the solution of a number of problems of a marine character on request of interested parties. Pending the completion of the Council's laboratories, the work has been done through a department of a university either (a) by subsidizing the research in the university laboratory; or (b) by providing a scholarship for a graduate student to work under the direction of a university. The work done in curing the disease causing the discoloration of canned lobsters is an example.

It has been suggested in the past that the National Research Council and the Biological Board should have some common membership, for example, that the Research Council might have representation on the Biological Board and the

Biological Board on the Research Council for the purpose of completely coordinating the work of the two organizations. The real difficulty has been that the National Research Council has been working under a permanent executive while the Biological Board has been under honorary direction, so far as executive control is concerned. There can be little doubt that a great saving could be affected, or the amount of work done considerably increased if better coordination were brought about.

11. The Laboratory of Hygiene, and possibly also the Pharmacological Laboratory, of the Department of National Health, would enormously benefit by being in association with the National Research Laboratories where general biological work is being carried on, even if their workers remained under the control of their own department.

12. It is believed that the scientific work in the Observatories would also be similarly benefited by closer association with the Research Council's activities, as their work is almost wholly research.

B. *Laboratories Engaged in Analytical Work for the Purpose of Administering Acts of Parliament*

Two outstanding examples under this heading are the Food and Drugs Laboratory under the Department of Health and the Laboratory under the Department of Customs. There are also a number of special purpose laboratories in various other departments of Government, especially in the Departments of Agriculture, Marine and Fisheries.

The Food and Drugs Laboratory stands by itself. The advantage it would have by being part of the general laboratory system would be the contact with a group of scientific workers following similar lines of work. The work of this laboratory is mainly routine, administering a special Act.

In the National Research Laboratories it has been found absolutely necessary to have a division of work devoted entirely to testing and chemical analysis. Without question the bringing under the control of one body of all the analytic work done for the Government Services in the various small departmental laboratories would be a tremendous advantage. Under highly trained technical officers much more work could be done by junior men than if left to work in small groups by themselves . . .

Such a centralization would result in two or three great advantages:

1. It would bring the routine work under the direction and supervision of highly trained specialists. This could not do otherwise than increase enormously the efficiency of the service and the quantity of work turned out per person.

2. It would make available to a central body a mass of information which should be useful for the standardization work of the National Research Council.

3. It would assist in providing information of value in drawing a complete picture from a technical point of view of the industrial and agricultural activities in Canada and would without question suggest openings for research.

4. By bringing this routine and semi-routine work in contact with the research point of view, it would improve its quality and lead to the use, where desirable, of improved testing methods.

In other words, bringing such laboratories in contact with the research and standardizing work of the National Research Laboratories would open the door to many new and important developments.

To bring this about effectively, without question changes in personnel would in due course have to be considered.

The list of laboratories submitted is not by any means complete, but the general principle stated above might be considered as applying all round. To get a final answer as to which ones were suitable to be included in a central scheme would necessitate a careful and intensive study of the actual work going on in the laboratories . . .

*The National Research Council*

Since its inception the Research Council has made it a matter of policy to secure coordination of effort not only with the Government departments, but as far as possible to secure the cooperation of all research agencies available in Canada. No large research enterprise has been undertaken without calling together the scientific leaders in the country to secure their judgment—

1. As to the wisdom of undertaking the special research;

2. If the research was to be undertaken as to laying down a scheme of studies in a comprehensive way.

For example before the cereal rust research was undertaken on its present scale, an international conference of experts was called at Winnipeg . . . The Department of Agriculture undertook to build and staff the Winnipeg Laboratory and to devote their efforts to the study of the sources of infection and possible prevention measures. They also took a part of the plant breeding program for rust resistant varieties. The University of Manitoba undertook a section of the plant breeding work. The University of Saskatchewan undertook a plant breeding program and other scientific aspects of the problem. The University of Alberta undertook to study the cause of rust infection and the conditions associated with immunity. The National Research Council undertook to finance the work of the three universities in so far as additional equipment and routine help was concerned. A permanent committee of management was appointed to guide the work. This committee meets each year after the work of the year has been concluded to study results and plan new work if necessary.



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# 4

## THE SECOND WORLD WAR AND ITS AFTERMATH: A COUNTRY WITHOUT A SCIENCE POLICY

When war broke out, General McNaughton resigned as president of NRC and was replaced by Dr. C. J. Mackenzie. According to the new president, there were in 1939 "not more than two dozen" graduate students in applied science in Canadian universities and "only a few industries did any research."[1] NRC had a total staff of 300 employees and was operating on an annual budget of about $900,000. If science and technology were to serve the Canadian war effort, the only practical solution was to expand NRC laboratories. As a recent review by the Organization for Economic Co-operation and Development put it:

> Research in private industry for military purposes seemed to be more difficult in Canada than in other countries. There were few firms engaged in research and development and their research potentialities were relatively limited. Thus, it is not surprising that in the face of such enormous demands the government itself should have sought to create the necessary research centres.[2]

Within months after the start of the war NRC's staff had expanded to almost 2,000 and its yearly budget was close to $7,000,000.

During the war NRC established 21 laboratories, some of them large permanent installations, and it is claimed that "by the end of the war the National Research Council actually had more buildings than it had scientists in 1939."[3] In the words of Dr. Mackenzie, it was an organization six to ten times larger than before the war and immeasurably more effective.

It took some time to develop, of course. As Canada was not as well endowed with research and industrial resources suitable for weapon development as Britain or the United States, "the belittling idea was even advanced that Canada could most usefully serve the common cause by sending a few of her top-ranking engineers and scientists to lend Britain a hand in the laboratories of the United Kingdom."[4]

Instead Canada chose to expand the NRC laboratories dramatically and to encourage Canadian scientists to participate actively in the domestic research war effort.

The decision-making process during the war seems to have been simplicity itself. Dr. Mackenzie, the war-time president of NRC, tells how, at the beginning of the war, Canada decided to co-operate with Britain in nuclear research:

> It was surprisingly easy. In those days the NRC reported to C.D. Howe. C.D. was a particular friend of mine. We all went to C.D.'s office and discussed the idea with him. I remember he sat there and listened to the whole thing, then he turned to me and said:
>
> "What do you think?" I told him I thought it was a sound idea, then he nodded a couple of times and said, "Okay, let's go!"[5]

With every respect to the two men involved, this type of decision making is highly questionable. One is immediately reminded of Lord Snow's conclusion, based on wartime experience in Britain of Churchill's chief scientific advisor, that no scientist should be given the power to make such overwhelming decisions:

> . . . the obvious dangers outweigh the vestigial possibility of good. That is fairly clear, we ought not to give any single scientist the power of choice that Lindemann had.[6]

How ironic that, although NRC originally requested laboratories of its own to benefit the long-term development of civil industry, it was only during the war that it obtained a sizeable laboratory complex. And this large expansion was justified because the research facilities of industry, which the Council had intended to strengthen in 1919, were too weak and inadequate in 1939 to meet the requirements of the war effort.

The approach was very different in the United States where it was decided at the outset that the government would not build laboratories or engage directly in research of its own but would contract out the work to the university or industrial firm best fitted to conduct the work. In June 1941 the President established the Office of Scientific Research and Development (OSRD). Thus research and development were united in a phrase that was to become standard American terminology. The process of contract research had been developing for some time in the United States, but its widespread and successful use during the war made it a standard instrument of the U.S. government.

During the war Canadian scientists worked closely with the scientists of Great Britain and the United States, and thus entered the post-war era fresh from the front lines of new science and technology and looking forward to the peaceful use of such advances as microwave techniques, the aircraft jet engine, nuclear power, and the digital computer. While Europe lay ravaged, Canada not only had her full storehouse of natural resources but expected to build a more mature industrial society on the base of the new technologically intensive industries. There was also a conviction that the design and development of advanced military equipment would enhance the technological abilities of Canadian industry.

From 1945 to 1960, important new organizations related to science and technology were established and new major R&D programs were initiated. In 1944 Eldorado Mining and Refining Limited was founded as a crown company for the important task of mining and refining uranium ore and for the production of nuclear fuels. Central Mortgage and Housing Limited was established in 1945; one of its functions was to fund research in the field of housing. The Atomic Energy Control Board was formed in 1946 for the regulation and control of atomic energy in Canada. In 1947 NRC founded a subsidiary, Canadian Patents and Development Limited, mainly to make NRC's inventions available to industry. In the same year the Defence Research Board came into being. NRC's nuclear research group was reconstituted in 1952 when the crown corporation Atomic Energy of Canada Limited was founded, and one of its major goals was the development of economic nuclear power for Canada. The Canada Council was constituted in 1957. The government, at least, obviously expected research to provide answers to many of the new problems of the post-war world.

During that period, there was no substantial change in the central machinery for overall science policy. According to the Massey Commission, the Privy Council Committee on Scientific and Industrial Research set up in 1916 had been reduced to "a yearly review of National Research Council estimates".[7] According to the Glassco Commission, in 1947 "its duties were amended to provide that it should scrutinize all the new proposals of a scientific nature before final authorization by the appropriate authorities. This proved unworkable and the Committee now [1963] considers only major developments or new projects involving important changes in policy or expenditure."[8] Such developments, if one were to judge only by the committee's activities, were infrequent, because, according to Glassco, it did not meet once between 1950 and 1958.

In 1949 a new body, the Advisory Panel for Scientific Policy, was formed to advise the Privy Council committee on the formulation and conduct of government scientific policies. Its membership was to consist of 13 deputy ministers or deputy heads from departments or agencies with scientific responsibilities, together with the Clerk of the Privy Council and the Secretary of the Treasury Board. The president of NRC was to be ex-officio the chairman.[9] In 1963 the Glassco Commission reported:

> The Advisory Panel met formally fourteen times in its first ten years of existence and has since been convened only infrequently. Proposals for new scientific programmes have usually reached Cabinet on the recommendation of individual Ministers, via the Treasury Board, with support provided in some cases by interdepartmental committees or recommendations from scientific and industrial groups outside the government. The Treasury Board has itself provided the principal review.[10]

The OECD review of Canada's science policy in 1969 commented that the advisory panel "rarely meets; its members have heavy responsibilities in their respective departments. According to some government observers moreover, the composition of the Panel did not guarantee a high level of capability in matters of science."[11]

Thus, during the post-war years, the science policy machinery appeared to be not more effective than it had been half a century earlier, even though Canada was enthusiastically propelling itself into the age of the new scientific and technological revolution. In 1939, expenditures devoted to R&D activities by the Canadian government were estimated at $5 million. In 1959, they exceeded $200 million. Canada was rapidly building her national science effort without a coherent policy.

## TWO NEW VERSIONS OF NRC'S 1919 MODEL

Although the model and strategy for science and technology presented by NRC to the Cronyn Committee in 1919 had obviously failed, two new versions of the original plan were submitted after World War II, by the Royal Commission on National Development in the Arts, Letters and Sciences (the Massey Commission) in 1951 and by Dr. E. W. R. Steacie in a number of public statements between 1952 and 1962, when he was president of NRC.

The Massey Commission put its main emphasis on the arts, the humanities, and the social sciences. It found that these areas were poorly nourished and recommended the creation of the Canada Council, which was established six years later. But the report[12] also dealt with research and other issues of science policy. It does not leave the reader wondering which type of research is most important or where it should be conducted:

> It has . . . been pointed out to us repeatedly that fundamental research in science makes an essential contribution to our intellectual development and to our understanding of every aspect of modern life, and that without fundamental research there can be no proper teaching of science, no scientific workers and no applied science . . .
>
> In Canada, fundamental research is centred in the universities, traditionally and appropriately . . . Although universities do undertake work in basic and applied research, it is their policy to devote themselves mainly to pure or fundamental research. It is generally agreed that this is their proper function and that fundamental research should be left largely to them . . . Governmental laboratories with all their advantages cannot reproduce this special atmosphere . . .[13]
>
> Since all scientific work depends on fundamental research, since fundamental research is properly carried on chiefly in the universities, and since universities state that they are increasingly hampered by lack of funds, the need for extending immediate and adequate financial assistance to them is generally accepted.[14]

The report's view of industrial research follows the tradition established in 1916—which in fact continues to the present day:

> In most modern countries, industry makes very important contributions to this kind of scientific work [research in applied science]. In Canada, however, although there is an increasing awareness of its importance, industrial research lags behind the general development of industry. This may be partly accounted for by the very rapid process of industrialization which has hardly left time for long-range planning. The most important cause of the deficiency however, is that so many Canadian firms are branches of British or of American companies.[15]

Although industrial research was considered to be weak, the Massey Commission did not propose greater university/industry co-operation as a solution. Instead it warned the universities to be wary of industry, and its stricture also applied to government laboratories requested to conduct work for industry:

> In government laboratories, men fitted and trained for serious research may have to spend much time on routine experiment, demonstration and extension work. These are essential services but they could be performed as well by others. In the universities, the problem is even more serious. Not only commercial firms but even government agencies offer grants for applied research which cannot be expected to add in any way to the knowledge of scientific

principles. Occasionally private donors offering research grants require that research projects be approved by them. University authorities generally agree with scientists that these gifts should be steadily refused . . .[16]

Here again, concern was expressed about the poor state of industrial research, but no government measure was proposed to promote and support it.

As were ministers in the 1920s and 1930s, the Commission was worried about the lack of co-ordination. It referred to proposals for removing the laboratories from NRC:

> The suggestion has been made that the National Research Council should be relieved of all direct administrative responsibility for the laboratories now under its control, and restored to what is conceived to have been its original advisory function. Applied research, it is agreed, must and should be decentralized. In the opinion of some it is highly desirable that a responsible body (for example, the National Research Council) should be charged with the duty of advising on general policy, of centralizing the interests of the Federal Government in fundamental and basic research, and of maintaining close relations with provincial and industrial research organizations. Such a body would also be especially concerned with continuing and extending the aid now given by the Federal Government to universities for fundamental research.[17]

Noting NRC's original mandate to "co-ordinate competing [research] interests", the report explains its failure in this way:

> It was prevented from doing so for some years for various reasons; and the government agencies interested in research (agriculture, fisheries, mining and defence) gradually developed their own laboratories. Later the Council was increasingly preoccupied with its own laboratories.[18]

The Massey Commission took note of the existing co-ordination machinery, the Privy Council committee and its newly appointed scientific advisory panel, but without obvious satisfaction. The report states that "there are those who think that the time has now come for a further step. They point out that the Advisory Panel can give only limited and fragmentary advice, whereas what is needed is a source of advice on broad scientific policy, and an impartial arbiter to co-ordinate competing interests".[19] This was a sound diagnosis. But the commission's prescription was perhaps not strong enough.

> Problems of duplication may not yet be serious and there is now much co-operation, but we are of the opinion that the increasing number and complexity of these activities may make necessary in the future some centralized controlling agency. We do not think that a detailed recommenda-

tion on this matter would be warranted by our Terms of Reference, but we do consider that an investigation of this problem should be made in the near future by suitable persons. *We therefore recommend:*

(*a*) That under the direction of the Privy Council Committee on Scientific and Industrial Research a study be made as soon as possible of all research activities of the Federal Government with a view to their adequate coordination, the avoidance of any wasteful duplication, and the maximum co-operation that may be possible.[20]

This recommendation was ignored by the government since the Privy Council committee did not even meet in the 1950s. As before, co-ordination remained the forgotten function.

In the absence of any overall science policy or effective central machinery to formulate and implement it, the orientation and development of government science activities were left largely to the scientists themselves, a system which has since been described as the "Republic of Science".[21]

In Canada at that time, this Republic of Science was headed by the internationally known and greatly respected scientist Dr. E. W. R. Steacie. He was president of the National Research Council and chairman of the Advisory Panel for Scientific Policy. Dr. Steacie was a skilled and noted researcher in fundamental science, who spent considerable effort to preserve the integrity and freedom of fundamental science and took effective steps to promote its development. He was concerned about the possible conflict between science and technology and worried that science's importance might be diminished by the glamour and utility of technology.

Dr. Steacie was faithful to his predecessors but probably more articulate and straightforward. He defined NRC's functions as follows:

The Council has rather complex responsibilities. We are, in effect, five things at the same time. The first is a government laboratory with certain narrowly defined specific duties: this is a minor part of our work. Secondly, we are in many respects a foundation with purposes almost identical with those of the Canada Council. In the third place, we are an industrial research laboratory similar in many ways to places like the Mellon Institute, or to the laboratories of major industrial firms. Fourth, we are a research institution much more like the Rockefeller Institute or a university laboratory than a government department. And finally, we have many of the functions of a national academy, functions similar to those exercised in Britain by the Royal Society of London or in the United States by the National Academy of Sciences.[22]

It is difficult to imagine how one council and one administrative unit could effectively cope with these five important and very different functions. As a distinguished pure scientist, Dr. Steacie solved this difficulty by assuming in practice that NRC was mainly a university laboratory of basic research. He said:

> Decentralization has been accomplished because of two main factors. The first of these is the development of an administration whose main function is the protection of the scientist to the greatest possible extent from the red tape inevitable in government operations. The second factor has been the far-sighted attitudes of successive governments in leaving the Council free of many hampering restrictions.[23]

Scientists and engineers had to be made responsible to other scientists and engineers; they had to be safe from administrators:

> The fundamental feature of the administration of the Research Council . . . is to make sure that the administration can never issue any instruction to scientists in connection with any technical subject whatever. . . . I think that the organization is almost unique from the point of view of scientific organizations, and I might say that almost every government laboratory in the world is trying to copy it.[24]

NRC's president stressed the importance and prestige of fundamental research or applied research of a long-term nature:

> In my view, at least as far as the National Research Council is concerned, long-term investigations, fundamental or applied research, *must* constitute the major effort of the Laboratories if they are to keep the scientific reputation they have earned. . . . In general the government laboratory is interested in keeping the problems as long-range as possible.[25]

Dr. Steacie was impatient with any suggestion relating to the organization, co-ordination, or planning of science, but it must be remembered that although his organization, the NRC, and the advisory panel he chaired were not restricted to the consideration of fundamental science, by his own interest and background he himself was deeply committed to this aspect of science. Talk about the new approach of "co-ordinated research programs" brought from him the rejoinder that "vast 'co-ordinated' efforts are being made, with the inevitable attendant inefficiency. Even the fundamental workers at universities are being steadily sucked into this."[26] He advocated that one should "regard 'co-ordination' as a dirty word!" and said "I think planning, like security, should be regarded as an evil, even if it is an essential evil."[27]

He did, however, distinguish in this aversion between pure science and development: " . . . Ideally, because pure science has no specific end in view, there should be as close to no organization and planning as is humanly possible. Because development has specific aims however, a development programme should necessarily be highly organized."[28]

He did not accept the idea, born during World War II, that team work was effective in research: "There is a popular view that the day of individual accomplishment is past. I don't believe a word of it . . . A university professor and a few students . . . in my mind, is the ideal team".[29]

Dr. Steacie also turned his attention to the state of industrial research and, like everyone before him, found it in a weakened and backward condition. It was behind in time: ". . . the development of industrial research in Canada is following the general pattern of development in the United States, but one war behind."[30] He noted the fact that Canada had no large semi-public applied science institutions such as the Mellon Institute, nor large private industrial laboratories like DuPont and General Electric in the United States. He believed that because of the size of the country we would not have such institutions for the foreseeable future. (Eleven years later, the Northern Electrical Co. reported to the Senate Committee that they conducted R&D work in their laboratories of the same order of magnitude as *all* of NRC's current in-house research.) Dr. Steacie's gloomy forecast led to only one conclusion if Canada wanted to avoid "scientific colonialism".

> It therefore seems essential that such large-scale laboratories be maintained and operated by the federal and provincial governments . . . Such laboratories need to be free to follow their own inclinations. This means that the job can be done much better by an institution with government support. No institution can do research of high quality unless it can devote a considerable share of its effort to problems of its own choosing.[31]

Here once again is the suggestion, first made after World War I, that government research should support industry. Today one would have to question how effectively research for industry could be carried on outside the environment of the marketing/design/production function, considering that research is just one aspect of innovation. And the industrial process must inevitably put *some* boundaries on the scientists' freedom to follow their own inclinations.

Dr. Steacie believed that graduate science research should be increased in Canadian universities and the NRC steadily increased its supporting funds in this direction. He never lost his protective love for the freedom of science and stated that "The chief reason why the university is the ideal place for scientific work . . . is that the work is uncommitted. The university man is free to proceed in any direction which he sees fit, and should not be in any way influenced by practical considerations."[32]

There was, he saw, a danger in training graduates so as to make it easy for them to work in industry:

> Certainly, because most graduates will take their place in industry, there *is* a responsibility not to ignore the needs of industry. A direct responsibility to produce the kind of graduate industry wants would, however, be a degradation of the university to the level of a vocational school.[33]

and

> There is no reason why an engineering student should ever have seen a plant or a mine before he graduates. "Practical" knowledge can be acquired on the job and is certainly not a proper part of a university education.[34]

Very few people even today would question Dr. Steacie's views if he had been in charge of a laboratory engaged only in fundamental research. He was an eloquent and sincere spokesman for the Republic of Science. But he also had responsibility for an industrial laboratory complex and for advising the Privy Council committee on the whole spectrum of mission-oriented research and development, both as NRC president and as chairman of the Advisory Panel for Scientific Policy.

Between 1919 and 1962, the conventional wisdom of government science advisors remained remarkably identical. Universities had to remain remote from industrial needs and to concentrate on basic science. Canadian industry was unable for a variety of reasons to carry on R&D activities of good quality. Government laboratories had to be maintained and expanded to provide employment opportunities for Canadian scientists graduating from universities and to concentrate on "long-term investigations" of their "own choosing" in the hope that industry would pull itself up and develop the wit and the ability to utilize their long-range science output.

The basic assumption throughout that period was that free and fundamental research was the initial and indispensable step in the production of new technology and innovation. Today this assumption has proven to be invalid. It has been shown, as we have indicated in Chapter 1, that technological change and innovation can be quite independent of scientific progress over long intervals of time. It has also become apparent that engineering cannot be viewed as a branch of applied science. One of the many experts to reach this conclusion is Dr. Julius Stratton, a noted physicist and onetime president of Massachusetts Institute of Technology:

> . . . While it is quite clear that the bonds between engineering and science are growing tighter, we could make no more disastrous error than to attempt to recreate the engineer in the image of the scientist. The engineer is as

> concerned with means as with use and purpose, with ideas of design, cost and reliability that are largely alien to the scientist. So much has been made recently of the need for more mathematics and physics that we are in danger of losing sight of the problem that remains, in fact the most difficult in engineering education: how to balance theory with experiment, how to couple purpose and action with theoretical competence, and how to develop an appreciation of the empirical judgments that so often determine design.[35]

In the absence of empirical studies of these relationships during the postwar period in Canada, the fundamental assumption of conventional wisdom was unchallenged. The application of NRC's model is illustrated by the evolution of the council's budget from 1952 to 1962, the years of Dr. Steacie's presidency. According to Thistle, the council's expenditures on university support increased tenfold; $36 million was expended on additional NRC laboratories, and the operating expenditures of these laboratories rose threefold. NRC's support for industry began in 1962 when half a million dollars was provided for research performed by the private sector.

The other important aspect of the conventional wisdom was its lack of confidence in the capacity of Canadian industry to carry out adequate R&D activities because of its short-term views, or because of the importance of foreign ownership, or because of the small size of the Canadian market. Dr. Steacie had noted that industrial research in Canada in 1960 was at the level of Canadian university research in the 1930s. Little had been done by the Canadian government during and immediately after World War II to correct the situation. In those same years, as indicated earlier, the American government had contracted out its major R&D programs to private firms.

## THE CRUCIAL FIFTIES: NRC'S MODEL AND CANADIAN SELF-SUFFICIENCY

It is necessary to keep in mind the official doctrine and strategy for science and technology just described to understand the crucial events of the '50s. It is also important to note that the main Canadian spokesmen of the Republic of Science had acquired a great deal of confidence during the war and had come to the conclusion that Canada should try to be self-sufficient as the new scientific revolution emerged.

These were the main elements of the atmosphere prevailing in Canada when the government decided to promote major innovation programs involving high technology. There was no highly developed industrial infra-structure to support these programs, but it was claimed that "spin-off" from the programs would help solve that problem. These aspirations were fed by a desire to consolidate our sense of equality with Britain and the United States and by the myth of invincible research based, as Donald Schon has pointed out, on wartime experience with nuclear weapons:

> The Manhattan Project was the great model of the research enterprise. What the Manhattan Project said was that if you take a great doctor and surround him with scientists in a laboratory, and if you have a clear-cut objective and pour essentially unlimited amounts of money into that system, you can do anything.[36]

That myth was accepted by many nations. Eventually their gullibility led to great disenchantment with research. In Britain, two decades after this original euphoria, a Minister of Technology wrote: "The lobbyists for glamorous programmes of scientific research will in future have to prove their merit against the claim of others seeking to solve more mundane problems . . . The era of technomania is passing."[37] In 1970 the French Minister of Industry and Scientific Research reflected on some of France's large, prestigious high-technology projects, including the Concorde and the development of a French line of nuclear power reactors, labelled them expressions of national *amour propre,* and cautioned that science and technology might better have been directed at more mundane matters.[38] But in the early '50s the promise of the national prestige and a technical capability equal to the 'super powers' was irresistible, and high technology entered the world of the fabulous.

It is interesting to review some of the major programs that were undertaken during that period, inspired by the traditional doctrine and strategy of the conventional wisdom and animated by its new aspiration for Canadian self-sufficiency. Nuclear energy and military aircraft have been selected because they were the two major initiatives taken by the government in the '50s; the computer technology was on a smaller scale but demonstrates much the same lessons. The purpose of this review is to profit from the lessons of the past and to show what can happen in the absence of a realistic strategy for science and technology and of an effective central machinery to enforce it.

### 1. *The Canadian nuclear energy program*

It was at the beginning of the 1950s that Canada set its strategy for nuclear power, one of the most important science policy decisions ever made in

Canada. Dr. C. J. Mackenzie has said that "those of us who carried some responsibility in such matters felt that Canada had, for the first time in her history, an opportunity to 'get in on the ground floor' of a great new technological advance, an opportunity that must not be lost."[39]

In January 1951 Dr. Mackenzie began a series of discussions with the Hydro-Electric Power Commission of Ontario that proved very fruitful. Not only were the Ontario Hydro officials receptive and enthusiastic but the talks resulted in an active collaboration. In 1952, the main responsibility for the Canadian R&D nuclear program and the staff involved were transferred from NRC to a new crown agency, Atomic Energy of Canada Limited. In June 1953 AECL and Ontario Hydro held a long day's meeting at Chalk River and decided to go ahead with a nuclear power project. Ontario Hydro was to initiate the power station and the crown corporation was to assist them.[40] Early in 1954 AECL established a nuclear power branch at Chalk River. In June 1956 it was still staffed by only nine engineers. Most of them came from Canadian companies interested in the development of nuclear power; only two, provided part-time by AECL, had previous experience with nuclear plants.[41]

The engineers had embarked on a three-stage program in 1953. The first stage was training. They spent the better part of seven months reading about the design of nuclear plants.: "While numerous types were studied on a qualitative basis only, most of the effort during the instruction stage was directed specifically toward an understanding of the heavy water moderated natural uranium reactors—the type on which AECL has specialized,"[42] in the words of an AECL statement in 1956.

In the second stage the engineers made preliminary designs for a small nuclear plant. "The scope of the work was . . . limited by restricting the design to the heavy-water moderated type of reactor, fueled with natural uranium . . . Before a physical design could be undertaken, it was necessary to develop an outline specification with supporting data, where practicable, and with quantitative reasons where the necessary data were lacking . . . This was accomplished essentially by pooling design suggestions from the various engineers of the Branch, assessing this on a semi-quantitative basis and selecting those ideas which were favoured by the majority of the group."[43]

The third stage, at that time still in progress, was the preliminary design of a plant large enough to be useful to an electrical utility.

Two main factors determined the Canadian choice of a reactor using natural uranium and heavy water. First, this type of reactor was in line with previous work done at Chalk River by Canadian scientists. Dr. W. B. Lewis of AECL commented on Canada's choice at a 1959 symposium:

> In 1953 when we gathered the engineers under Harold Smith to undertake the preliminary design of the first power reactor plant, it is not surprising that this was a natural uranium, heavy water plant like that envisaged in 1951 . . . Given the background of Chalk River, it is no discredit to those engineers that the essentials of their design appear natural.[44]

Second, there was also the consideration that Canada should be self-sufficient and that it would be too expensive to produce our own enriched uranium. In a paper presented in 1960, H. A. Smith and J. S. Foster compared the relative merits of a British graphite-moderated gas-cooled reactor, American light-water reactors utilizing enriched uranium, and the CANDU (Canadian Deuterium-Uranium) reactor. After discussing the respective power costs they introduced another, non-technical consideration about the American reactors:

> However, perhaps the most serious deterrent to the use of this type of plant in the Ontario Hydro system is the requirement for enriched fuel. This imposes dependence upon a relatively few alternative production facilities and requires an important component of fuel manufacture to be performed outside the country. Furthermore, although it may not preclude the use of uranium from domestic ores, the requirement for enriched fuel implies, at the very least, special arrangements to ensure its use.[45]

In retrospect, these two considerations do not seem to have been as well founded as they appeared in the '50s. Other countries, notably West Germany and Sweden, have negotiated "special arrangements" with the United States for the supply of enriched uranium. And Canada has so far had to rely exclusively on others for the supply of heavy water.

The know-how acquired at Chalk River was greatly over-estimated. It was necessary to invite British physicists to join the Canadian team. Much more important, there was an astonishing shortage of skilled technologists and designers available for a project in what is probably the most taxing area of high technology. Only two members of a somewhat transient group had experience with nuclear plants and those were on a part-time basis.

This crucial gap which is obvious to us today was not too important to the conventional wisdom of the time. Dr. Steacie had stated in 1956 that " 'practical' knowledge can be acquired on the job." It soon became apparent, however, that basic science and fundamental research were not enough to build good reactors and that the two worlds of science and technology were indeed different. Learning on the job proved to be a long and costly process.

Dr. J. L. Gray of AECL wrote a paper, *Canadian Industry and Atomic Energy*, presented to the House of Commons committee on research[46] in June 1956, that stressed the difficulties involved:

> One of the major hurdles to early economic nuclear power is the applied engineering required in the design and fabrication of reactors and reactor equipment. Economic nuclear plants can be specified now, but until many of the technical fabrication problems are solved, they cannot be built within the limit of funds that keeps them economic . . . The only logical approach to the combined problem of putting Canada in its proper position in the new field of nuclear engineering and of getting reactors and their equipment designed and manufactured is to encourage industrial participation, and this the Company is doing, but with considerable difficulty.

The difficulties Dr. Gray mentioned were based on AECL's judgment about industry's ability to support a nuclear power program. He said: "The Company, and the Canadian reactor designer, is finding the greatest difficulty in bridging the gap between proven research results and the production of operating equipment at a reasonable cost."

Dr. Gray said that designers in Canadian industry lacked the necessary experience and could not find solutions to new problems in existing handbooks:

> This is where Canadian industry falls short. The problems are beyond the normal industrial design office and can only be answered by actually building and testing equipment in an orderly fashion and by employing an experienced development group . . . Lack of fabrication experience cannot be clearly separated from lack of general engineering development resources and experience. One manufacturer, for instance, was asked to make some very accurate and somewhat complex parts for the fuel-changing mechanism for NRU. He had a suitable plant, capable of the accuracy required, but he clearly did not know how to use it to ensure success. Another manufacturer to whom this work was transferred had had the experience at someone else's expense and achieved the desired results without undue difficulty. This happy result is a more or less isolated case, and development of expensive trial and error has been the rule. The lamentable fact that comes out of the NRU experience is that the potential education, which has been a very expensive by-product of the project, may have been lost to industry. By trial and error methods on the shop floor—and at no higher level—various individuals have learned some new techniques.[47]

This bleak picture painted by Dr. Gray related to the construction of the NRU reactor, which was developed and designed at Chalk River and originally planned to be used almost exclusively for the production of plutonium.

In spite of these serious difficulties, by the end of 1954 firm decisions had been reached for a "nuclear power demonstration" reactor (it became the NPD reactor at Rolphton), which was to be used as a prototype for the construction of a large commercial plant, the future CANDU reactor at Douglas Point. Up to that point AECL's strategy, as described by its president, W. J. Bennett, in his annual report for 1953-54, seemed logical and consistent, despite the risks involved:

> While the design, construction and successful operation of NRX reactor and the design of the NRU reactor have demonstrated the capacity of the establishment [Chalk River] to apply the results of the research programme, the design and construction of an economic power reactor presents a new challenge. It is now clear that if this challenge is to be met successfully, *the design and development resources* of Canadian industry must be used to the fullest extent.[48]

Thus, in 1954, the strategy was clear. A demonstration reactor would be designed and developed by private industry to prepare it for similar work on larger commercial plants. Canadian General Electric Company was selected from seven Canadian manufacturers. The company experienced technical difficulties, as did all others in the world involved with this new and complicated technology. It is generally recognized, however, that it performed efficiently and that it had constituted an experienced team of technologists and designers when the construction of the NPD reactor was completed.

In February 1958 the Nuclear Power Plant Division of AECL was established in Toronto. It was given the responsibility of over-seeing the construction of the NPD reactor at Rolphton and the *"design and development* of the large power station which at that time was called CANDU".[49] In June 1959 the Honourable Gordon Churchill announced that the cabinet had approved the construction of the 200-megawatt reactor at Douglas Point.[50]

These developments meant a complete reversal in the strategy described by AECL's former president, W. J. Bennett. Indeed, it was decided to authorize the construction of CANDU *before* its prototype had been completed and "not to wait", in Dr. Gray's own words, "until the development phase on CANDU had been completed".[51] This hasty decision was apparently based on Ontario Hydro's urgent need for power.

It was also decided that AECL's new Nuclear Power Plant Division would be responsible for the design and development of the large station. This meant that this type of work was withdrawn from private industry and that

AECL would have to assemble a new team of designers and technologists to develop a big commercial project while the more experienced team established by Canadian General Electric continued to work on a small experimental reactor. This other decision was apparently also imposed by Ontario Hydro, which did not wish to deal with a private company that had been granted a monopoly when the time came to build its own reactors.

In June 1960, Dr. Gray stated to the House Committee on Research:

> It [CANDU] is scheduled for completion in mid-1964 with full operation later in that year. AECL will own the complete station... When the plant has demonstrated that it can be successfully operated in the Ontario Hydro system—estimated at three years—Hydro is committed to purchase the complete station at a price that will allow them to continue generation at the same cost as though they were operating a modern coalfired plant.[52]

Today the Douglas Point reactor is still owned by AECL. At the end of 1969 the reliability of total plant performance at Douglas Point had still not been satisfactorily established. All those directly concerned with the nuclear power program were disappointed with the operation of the reactor, although it was supposed to be in "full operation" at the end of 1964. The complaint still was that a complex system was being introduced by a new design organization, using inexperienced suppliers and construction forces and operating with crews with limited experience on a much smaller and less complicated plant. Other power reactors in the western world have also experienced difficulties, but this is little consolation to Canadians.

The process of learning on the job envisaged by Dr. Steacie does not seem to have worked very effectively in the sector of nuclear energy. It began on a basis of trial and error early in the 1950s, and almost 20 years later it was still unfinished. Moreover, the involvement of private industry in the Canadian nuclear energy program, which was seen as a necessity in 1954 by the then president of AECL, W. J. Bennett, has not been too successful. In its 1970 annual report, the Science Council stated:

> The critical importance of involving industry in the program still remains but no satisfactory solution seems to be in sight.[53]

And after mentioning some of the underlying causes of this problem, the report continued:

> Canada's objective should continue to be the creation of a competitive and independent nuclear industry. However, there is little likelihood of such an industry emerging in the immediate future.[54]

Most other countries in the world do not seem to have Canada's patience and aspirations. They negotiate special arrangements with the United States or they seek to be interdependent.

This long but incomplete historical review of a major R&D program involving high technology is not intended to pass judgment on the current or future potentialities of Canada's involvement in nuclear energy. The Senate Committee shares the hope of AECL's president, Dr. Gray, that the Canadian program will soon be a complete success. In presenting this historical background, it only wished to show that the conventional wisdom prevailing in Canada in the '50s was wrong in neglecting technology and design and that an effective and impartial central machinery for science and technology with a clear view of the objective to be achieved and of the strategy to be used could have provided useful guidance and assistance to AECL during those difficult years.

Instead, according to Dr. Gray, the Privy Council Committee on Scientific and Industrial Research never met to discuss AECL's plans. Highly competent scientists had to devote their time and energy to problems of technology, design, and industrial management. It appears to outsiders that in the absence of proper federal mechanisms Ontario Hydro ultimately exercised the responsibility for defining the objective and the strategy of the Canadian nuclear program, while AECL was assuming the technical and financial risks involved in this complicated venture.

In the related field of heavy water production, which did not involve AECL directly, a serious and costly mistake was made when a proposal based on unproven technology was accepted. We do not propose to describe it here, although it shows that originality should always be carefully scrutinized before being accepted.

### 2. *Military aircraft development*

Just before the decade of the '50s Dr. Omond M. Solandt, then chairman of the Defence Research Board, announced that "Canada has embarked upon the largest peacetime defence program in its history."[55] Behind this decision was the desire to be independent of other countries—in the same way as the nuclear power people desired to be independent of foreign sources of enriched uranium. The desire for an independent source of arms came largely from World War II experience, but there were other considerations. One was that the design, development, and production of modern weapons has a spin-off that raises the whole technological and economical level of a nation. This view was stated by Air Marshall Curtis in the last days of the Arrow: "Doing this work in Canada has and is giving employment to thousands of Canadians. . . . Money spent in Canada helps our industrial growth. . . . It provides opportunities for thousands of young engineers who used to have to go elsewhere to make their careers. . . . It has . . . increased the level of our technological know-how and capability in the fields of metallurgy and power."[56]

The weapons, aircraft, and aircraft engine programs of the '50s were ambitious, costly, and in some cases a traumatic experience for those participating in them. A quick look at some of the major projects recalls the spirit of those days. Here again, our intent is to show that they were fit subjects for an overall science policy review. One vital function of such an impartial review is to put unrealistic ambitions into perspective and, more importantly, to ensure that glamorous projects are not actually initiated until all their implications are fully explored, their market established, their feasibility assessed. Nothing could cause the public, its Parliament, and its government to become disenchanted with science and technology faster than the launching of a series of unrealizable technological dreams.

One such example is Avro's Project Y or "flying saucer" aircraft. In 1953 London's *News Chronicle* exclaimed: *"Flying Saucer? This Could be IT"* and quoted Air Vice-Marshall D. M. Smith, RCAF, as saying, "We are giving preliminary consideration to a project of this nature."[57] *The Times* of London reported a Canadian design for a 1500-mile-per-hour "flying saucer" that was "so revolutionary that when it flies all other types of supersonic aircraft will become obsolete." This was the beginning of a project that finished, many years later, as the much more mundane subsonic "Avro Car" built for study under a U.S. Army contract.

In 1950 it was decided that Canada would design, develop, and manufacture an air-to-air guided missile called the "Velvet Glove" and the Defence Research Board's CARDE unit at Valcartier began its design. It had been hoped that this weapon would be used on the RCAF's CF-100 jet interceptors. In July 1956, the Minister of National Defence told the House of Commons that the project was cancelled and that the U.S. Sparrow missile would be used instead. The cost of the Velvet Glove program had been $24 million, but the minister pointed out that this sum had not only helped train some 400 scientists and technicians, but that three or four plants and their several hundred staff could immediately start manufacturing the Sparrow missile. During the next year, 1957, the press wondered whether the government was in turn abandoning the Sparrow.[58] In September 1958 the Minister of National Defence announced that the government was cancelling the special flight and fire power control system for the CF-105 and the Sparrow air-to-air missile. By then some 2,000 were employed on these projects in three Canadian firms.[59] The Prime Minister announced that the purchase of a fire control system and weapon already in production in the U.S.A. would bring about a saving of $33 million in the completed program of 100 aircraft.

The Velvet Glove air-to-air missile was the largest project DRB attempted, and the account of it in Captain D. J. Goodspeed's official history of DRB's first decade contains some interesting comments. It was felt that guided weapons were going to be important and it was therefore decided "that Canadian scientists could best be indoctrinated in guided missile techniques by actually manufacturing a missile."[60] That was in 1950: by 1955 over 300 missiles had been manufactured and fired. The team had grown from the original four or five DRB staff to a group of about 400 scientists and engineers working in DRB laboratories, other government laboratories, and industry. The largest group was in industry (250 engineers with 600 supporting staff).[61] The government laboratories appear to have taken the lead in design and then to have handed the work over to industry.

Goodspeed says the proposals for Velvet Glove "were approved by an *ad hoc* technical committee of American and British guided missile experts."[62] It is difficult to decide what this "approval" implies when Goodspeed goes on to point out that Velvet Glove failed because it was designed to cope with bomber aircraft similar to the then existing American B-29. He explains:

> . . . There was a general belief that the nations of the West had a commanding technological lead and that, although other countries might copy Western scientific developments, they were unlikely to produce effective modern aircraft of their own. The high-speed, high-altitude jet bombers which were later to be displayed were still in the development stage and Western intelligence had no firm evidence of them . . . Furthermore, the Canadian requirement had been drawn up bearing in mind that guided missiles were a new field for Canadian scientists, that the primary objective of the programme was to acquire new knowledge, and that it would therefore be inadvisable to set too difficult an initial task.[63]

The obvious rejoinder is that it might have been better to have taken a less ambitious task or to have set up a joint program with an ally. Goodspeed says "The decision to design and build a Canadian guided missile was a bold one. There were some, of course, who had been dubious about this decision, who felt that in entering the field of guided missile development Canada was trying to run before she could walk. There were others, enthusiasts for the project, who retorted that this was exactly the attitude of mind which had kept mankind on all fours for countless eons. In any case, the bolder counsels prevailed . . . . The principal objective of the programme—the acquisition of technical knowledge—had been achieved."[64] The cost was $24,000,000.

This example shows the need for technological forecasting and co-operation with other countries and a clear statement of objectives when large, complex projects are considered necessary. In this case it appeared to be too easy to downplay the objective of developing a *usable* device and concentrate on the objective of educational spin-off. Could this education have been obtained at less cost? Was it even necessary? Instead of indirectly assisting an area of technology with spin-off, why not promote it *directly* by projects whose objective is to meet a real need?

One military aircraft, the CF-100 jet interceptor, was designed and produced in Canada. This aircraft served with the RCAF and was purchased by one of Canada's NATO partners. The Minister of Trade and Commerce told the House in 1955 that the government had supplied $122 million and about $44 million worth of equipment to the firm before the first all-weather CF-100 was produced.[65] The first Mark IV CF-100, the version used in RCAF squadron service, came off the production line in September 1953.[66] In 1956 it was reported that the RCAF would spend $150 million to re-equip its home defence forces with the Mark V CF-100. Later the Mark VI was proposed, but in 1957 the government announced that the new version would not be produced, according to news reports, "because the air-to-air missile with which the aircraft was to be armed was nowhere near the production stage. The missile—the Sparrow . . . . [It] would be three or four years before it would be available."[67] It was estimated that dropping the Mark VI saved about $100 million. This program successfully achieved its mission partly because of an available export market.

In 1953 the government awarded $250,000 for a design study of the CF-104 delta wing supersonic aircraft which, the press noted, "marks the first government move following a recent decision to back original Canadian military aircraft designs where possible."[68] This led to the well-known CF-105 Arrow aircraft program and the Iroquois engine. The Arrow was the subject of much controversy. The Minister of Trade and Commerce told the House of Commons in June 1955 that there had been difficulties with Avro Canada Limited during the development of the aircraft:

> After we had got in for $30 million to $40 million, it was quite obvious that the management of the day was not going to produce what we required—

the top management which was in England. The men on the job just did not have the experience to carry out the work and that became obvious to all concerned.[69]

The Arrow was very much the subject of controversy but nevertheless it was designed, built and made its first flight on October 4, 1957. That was the day the Russians launched the first Sputnik, which drew away some attention and also created some doubt that the Arrow could cope with weapons of the future. By the time of its first flight the Arrow program had cost over $300 million. To have put it into squadron service would have raised the cost to anywhere from $500 million to $1 billion, depending on what items were included. Opinion varies as to whether or not the Arrow was all that was claimed for it, but in any case attempts to sell the aircraft to Canada's allies failed. W. R. McLaughlan, executive vice-president of A. V. Roe Canada, warned: "In the days ahead Canada will have to undertake projects more costly and more advanced or abdicate her present position as a respected partner in the free world. The alternative is to turn the job of national security over to someone else."[70] A seasoned parliamentary reporter commented that " . . . the Arrow failed to reach its main objective. It showed every promise of being the best aircraft of its class in the world. But the cost, in the absence of sales abroad, had reached staggering proportions. . . . Foreign observers agreed that the CF-105 was an excellent aircraft. But a resourceful sales campaign didn't net so much as a nibble."[71] The Prime Minister announced the cancellation of the Arrow in February 1959.

The spin-off from the Arrow project was described to the Senate Committee by Dr. Howard Petch: "I have never been and I am not in a position to evaluate it as a defence weapon, but I think the country has lost very heavily by its discontinuance. I was very close to both the metallurgical industry and the electronics industry at that time and I feel we have not yet regained the impetus in those two industries that we lost on the cancellation of the Arrow project. . . It is the loss of exciting projects like this that cost us considerably in terms of our very best manpower because our best people tend to be excited by these projects. . . . There is lots of what I call bread-and-butter engineering in Canada but there is not very much to interest the top 15 per cent of our graduates in applied science."[72]

When the Arrow and the many projects associated with it were cancelled hundreds of engineers and scientists moved to the United States. Dr. Solandt recalled for the Senate Committee a visit to the U.S. NASA Manned Space Center in Houston. He commented: "Of the 200 scientists involved in their program, 40 came from Avro and most of them are still there, and at the Manned Space Center out of the half-dozen we met, three were from Avro. I might say they were all Englishmen—not Canadians—who had come to Canada intending to stay."[73] It was pointed out that this just high-lighted a continuing and serious "brain drain" that had afflicted Canada for some years. For example, in 1957 the Technical Service Council, an organization that helps Canadian scientists find posts, published a report showing that between 1951 and 1956 the number of Canadian engineers and scientists that emigrated to the United States was equal to almost one-third of the graduating classes of that period. The drain increased from 11 per cent in 1951 to 46 per cent in 1956. Dr. Robert A. Bryce, who released the report, claimed that many of them were research scientists with post-graduate degrees who "leave Canada because they cannot get positions in their field of interest."[74]

### 3. *Computer technology*

The other major technology undergoing rapid development in the '50s was the digital computer. The government funded an advanced project in this field, and according to Professor Arthur Porter's evidence before the Senate Committee, it was imaginative and ahead of its time and eventually led to sizeable computer activity in Great Britain. Professor Porter described this abandoned defence-oriented Datar project "in which Canada made a tremendous breakthrough in information technology . . . . I believe Canada was the first nation to set up three individual data-handling systems and to tie them together over radio links."[75] Professor Porter stated further that as a result of this project, Britain's ICT computer series could be said to have been "conceived and designed" in Canada. The ICT company now has some 30 per cent of the British business in this field.[76] He added, "This is a case where perhaps only $2 million at the time, 1954-55—I was heading the Canadian group so I know at first-hand what was involved—would have made a profound impact in this whole field, because we were ahead. We were not only ahead in interactive computer systems, but we were ahead in modular solid state computer technology, which is the basis of the modern computer."[77] The project closed down for lack of funds and many of those involved left Canada, taking their knowledge and experience with them.

## CONCLUSION

Canada approached complex problems of science and technology as they arose in the postwar years without a consistent strategy or a coherent policy.

Most other Western countries were in the same position. Some nations, such as Great Britain and France, tried like us to face the challenge of fabulous technology positively but on a basis of national self-sufficiency and without adequate preparation. Like Canada, they made costly mistakes. Other countries, such as Japan, Switzerland, and West Germany, did not rush into the new era but gradually built a less glamorous and more realistic capability. In the United States the already established strategy of awarding the bulk of government R&D programs to private industry paid off handsomely.

During this period, in Canada, two seemingly inconsistent directions were being followed. The postwar spokesmen for the Republic of Science continued to express the conventional wisdom, putting the emphasis on basic science and fundamental research and neglecting the problems of technology and the importance of research performed by industry. On the other hand, the government decided that Canada would face the main challenges of the new technology alone, and that private industry would be given the strategic job of development, design, and construction.

After long years of neglecting industrial R&D and concentrating science activities in government laboratories, it should have been obvious that industry was not prepared to achieve its mission effectively. The paradox was that after it had acquired the necessary experience, industry did not get the main construction assignment either because it was a private monopoly, as in the case of Canadian General Electric, or because the innovation was too expensive for Canada in the absence of foreign sales, as in the case of the Arrow.

These problems, which an effective government central machinery for science and technology should have been able to detect in advance, were not foreseen at the time. Decisions were then often taken on the spur of the moment, on the basis of good friendly contacts, but without a careful analysis of the main requirements or immediate objectives. The result has been that Canadian teams of technologists and designers have been trained at considerable cost and then left practically idle or lost to the United States. This experience of the postwar years shows that it can be expensive and frustrating for a country to proceed without a realistic strategy for science and technology.

Meanwhile, the first major government attempt to promote R&D in Canadian industry had failed to a large extent, except when government contracts had been used within the framework of our sharing arrangements with the United States. In any case, this failure contributed to the substantial decline of government support for civilian industry in later years.

At the beginning of the '50s, federal government funding of R&D in industry was less than $3 million per annum. This grew to about $50 million a year in 1957-58, after which it dropped sharply and did not again reach $50 million a year until 1965-66. Large technological projects had been funded at the frontiers of the most advanced fields; avionics, supersonic aircraft, large jet engines, nuclear power reactors, computers. These programs involved hundreds of millions of dollars, and one has to think that the demands placed on Canada's scientists and engineers and on laboratories such as those of NRC called for careful but imaginative co-ordination and co-operation. We have been told that this was not the case. For example, during this period relations between the Defence Research Board and the National Research Council were often strained.

While the president of NRC continued to promote the interests of basic science, and while the government was trying to meet the challenges of fabulous technology, other government agencies were continuing to get successive annual increments for their science activities according to their own isolated priorities and to the overall budgetary requirements determined by Treasury Board. Even the Massey Commission's recommendation of a large-scale R&D study was completely ignored during those crucial years.

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# 5

## THE 1960's: A SECOND ATTEMPT AT BUILDING A CANADIAN SCIENCE POLICY

Canada was not the only country to have difficulty in managing the large problems of advanced technology in a rapidly changing environment or in resolving at government level the many policy problems raised by science and technology. Toward the end of the 1950s the governments of most advanced nations began to show a renewed interest in science policy and its mechanisms.

In 1957 President Eisenhower created a new position in the White House staff, that of Special Assistant for Science and Technology. The first person to hold this position, Dr. James R. Killian, Jr., told the Senate Committee that "the mandate that I received from President Eisenhower noted that I was to have, and I quote, 'full access to all plans, programs, and activities involving science and technology in government'. I was to be available as an advisor to cabinet members and other officers of government holding policy responsibilities. I was to try to anticipate future trends and developments . . . and I was to advise on scientific and technological matters at top-level policy deliberations."[1] At the same time the President reconstituted the President's Science Advisory Committee, a committee drawn from the non-government sector, that in Dr. Killian's words would advise the President directly and personally "on matters of science as they affected policy. He broadened its scope to include any and all scientific matters it felt should be brought to the attention of the President and his Special Assistant."[2]

In 1959 the OECD began to develop an interest in national science policies. It invited a distinguished Canadian, Mr. Dana Wilgress, to prepare a study of scientific organization and of the major problems relating to science in the member countries. Mr. Wilgress underlines the importance of science



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for economic growth: "Too much emphasis cannot be placed on the importance of scientific efforts for the future of the European economy." He stated that the relative industrial decline of Europe could only be met by the "most energetic applications of science to economic growth." His prescription was clear: "The first thing should be for each country to draw up a national science policy."[3]

As a result of Mr. Wilgress' report, the OECD established a division for scientific affairs and held its first ministerial meeting on science policy in October 1963. International comparisons of national science efforts were published for the first time. Most countries in Western Europe began to look seriously at what they were doing in the area of science, technology, and innovation.

In 1960 the Canadian government established the Royal Commission on Government Organization, patterned after the Hoover Commission in the United States. Under the chairmanship of J. Grant Glassco it considered scientific research and development as one of its "special areas of administration." It published its findings in 1963, twelve years after the Massey report.[4]

This was the first detailed public report on the subject of science policy ever made in Canada. Twelve project officers were assigned to investigate this special area (five from universities, four from the electrical industry, and three from the Federal Government—two from NRC and one from the Department of Labour); two of the project officers, Dr. Robert Weir and Dr. J. Rennie Whitehead, later took posts in the Science Secretariat when it was established. These officers were aided by an advisory committee of four, one of whom, Dr. Roger Gaudry, later became the Vice-Chairman of the Science Council.

## THE FINDINGS OF THE GLASSCO COMMISSION

The Commission noted the importance of science to the development of the nation and the well-being of its people. It observed that expenditures for science and technology were increasing rapidly but, in the absence of policy guidelines, on a piecemeal basis. It concluded that the government's science policy had broken down and was inoperative.

> It is not unfair to say that the scientific policy of Canada today is the result rather than the cause of growth in the many scientific activities undertaken by government.[5]

The report noted also poor co-ordination and little control within specific agencies of government:

> In fact, there is abundant evidence that the existing tendency to preserve maximum freedom throughout the whole investigative spectrum has resulted in an inadequate level of supervision, planning and direction, sometimes with costly results . . . . For fear of inhibiting the creativity of the scientists, specific projects in the applied field have been allowed to continue for years after they should have been terminated on practical grounds.[6]

With respect to the National Research Council, the Commission observed:

> The National Research Council, originally established to promote research in industry, has not been successful in its role as a promoter of industrial research. While industry has benefitted considerably from the scientific accomplishments of the National Research Council laboratories, particularly in several special areas, such practical steps as have been taken to encourage the conduct of research by industry itself have been ineffective. For this the rather academic orientation of the National Research Council and its preoccupation with basic research may be in part responsible.[7]

The failure to stimulate industry, the Commission claimed, was true of government research operations in general:

> One of the original purposes of government in devoting money to research was to encourage and stimulate Canadian industry. From being a primary goal this has, over the years, been relegated to being little more than a minor distraction—a desirable but rather difficult task and certainly of less pressing urgency than other items on the program.[8]

Government's responsibility for science policy was clearly defined by the commissioners:

> The ultimate responsibility is a heavy one and in a Parliamentary democracy must be borne by the government of the day, the Prime Minister and his Cabinet. The fact that political leaders usually possess only a lay knowledge of scientific matters provides no grounds for escaping this onerous task. For good or ill someone must take decisions, and their consequences are so vital and far-reaching that they cannot safely be left to public servants or to anyone of the several groups which have a special stake in some part of the scientific spectrum.[9]

And yet, regarding the many federal agencies engaged in R&D:

> These diverse government bodies are not subject to any overall scrutiny or supervision nor is there available to the Prime Minister and his Cabinet any independent or disinterested advisor qualified to give counsel on their scientific policies or programmes and the priorities which should be accorded.[10]



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The commission took stock of the existing science policy machinery: the Privy Council committee and the Advisory Panel for Scientific Policy set up in 1949 to advise it. The Privy Council committee was found (as has been mentioned previously) to have "met infrequently, and between 1950 and 1958 was not called together at all."[11] The advisory panel "met formally fourteen times in its first ten years of existence and has since been convened only infrequently."[12] As a result, the government's responsibility for science policy was exercised in an inappropriate way:

> New programmes have depended for their adoption on the persuasive powers of the Ministers concerned, on the weight of non-departmental support, and at times on an assessment by the permanent staff of the National Research Council.[13] . . . It is against such a background of disjointed promotion that the Cabinet is called upon to approve plans for expansion of existing agencies and their programmes, or the creation of new ones. Too often, in the existing organizational vacuum, the decision for or against is made in fact by the Treasury Board, largely on the advice of its own staff. These officials, although possessing widely recognized ability, make no claim to scientific competence or foresight.[14]

The commissioners reflected that "In view of this evident breakdown of the system as designed, it is remarkable that science in the government has, from some points of view, flourished as never before. Budgets more than tripled in a decade." It was apparent that "the failure to build on the basis of a cohesive programme has not inhibited the spending of public money."[15]

The Glassco Commission saw three principal reasons "for the failure of the existing [federal government science policy] organization to function as intended."[16] They were:

1. . . . The Cabinet has lacked a 'spark plug' . . . The lack of a single minister having responsibility for guiding Cabinet in the making of science policy. "A Committee of ten Ministers creates diffusion of responsibility and is hard to assemble, while its members are so concerned with their own departmental responsibilities that the devotion of time and study to scientific proposals must seem to many a formidable distraction."
2. The lack of a secretariat to prepare and assemble the considerable background of information of a scientific, economic, and social nature that is needed for adequate consideration of science policy questions.
3. "The failure to distinguish between high policy as the embodiment of national aspirations in the whole field of science, and operating an administrative policy concerned with the running of a massive governmental apparatus. Both of these require great skills, discriminating surveillance, and advice from non-government sources, but the approaches are quite different and no common procedures will satisfy both needs."[17]

On the basis of their findings regarding overall government organization, the commissioners recommended the establishment of a new cabinet post, President of the Treasury Board:

> . . . It is our conclusion that the Treasury Board needs to be strengthened by the appointment of a presiding minister with no departmental responsibilities, who would give day-to-day guidance to its staff, provide the initiative needed within the Board itself, and ensure that general considerations of good management find adequate expression within cabinet on all matters to which they are relevant.[18]

This new office would have responsibility not only for budgetary matters but for the "general quality of administration in the public service."

The commission also recommended a new science policy machinery. It suggested that the President of the Treasury Board should also be "the Minister responsible for the scientific policy of the country and the co-ordination of existing activities in the field of research and development."[19] The commissioners considered that science policy was a matter of "fundamental importance", of such gravity that the Prime Minister should be responsible for it. However, they did not think that was practical. Nor could they accept the concept of integrating R&D activities into a Department of Science, "because scientific activities, like economic activity, pervade such a large segment of the public service that attempts to centralize scientific activity would impair the effectiveness of the many departments of which today it is an important part."[20]

The commissioners saw that the President of the Treasury Board must have a staff of specialists at his disposal to assist him with matters of science policy; they proposed a Central Scientific Bureau to act as a science secretariat to the cabinet under an officer of deputy minister rank to be known as the Scientific Secretary, who would report to the President of the Treasury Board.[21] The bureau's duties would include "the assembly of data and conduct of investigations and studies required in the field of scientific policy. In addition, a general and continuing scrutiny of all government scientific programmes should be maintained . . . The Bureau should, however, direct no programmes of its own and have neither operating responsibility nor authority over the conduct of government scientific establishments."[22] The bureau could be manned by a "small but expert staff . . . possessing scientific, economic, financial, and statistical skills" and the staff would be periodically rotated with operating branches of government to avoid an ingrown or static approach.

In addition to the secretariat, the commissioners proposed another body, a National Scientific Advisory Council, "in order to mobilize the independent views and advice of knowledgeable groups both within and outside the government."[23] Its members would be drawn from "the scientific disciplines, the universities, industry and the community at large, to review and submit independent advice with respect to national scientific policy."[24] The Central Scientific Bureau would provide services to the council and the Scientific Secretary would be the council's secretary. The commissioners warned that "care is needed to secure breadth of representation and freedom from domination by any group, which are essential in a body charged with advising on high policy."[25] To avoid embarrassment and a possible conflict of interest for people in government employment it was suggested that "the council and its committees should always be presided over, and committees at least fifty per cent manned, by members drawn from outside government service."[26]

From the point of view of the central control of science policy, one function suggested for the National Scientific Advisory Council stands out in importance:

> The Council should be called upon each year to review all government scientific programmes. All changes in emphasis or scope should be scrutinized and proposed expenditures as reflected in the Estimates should be considered by the Council before submission to the Treasury Board for approval. A report containing the Council's views and recommendations should be submitted to the President of the Treasury Board following each review.[27]

The commissioners also gave the council a responsibility for *ad hoc* problems: "In addition, special meetings of the Council may be required from time to time to consider specific problems or proposals in respect to which policy decisions are urgently required."[28]

The commission's proposals represented the first major attempt since 1916 to provide a central machinery for science policy. The proposed scheme had several revolutionary features, especially when considered in the light of conditions prevailing in the Western world in 1963. Some of its aspects were inconsistent and inappropriate.

While other countries had assigned the specific responsibility for science policy to the Prime Minister or President, the commission rejected this idea as impractical. It did not attempt to rehabilitate the inoperative Privy Council Committee on Scientific and Industrial Research created in 1916. Instead it concluded that a single minister should be responsible for national science policy and for co-ordination of existing R&D activities. However, it recommended that this minister should be the President of the Treasury Board—after having expressed the view that the latter would be a busy man and should have "no departmental responsibilities." The commission did not consider any conflict of interest the President of the Treasury Board might have to face the exercise of his proposed dual role.

In 1963, most countries were still playing with the traditional concept of co-ordination, which implied a weak central machinery. The long and unsuccessful experience that Canada had had with this approach convinced the commission that a much more powerful and enlightened agency was needed at the centre. It proposed that the National Scientific Advisory Council should have the authority to review and advise on the detailed budgetary proposals for government R&D programs presented by departments and other agencies before these estimates were approved by the Treasury Board.

At that time this special budgetary procedure for science activities had been developed only in France and there only in a limited way. The commission's assignment of this budgetary responsibility to the council, however, was hardly consistent with its views on the composition of the proposed agency, which it suggested, should include members of government research organizations as well as people from the private sector.

Under the proposed procedure, heads of government research agencies would have first submitted their budgetary proposals to their ministers for approval. Then these estimates would be submitted to the council and therefore to at least some of the same officials. How could these officials be expected to be objective and impartial as members of the council? How could they be expected not to dominate the council, even if they were a minority group, while they were responsible for the allocation of government grants to the academic community and to industry? How could the other members of the council be expected to provide independent and enlightened advice on all government R&D programs while devoting only a small portion of their time to the business of the council? The commission did not raise these questions.

Finally, the commission's plan placed the Central Scientific Bureau in a delicate and difficult position. The bureau was supposed, among other things, to maintain "a general and continuing scrutiny of all government scientific programmes." In this capacity as well as others the bureau was to be directly responsible to the President of the Treasury Board. It was also expected to provide expert staff for the council and its head, the Scientific Secretary, was to act as the council's secretary. It was to be manned by a small staff with "scientific, financial and statistical skills," to be rotated periodically. Under such conditions, how could the bureau be expected to perform all its tasks equally well? How could it divide its loyalty between the minister and the council? A similar arrangement in France was already raising these difficulties.

The Glassco recommendations were the most elaborate proposals ever submitted to the Canadian government for the central administration and co-ordination of science policy. Although the commission did not mention its source of inspiration, its plan was remarkably similar to the French model, except that in France the Prime Minister was still formally responsible for science policy as chairman of a special ministerial committee and no government official was allowed to sit as a member of the advisory council.

## THE GOVERNMENT RESPONSE

The Prime Minister responded to Glassco's recommendations by asking the opinion of Dr. C. J. Mackenzie, who in January 1964 presented an informal progress report containing two recommendations for immediate action, together with a reference to steps that had to follow. The two recommendations dealt with what became the Science Secretariat and the Science Council.

Dr. Mackenzie was sure that an overall science policy machinery was needed. Before he was asked for comments by the Prime Minister, he wrote, "There has not yet emerged a comprehensive and accepted government policy for co-ordinating and supporting the interlaced activities of the three scientific sectors of our economy (i.e. government, universities and industry). This is an immediate and pressing need."[29] He repeated this in his report to the Prime Minister and added "that science has now become such a major factor in our national economy that a more formal way of arriving at policy decisions with reference to expansions and co-ordination is imperative."[30]

When it came to making specific recommendations, however, Dr. Mackenzie did not have an easy task. In his report, he expressed strong personal views on what ought to be done although he realized that they were no longer applicable. He drew attention to the British roots of Canadian scientific organization, noted that the Department of Scientific and Industrial Research set up in Britain in 1915 "was the prototype of the Canadian National Research Council,"[31] and suggested that British concepts and institutions should continue to inspire the Canadian government in its organization of science policy machinery.

What Dr. Mackenzie had in mind more particularly was the recommendations made by the committee on "The Machinery of Government" chaired by Lord Haldane, which reported in 1918. Lord Haldane, he wrote, was "extraordinarily perceptive". Some of the troubles confronting Canadian government science policy machinery arose because the government had departed from the principles laid down by Lord Haldane.

The report of the Haldane Committee established the principle that the control of research should be separated from the executive function of government. Research should not be carried out by government departments, it should be funded by research councils. It was argued that this allowed the promotion of research and development while simultaneously guaranteeing the independence of the scientific judgments involved.

In his report to the Prime Minister, Dr. Mackenzie stated that "after 1924, to my knowledge, there were few if any public discussions by any Government on the overall question of national science policy."[32] The problem was that "Canada, in recent years, has seldom had a Chairman of the Committee of the Privy Council on Scientific and Industrial Research who was not immersed in pressing executive departmental problems; the result has been that Ministers have had little time for leisurely thought about scientific matters."[33] This, he claimed, was the "first deviation from the Haldane concept."[34]

The second deviation from the Haldane concept "was that departments such as Agriculture, Mines and Technical Surveys, Forestry and Fisheries, were permitted during the rapidly expanding period, to build up in executive departments large research activities of a general character."[35]Also, "our Canadian difficulty is that in 1917 the Government of the day did by a statute set up such a body [that is, a body like the National Scientific Advisory Council recommended by the Glassco Commission], i.e. the Honorary Advisory Council for Scientific and Industrial Research, and gave it the wide responsibilities and duties mentioned. In the intervening years national laboratories were set up under the Council and successive Governments by adding other extensive research establishments to departments and agencies did, without amending the Research Council Act accordingly, make it impossible for the Advisory Council of the National Research Council to carry out all its originally conceived obligations."[36] Nevertheless the situation when Dr. Mackenzie reported in 1964 was that the National Research Council "is still the *only* federal scientific organization that was designed to serve the general science of the nation and give advice to the Government on general scientific questions."[37] And during the preceding 25 years, Dr. Mackenzie reflected, NRC "has been by far the most influential single influence in the development of our national scientific structure" and has "achieved world wide recognition as a most efficient and valuable organization."[38]

Dr. Mackenzie considered that the Haldane principle should have been followed and that, as in Britain, research should have been under research councils (presumably part of NRC, somewhat like the original Medical Research Council). For example, an Agriculture Research Council should



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have expended the bulk of R&D funds rather than the Department of Agriculture.[39] Thus, in 1964, Dr. Mackenzie expressed the same basic views that Dr. Tory had put in his 1932 memorandum, which is reproduced as annex 2 of Chapter 3.

Dr. Mackenzie, however, was realistic enough to realize that it was too late in 1964 to apply the Haldane principle. He considered that "in Canada these anomalies of having general research activities in executive departments cannot be easily changed and with the exception of activities like astronomy, museums, oceanography, etc., probably no basic change should be made. The practical approach now is to see to it that as far as possible such units operate under the research council type of environment."[40]

Dr. Mackenzie accepted with reservations Glassco's recommendations to set up a secretariat and an advisory council because it was impossible to concentrate the bulk of government science activities in the National Research Council and in similar institutions. He wanted to make sure, however, that no interference by the two proposed agencies would destroy the good that had been accomplished by the established institutions.

About the proposed advisory council, for instance, he warned that "the most difficult problem is how to bring into being such a committee as it must reflect the advice and views and needs of all the sectors of scientific effort in Canada without infringing on the rights and privileges of current advisory councils and authorities. . . . Under no condition then should the operations of the Council (i.e. NRC) or its research laboratories as now carried on, be restricted or curtailed nor its position be undermined. On the other hand, a National Committee on Scientific Policy covering all national scientific activities can be set up that will serve the ends suggested in the Glassco report without infringing on the rights and responsibilities of the National Research Council, Atomic Energy of Canada Limited or the departmental establishments."[41]

Dr. Mackenzie thus advised against the important powers that the Glassco commission had assigned to the proposed council. He recommended that the council should not "interfere with the normal channel of communication and recommendations that originate in the units and reach Cabinet and the Treasury Board through the responsible Minister."[42] In accepting Dr. Mackenzie's advice, the Prime Minister rejected a major recommendation of the commission.

Dr. Mackenzie suggested also that the council should consider mainly "which broad areas of research should have the highest priority and be given most support in the interest of the country and its economic prosperity."[43]

Presumably in Dr. Mackenzie's mind such studies were to remain broad and general enough not to interfere with "the rights and privileges" of existing government agencies. Accordingly the council proposed by the Glassco Commission should only have the status of a committee reporting to the Prime Minister, although the commission had clearly indicated that it was impractical to assign the responsibility for science policy to the head of government.

The Glassco Commission had envisaged for the council a role very similar to that of the *Comité consultatif de la recherche scientifique et technique* in France. Dr. Mackenzie recommended a committee that would be expected only to give its general views on broad science policy questions and that in this respect was very similar to the President's Science Advisory Council (PSAC) in the United States.

Glassco's Central Scientific Bureau was supposed to be responsible to the President of the Treasury Board. Dr. Mackenzie recommended that it should be placed in the Privy Council Office and be responsible to the Prime Minister. When he described its functions he did not mention the "scrutiny of all government scientific programmes" that had been envisaged by Glassco:

> ... Assembling, digesting and analyzing all information concerning the government's scientific and technological activities and their inter-relation with university, industrial and provincial research establishments... the Bureau must acquire, by personal contacts, first a detailed knowledge of the organization, personnel and working programs of all federal and provincial government research establishments and university science departments. As far as is possible the Bureau should also become personally knowledgeable about the research and development facilities of private industry... Naturally a study of the Canadian picture will have first priority but at least paper studies of scientific organizations in all other developed countries should be carried on currently with actual visits to follow.[44]

In other words the bureau would be a data gathering and processing agency; it would collect raw data and convert it into meaningful and purposive information for the makers of "broad government policy."

Both the Glassco Commission and Dr. Mackenzie agreed that the bureau should have a "small but expert staff." Dr. Mackenzie specified the staff in detail: a minimum of a chairman and two senior assistants with supporting stenographic and clerical staff. The chairman ought to "bring prestige to the job", and be "*persona grata* with the senior officials", and his "governmental status" had to be high.[45]

Dr. Mackenzie recommended that the bureau should be set up before the advisory committee or council and that it should be the advisory council's secretariat, thus adding an important responsibility to this small unit. The



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Glassco Commission had envisaged the bureau as being rather like the *Délégation générale à la recherche scientifique et technique* in France. In contrast Dr. Mackenzie's proposal closely resembled the model of the U.S. Office of Science and Technology (OST), created in 1962.

Both the Glassco Commission and Dr. Mackenzie believed that the government needed an effective central machinery for science and technology. The commission consciously or not, proposed new structures and mechanisms closely similar to the French model. Dr. Mackenzie had a strong preference for British institutions but he recognized that it was too late to apply Haldane's principle in Canada by concentrating government science activities in research councils. However, his belief that "the rights and privileges" of these existing agencies had to be preserved led him to propose a science-policy machinery closely resembling the American model and much less influential than that envisaged by the Glassco Commission.

### THE IMPLEMENTATION OF DR. MACKENZIE'S RECOMMENDATIONS

The Canadian government accepted the substance of Dr. Mackenzie's report. On April 30, 1964, the Prime Minister recommended to the House of Commons that "a Scientific Secretariat be established to assemble and analyze information about the government's scientific programs and their inter-relation with other scientific activities throughout Canada. This organization will be a small fact finding and analytical group serving in a staff capacity without executive authority." The secretariat was to be established as part of the Privy Council Office and would provide "day-to-day support in the work of the Privy Council Committee on Scientific and Industrial Research."

In a recent article, Dr. R. J. Uffen, the chief science adviser to the Cabinet and head of the secretariat, gave a more specific account of the secretariat's work:

> . . . The secretariat is an arm of government. It is a service agency whose primary task is to assist government departments and other agencies in getting their proposals before the cabinet in an orderly manner and in such a way as to give the ministers the clearest picture of the problems under discussion and the options open to them. *The expertise rests with the departments and agencies. The secretariat is not equipped to argue with the experts, nor is it intended that it should be so.* It is, however, required to co-ordinate presentations to the cabinet so as to ensure that all departments and agencies concerned with a particular proposal are aware of it and have their views taken into account.[46] (Emphasis added.)

The secretariat must also react to the questions of ministers. According to Dr. Uffen:

> There are certain general scientific problems not covered by any present department or agency of government. In these areas, the Science Secretariat conducts its own studies and puts forward proposals when the government wishes it to. This is done by consultants, seconded specialists or temporary task forces . . . To summarize, the Science Secretariat, headed by the chief science adviser, is a staff agency serving the cabinet. It is required to respond quickly to questions and queries from the prime minister and cabinet members and to get answers from the experts wherever they may be, either in government, industry or the academic community.[47]

As can be seen, these functions do not include the type of scrutiny of government progress that had been proposed by Glassco. Neither would it be likely that ministers would request such a scrutiny from the secretariat.

Instead the secretariat often found itself dependent on government departments. The Senate Committee was told that Treasury Board worked closely with the secretariat and requested information about departmental programs. But when the director of the secretariat appeared before the Senate Committee, he implied that for any evaluation of research he relied on the department conducting it, presumably to safeguard "the rights and privileges" of specialized agencies.[48]

While the secretariat was located in the Privy Council Office to help departments put their science and technology proposals before the cabinet, the Science Council of Canada was asked "to assess in a comprehensive manner Canada's scientific and technological resources, requirements and potentialities."[49] The Science Council of Canada Act received royal assent in May 1966. The Prime Minister was designated as the minister to whom the council should report and the secretariat was instructed to provide whatever secretarial and staff services it required.

Speaking in the House of Commons, the Minister of Industry, the Honourable Charles Drury, said the council would advise the government on matters of broad national scientific policy, would define and determine feasible long-term objectives for science in Canada, and would suggest appropriate paths of approach for the various sectors. The council would be less concerned with day-to-day problems than with developing principles and evolving a philosophy on which future courses could be charted.[50] Here again care was taken not to infringe upon "the rights and privileges" of existing agencies and not to interfere with existing lines of communications.

Although Dr. Mackenzie had stressed the usefulness of the British model of policy making he advised against taking the advice of the recent Trend

Report,[51] that no heads of operating government establishments should be members of the council. Dr. Mackenzie argued: "While there is some logic to this suggestion I feel it would not be workable in Canada at this time, for currently the most practical knowledge about operations of sizeable scientific organizations is to be found in the government service, and while I feel strongly that there should be a majority of outsiders on the Committee I feel equally as strongly that for the immediate future the presence of government scientists on the committee is essential to the formulation of sound and acceptable policies."[52] On the face of it this implied that the situation had not changed for half a century: industry and universities were still behind in general and specific scientific expertise.

The council's act specified that membership must not exceed (a) 25 full members "chosen from among persons having a specialized interest in science or technology" and (b) four associate members "chosen from among officers or employees of Her Majesty employed in departments or agencies of the Government of Canada." In June the Prime Minister announced the appointments of the full members. Seven were from the government sector, nine from universities, and seven from business and industry. When associate members were included, the government component totalled 11.

## THE PRESENT SCIENCE POLICY MECHANISM

At the council's inaugural meeting in June 1966, the Prime Minister said that, on Dr. Mackenzie's advice, he had recommended the establishment of the council as "an independent, advisory body, having no responsibility for the operation of laboratories or indeed for any expenditure of research funds."[53] And here the question arises: Independent in what way? The 11 government members and associate members included all the senior officials most directly involved with government science policy: not only the heads of operating departments and agencies spending the great bulk of government research funds but also senior officials involved with economic and industrial policy. Added to this group were nine representatives from universities, and their independence must be qualified in the light of a comment made by the chairman of the Science Council, Dr. Omond Solandt:

> I would say that in general the people from the universities find themselves in a very difficult position in dealing with Government officials, because they, on the one hand, would like to be critical of what the Government is doing in many cases, but, on the other hand, recognize that most of their support comes from the Government.[54]

Another weakness has been pointed out by Dr. Weir, then director of the secretariat:

> One has to appreciate that the Science Council is composed of very busy and very senior people who usually devote one or two days every couple of months to Science Council meetings.[55]

Finally, how could the secretariat, as an arm of government that necessarily had to be responsive and loyal to ministers, at the same time be free to conduct impartial and critical studies of government operations for the use of the council's public appraisals and reports? This impossible situation was brought into sharp focus at a Senate Committee hearing in March 1968. Eight months later, the secretariat and the council were separated and in February 1969 the council was given a status similar to the Economic Council's.

The autonomy and wide-ranging activities of the National Research Council had not been altered substantially by the creation of the Science Council, as can be seen from the statement read to us by NRC's president, Dr. W. G. Schneider. The brief stated:

> In general terms, the role of the Council is that of developing and nurturing a national capability in scientific and industrial research, and of deploying scientific research for national benefit.
>
> In order to carry out these broad functions, and to ensure that the Council is responsive and adaptive to changing needs and new opportunities, a continuous and detailed monitoring of the whole of science and engineering is essential. The broadly representative character of the Council itself, as well as a strong cadre of advisory and associate committees, provide the Council with the broad and detailed input necessary for decision-making and policy formulation on all aspects of scientific research in Canada. In this respect, the Council also derives a special advantage from its own laboratories, whose staff represents a broad spectrum of scientific expertise and maintains close contact with industrial laboratories.[56]

At first sight this opening paragraph of NRC's brief appears to be a very general description of a central science policy machinery—one, in this case, equipped with large laboratory facilities. For the committee, it raises fundamental questions. In "developing and nurturing a national capability in scientific and industrial research," who sets the policies and strategies? Where are the objectives and goals determined? In "deploying scientific research for national benefit," who is responsible for selecting the benefits and who measures the cost and magnitude of these benefits? How is the "continuous monitoring of the whole of science and engineering" organized and how is this stream of perceived needs and opportunities fed to other government departments, and the private sector? How is this perception formally linked to the cabinet-level science policy machinery?

Some of the answers are provided by NRC itself when it states in its brief that a "strong cadre of advisory and associate committees" give it "the broad and detailed input necessary for decision-making and policy formulation on all aspects of scientific research in Canada." But what happens then to the Science Council's role as a central agency for science policy formulation? Dr. Schneider explained the relationship between the council and NRC:

> In practice, the Science Council concerns itself specifically with broad policy formulations. Of course, the Science Council has not been in operation all that long. They are still working hard at it. We do not yet have a complete integrated overall science policy emanating from that body, but this is the intent . . . Once the general policy framework is there, then certainly any programs that the NRC develops must be consistent with the broad policy objectives. Of course, if there is a vacuum and there is no policy, and yet there is a national need or a very urgent need, we will endeavour to try to do something about it. I think it is entirely proper for the Council to take the initiative where they see new opportunities or an urgent need to do something. Then, if it is a major program and it involves major expenditures, it will again go through the usual Government channels in respect of decision-making.[57]

Thus it appears that NRC has remained as a parallel central machinery for science policy, parallel to the Science Secretariat and the Science Council; that is in accordance with Dr. Mackenzie's recommendation, that none of the existing agencies should be deprived of their rights and privileges. NRC's president stated that if there was a national need and a policy vacuum, then "we will endeavour to do something about it."

The president said also that for decisions on major expenditures the "usual government channels" would be followed. This was the route envisaged by Dr. Mackenzie: from NRC to its minister to the Treasury Board. Thus there is really no new process for making science policy decisions. In the final analysis, Canada's strategy consists of a series of policies for individual sectors, all strongly influenced, at least negatively, by Treasury Board decisions. The Senate Committee regretfully regards this as a science policy by accident.

Meanwhile, the Economic Council of Canada, which had been established in 1963, also continued to interpret its mission in the same way after the creation of the Science Council as it had done before. The mandate of the Economic Council was broad enough to give it an advisory role in science policy. Two of its most specific contributions to the formulation of science policy were published in 1968, two years after the establishment of the Science Council.

The first one was a special study prepared for the Economic Council by Mr. Andrew H. Wilson.[58] The second one was a statement on science policy by the council itself. It was included in the council's fifth annual review and contained the following recommendations:

> (1) that innovation—the crucial stages beyond R&D—be given greater recognition in "science policy";
>
> (2) that the capacity for Canadian business management to undertake successful innovation be strengthened;
>
> (3) that new and more effective means be developed to harness information on science, technology and innovation, both from abroad and from Canadian sources, in both the public and private sectors;
>
> (4) that Canada's indigenous scientific and technological effort be strengthened, particularly in industry;
>
> (5) that support for the social sciences be greatly increased, and that "science policy" should have regard to the need for more interrelated activities across the whole spectrum of research, including the natural sciences, the social sciences and the humanities.[59]

With a Science Secretariat strengthened in 1969 and three councils involved in the process of science policy formulation, instead of the one that existed before the 1960s, it was not surprising to find a renewal of interest and activity in this sector at the ministerial level. In 1968, when the Honourable Charles Drury became President of the Treasury Board, he remained chairman of the Privy Council Committee on Scientific and Industrial Research. On August 14, 1968, when the Prime Minister announced that "the scientific policy still will report through him" (i.e. Mr. Drury), he went on to say:

> I do not think this will be a permanent situation. There is some argument for keeping it with Mr. Drury; he knows a lot about the subject and he is very keenly interested in it. There is the contrary argument that as President of the Treasury Board he may have divided interests in the amount of money we would want to invest in that and perhaps I would not want to put him in a position of having to argue against himself.

In 1969 the Privy Council committee began to meet more frequently. However, in 1970 Mr. Drury's responsibilities as President of the Treasury Board became heavier. The ministerial Committee on Scientific and Industrial Research, which had been in existence since 1916, was abolished in October 1970. Science questions have now been assigned to another Cabinet committee which deals also with information and cultural matters. It is expected, however, that this new arrangement will be temporary. At least this is the

Senate Committee's interpretation of the following statement in the Speech from the Throne delivered on October 8, 1970:

> There exists in Canada a great wealth of untapped and unco-ordinated scientific talent and experience not now adequately utilized in the quest for solutions to our modern problems. In order to serve better the industrial and technological sectors of our economy, as well as Canada at large, a programme will be introduced to gather and focus these sometimes divergent and competitive scientific resources. In this respect the Government will consider with care measures recommended by the Senate Committee on Science Policy and the Science Council of Canada.

Meanwhile, it is difficult to see how, under present conditions, the unrelated efforts of three councils and a secretariat can be more successful in establishing a coherent and efficient central machinery for science policy than the isolated action of one council in 1916. In 1963 the Glassco Commission presented proposals aimed at providing a central system of planning and control. Dr. Mackenzie advised against the substance of these recommendations in order to protect the "rights and privileges" of the then existing government institutions. Canada's second attempt to develop a central framework for science policy failed as definitely as the first attempt during and after World War I. Nevertheless a number of new initiatives were taken during the second attempt. We will now review them.

## THE INITIATIVES OF THE '60s

Prior to the creation of the Science Council, the Science Secretariat initiated five major inventory studies of scientific disciplines. At the time of the Senate Committee hearings two of the reports had been published, one on physics[60] and one on psychology.[61] Although these reports give valuable and unique insights into their subjects, the Senate Committee is concerned that each report suggests large growth rates for expenditures. The physics report for instance suggests that the normal expenditure on physics research should rise at a rate of 23% per annum and the psychology report recommends that funds for research in psychology should increase over 300% from 1966 to 1970 and double again by 1975 in order to meet "forecast demands". As for the source of this money, "probably five-sixths of the total funds needed will be requested from Canadian Government sources."[62]

In many respects these special studies parallel reports produced in the U.S.A. by the National Academy of Sciences[63]—reports that moved Alvin Weinberg to question the lack of public criticism of science programs. He identified one problem: that every field of science must assume every other field of science is as valid as itself (there is a "code of ethics" that prevents a practitioner in one field from commenting on another field). Weinberg insists that what is at issue is not the correctness of a scientific activity but its value, and he reflects:

> The reports of the National Academy of Sciences, whether they deal with physics, or chemistry, or ground-based astronomy, or botany, tend to be isomorphic: the field under review is very promising; its practitioners are excellent; and its needs are very great and expensive. I would think that such reports ought to be reviewed in sharp and critical, though responsible, vein by persons who are willing to serve as scientific critics.[64]

The Science Council has also published several valuable reports. Only one of them, entitled *Towards a National Science Policy for Canada,* attempted to build an overall plan for science and technology but, as its title suggested, it was not an exhaustive study. Other more specific reports contained important recommendations but in limited areas. Yet in the absence of the basic elements of an overall plan, how can the government best evaluate and judge such specialized studies? How could action be decided upon and implemented? There is plenty of evidence that the mere publishing of coherent scientific views in no way assures action. The Senate Committee has the impression that the Science Council has been working in a vacuum and that its impact on Canadian science policy has been minimal.

In the previous chapter it was shown how the Canadian government attempted in the '50s to involve private industry in big development and innovation projects, both military and civilian, on a contractual basis. This strategy was not too successful. During the 1960s, it was government policy to continue the promotion of science activities performed by industry. This policy and its justification were stated by the Honourable C. M. Drury in 1967 when he was still Minister of Industry:

> ... I would like to suggest that new product or process development offers a most promising and practicable method for meeting the challenge of widening export markets, increasing productivity, and realizing the full economic potential of our manufacturing industry (whether subsidiary or not). It is the purpose of our various research incentive and assistance programs to stimulate a major expansion of innovative activity in Canadian industry and thereby bring about the requisite degree of specialization to successfully compete internationally.... Finally, let us consider the implications of the foregoing for our National Science Policy. Above all, it seems to me that we must give top priority to scientific and technical endeavour directed toward economic and social goals. For without a prosperous economy based on an efficient manu-

facturing industry, we cannot afford the luxury of "prestige science" in either the public or private sector. Our first obligation, therefore, is to ensure that technical innovation activity in our industry is brought to a competitive level in the shortest possible time. To this end, the government must emphasize engineering research and support development activity in both its intramural and extramural programs.[65]

In the 1960s, the government put the emphasis on tax incentives and grants to industry rather than on contractual arrangements. In 1961, the Department of National Defence established *The Defence Industrial Research Program* (DIR) to improve the applied research ability of Canadian firms in the defence field, in the hope that this would help industry to supply effective equipment to the Canadian armed forces and to our allies at competitive prices. In the same year, the *Industrial Research Assistance Program* (IRAP), financed and administered by the National Research Council, became the civilian counterpart of DIR. Intended to increase the research staffs of Canadian industry, it covered the salaries of scientific and technical staff that a firm added to its existing personnel to undertake an authorized project.

In 1962, a new tax incentive under Section 72A of the Income Tax Act permitted a firm to deduct 50 per cent of the increase in its scientific research expenditures in Canada over the previous year. This incentive lasted from 1962 through 1966.

*The Programme for the Advancement of Industrial Technology* (PAIT)[66] established by the Department of Industry in 1965 provided "risk capital" to help firms undertake R&D designed to support new products or processes demonstrating substantial technical improvement and commercial viability. The department paid half the current R&D costs of an approved project. If the project was commercially successful, the firm had to repay its loan with interest to the government. This last provision was eliminated in 1970.

*The Industrial Research Institute Program*, established by the Department of Industry in 1966, was designated to make grants to universities "to help cover administrative expenses of institutes they establish to work with industry and in particular to undertake, on a contract basis, scientific research activity for industrial firms unable to maintain their own research facilities and personnel."[67] In 1966 grants were made to institutes at the University of Windsor, McMaster University, Waterloo University, and Nova Scotia Technical College. These four industrial research institutes began to hire staff and make contact with industry during 1967. The intent was to couple the expertise of universities (which has been developed to a considerable extent by federal grants) more directly to the productive sector.

The National Research Council began a program of negotiated development grants to universities in 1969. The original purpose was to back the formation of "centres of excellence." Later, an additional aim was to improve the regional balance of talents. In announcing its grants NRC stressed their effect on industrial development. The Senate Committee wonders, however, whether individual government agencies should be left with the decisions to establish research institutions or to help establish centres at universities, especially when assistance to industrial or regional development is the objective. It is the feeling of the Committee that such matters should be co-ordinated in the light of overall government policies—and in the light of provincial and regional policies.

*The Industrial Research and Development Incentives Act* (*IRDIA*), administered by the Department of Industry, was initiated in 1967 as a grant-based general incentive program intended to stimulate industrial R&D: "This grant amounts to 25 percent of eligible capital investment in R&D facilities and 25 percent of the increase in current R&D expenditures over the average of the previous five years."[68] The minister must be "satisfied that the scientific research and development in respect of which the expenditure was made is likely to result in benefit to Canada if it is successful."[69]

The Department of Industry also manages the *Defence Industry Productivity Program* (*DIP*),[70] which in 1968 combined into a single program the assistance formerly provided under the Defence Development Sharing Program and the Defence Industrial Research Program. The objective was "to develop and sustain the technological capability of Canadian industry for the purpose of defence export sales or civil export sales arising from that capability."[71]

Other Department of Industry, Trade and Commerce programs related to innovation, industrial specialization, design, and restructuring provide financial support in the form of loans, or direct grants: the General Adjustment Assistance Program (GAAP), the Automotive Adjustment Assistance Program (AAA), the Building Equipment, Accessories and Material Program (BEAM), the Pharmaceutical Industry Development Assistance Program (PIDA), the Industrial Design Assistance Program (IDAP), the Machinery Program (MACH), and the Ship Construction Subsidy Regulations (SCSR).

The number of programs involving three different agencies is impressive. It appears that government assistance to industry was developed in a piecemeal fashion and without an integrated strategy. Similar programs using different definitions for the same activities, offering different financial incentives, and administered by different agencies have been confusing to industry. Occasional changes made in them have added to the uncertainty, which is clearly undesirable in a sector that can develop only on a long-term basis.

Once again, it appears to the Senate Committee that the objective set by the government was not achieved. In October 1967 the Minister of Industry, Mr. Drury, stated: "Our first obligation, therefore, is to ensure that technical innovation activity in our industry is brought to a competitive level in the shortest possible time" (this was also an aim expressed in 1919 before the Cronyn Committee). So it is interesting to note the main changes that have occurred in the distribution of government expenditures on science activities in recent years. Between 1966-67 and 1969-70, total outlays in government assistance to the academic sector climbed from $60.9 million to $130.7 million. Total government contracts and grants to industry increased from $68.7 million to only $90.9 million.[72] The "first obligation" stated by the Minister of Industry in 1967 received in subsequent years the lowest priority: an increase in support to industry of $22 million, or 32%, as compared with $70 million or 115% for the academic sector and $130 million or 37% for government agencies. This clearly shows that it is difficult for the government to achieve its policy objectives in the absence of a coherent strategy and a central mechanism to carry it out.

## CONCLUSION

Dr. Weir, who appeared before the Senate Committee in March 1968, keenly perceived the weakness of the Canadian strategy. He indicated that there was a management gap when he said: "There are times when one has to look at the whole picture in a country such as ours and give some thought to and do some research into what the total picture is and the many complications there are going to be. I think this is best done by an organization or an agency that does not have responsibilities in the operating area . . . I think this is one thing in this country that we do need—some kind of planning agency or some sort of organization outside of the operating areas who will be able to plan programs and approaches and discuss this from a very broad point of view." Dr. Weir agreed that there was a problem in obtaining advice about a program from people who had a vested interest in it and he gave that as one more reason for having a "planning operation for research which is not in the operating departments."[73]

Thus, since 1916, the Canadian government has been searching for effective central mechanisms to plan and co-ordinate its science activities and has not been able to find them. Since 1916, too, the main objective of Canadian science policy has been to promote technological innovation by industry. This goal was clearly expressed before the Cronyn Committee in 1919; it was again re-stated by Mr. Drury in 1967. Almost every decade since the 1920s has witnessed renewed attempts by successive governments to achieve it but, on the whole, they have all failed. What progress has been made in this respect results almost exclusively from the initiative of industry itself.

The Senate Committee hopes that these four chapters, which have discussed the successive attempts of Canadian governments to develop a proper science policy and strategy, will serve a useful purpose. Our intention was to show that if governments are to use science and technology efficiently, it is not sufficient to identify realistic objectives and to have dedicated scientists and science managers in the public service. The history of Canada's failures suggests that a good strategy and proper mechanisms and machinery to enforce it are equally essential.

Since many past proposals were based on experience in the United Kingdom, the Committee believes that it is appropriate to conclude its historical account of the development of Canadian science policy by quoting long excerpts from a speech made in the British House of Commons in July 1969 by the Honourable Anthony Wedgwood Benn, who was then Minister of Technology in the Labour government:[74]

> It is the organization of science, its purpose, its control and supervision, and its social and political institutional implications which ought to involve everybody and which everybody is inherently able to discuss and debate. If people are too modest to join in a debate about these questions . . . then they are absenting themselves from participating in the central questions of the time in which we live. For our generation, this is the central power source, comparable with the ownership of industry in the 19th Century or of land in feudal times, and those who are not concerned with the use of scientific power are abdicating their political functions.
>
> Five years ago we decided that science could not be confined to a particular sector of our national life; to grammar schools, universities, research establishments and prestige projects to be handled under special procedures that reinforced its separateness and made it appropriate for a new élite.
>
> We have developed new priorities after very full discussion . . . we have set it as a major objective of our policy—I am speaking of my Department—that science should be harnessed to the job of earning our living as a nation . . .
>
> This involves the development of a capability for making judgments involving new techniques that have not previously been available to the government. This is why we have set up the Programmes Analysis Unit. This is why, in evaluating many projects for which we are accountable to the House, we use . . . calculations based on forward market analyses of a kind which are as

good, if not better, than those to be found in many firms and industries ... *Science seen as an arm of economic advance must be demand-oriented and not self-generated.* (Emphasis added)

The second shift of emphasis has involved moving away from the old exclusive Government support of aerospace and nuclear work ... towards a far wider range of industries upon which our economic future depends. A country of our size cannot aim to do everything. ... Choices have to be made ... painful as some of them have been. For example, in the nuclear field at Culham we are cutting down fusion research by 50 percent, just because its pay-off is so far ahead, if it ever comes, and we cannot spare the funds or the people for it. ... In the aeronautical research programme we have cut back hypersonic work sharply for the same reason. ... It may seem slightly off that a Minister should highlight the things that he has stopped so as to illustrate a positive policy, but *a positive policy must mean concentrating on where we can succeed and not in dissipating our efforts in the endless financing of work that is undertaken simply because it lies within the intellectual capability of the scientific community*. ... (Emphasis added)

The third change of emphasis has been from intramural to extramural research. ... As the I.R.C. and the Ministry of Technology have worked on the restructing of British industry, we have helped to create units big enough to run and finance more of their own scientific research capability. As this happens the role of Government intramural establishments will tend to change. ... The problems of transfer from innovation to exploitation, and the problems of making research programmes responsive to market needs are immediately more difficult if research is conducted under auspices separate from the needs it meets. The best transfer of technology is by the transfer of people or the establishment of joint teams, jointly funded, and this we aim to achieve. ...

One of the functions of the Ministry is clearly to provide an input into Whitehall thinking from industry over very particular types of problems. ... The final shift of emphasis ... is a shift away from research to the exploitation of science in world markets, because here is where we have failed dismally over the last 100 years. ...

... we think that it is the task of the Government, facing competition from other countries which may subsidize their industry through defence and space programmes ... *to put a lot more effort into the exploitation side, and not to think that research, however well-organized, can solve our problems.* ... (Emphasis added)

It is also the policy that I have been describing that led us to try to reintegrate science with industry by, amongst other things, reorganizing the nuclear industry to put our research programme under the management of committees upon which industrialists dominate. ... We gave the Atomic Energy Authority freedom to move into non-nuclear fields like desalination, ceramics and non-destructive materials testing, started industrial applications units at Farnborough and Malvern, and sponsored industrial units in universities ... to build bridges between science and industry. Anyone who thought that this would have a bad effect on the morale of scientists has been proved completely wrong. . . . *The old doctrine that one must keep scientific teams together, even if necessary by thinking up new projects, is totally wrong. . . .* (Emphasis added)

I will look ahead to see how we can use the men and facilities in the A.E.A. (Atomic Energy Authority), and our own civil establishments know that the design construction companies have been set up, the fuel company is to be started. . . . Talking to people who have faced the same problem in other countries, it has become clear that the relationship between civil scientific research and the needs to which it has to be put is increasingly being seen as one embodying a contractual relationship. The customer, whether it be the Government, local government, nationalized or private industry, pays for what it wants and, by paying, shapes the research programme itself and thus acquires an added interest in applying its results more quickly. This has certainly been the strength of some American practice and a lot of thinking is going on in Europe on it. Ministers in Communist and non-Communist countries are beginning to think in this way and it has certain self-evident attractions for us. Whatever the framework might be, and whether the customer is a Government Department that may be interested in the problems of pollution or noise, or a firm that might be interested in hydrostatic transmission or carbon fibres, the idea of paying for what you want done would certainly provide some form of methodology to clarification. It would simplify some very important and difficult questions of research management. . . .

. . . a new aspect of science policy, the collection, evaluation and dissemination of information which has become a matter of vital national and international priority. There is a commercial side to the information explosion, because the marketing of brainpower may well turn out to be one of our most valuable exports. . . .

It is still broadly true that this country and every advanced country tries to run itself with the help of institutions which were devised and formulated and reached their final stage of development long before the forces which have come into play in the last 10 years made themselves evident.

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# 6

## THE CANADIAN SCIENCE EFFORT IN AN INTERNATIONAL PERSPECTIVE

The four preceding chapters gave an account of the historical development of Canadian science, with special emphasis on government policy, its organization and methods. The present chapter reviews recent developments in Canadian science in the light of international comparisons, again emphasizing government policy. The national R&D effort is largely a reflection of science policy, because government decisions not only determine the level and content of science activities carried out by government itself, but also greatly influence the academic and industrial sectors.

Comparisons between the science efforts of countries that have reached about the same stage of economic and social evolution have become especially significant since World War II, when the international scientific and technological race really began. In the near future, even more than in the immediate past, as tariff barriers are lowered and as natural resources become more easily replaceable and transportable, technological innovations will be the key factor in economic growth in advanced countries; the level, distribution, and quality of the national science effort will become increasingly important because science and technology will constitute the main source of economic innovations. The quality of life itself will depend more and more on the rate of social innovations. Wedgwood Benn underlined this new aspect of international competition when he compared the power of science, technology, and innovation in this generation with the ownership of industry in the 19th century or of land in feudal times.

The technological race has now attained major proportions. It has been estimated that the total annual R&D expenditures in the world reached about *$50 billion in 1968*. This absolute amount can be expected to increase for the foreseeable future. It is, therefore, important for a country like Canada to know exactly its position in the international race and whether its participation in it is satisfactory, both in quantitative and in qualitative terms.

### THE LIMITATIONS OF THE COMMITTEE'S INTERNATIONAL REVIEW

A national science effort can be measured either by its input or its output. In monetary terms, the input can be viewed as the flow of expenditures and their distribution among major components, classified under such systems as sectors of funding, sectors of performance, or sectors of science activities. The definitions used by Statistics Canada to describe the various science activities are included in Appendix 1 at the end of this chapter. In real terms, the input can also be measured by evaluating the manpower, material, equipment, and plant capacity utilized by the national effort.

The output cannot be estimated so easily. The results of fundamental research are usually estimated by the number of articles published in reputable scientific journals, the number of references made by other scientists to those articles, and the number of Nobel prizes and other internationally significant awards. The output of development work can be measured by the number of inventions and innovations and their utilization, or by the number of patents taken out and monetary receipts for patents, licences, and technical know-how. Even those measurements, when they can be made, are far from satisfactory, but they give some indication, at least, of the benefits derived from research and development activities.

It is a major task to measure in detail all the aspects of a country's science effort, particularly in view of the lack of detailed statistical data about the output. It appears that in Canada, as elsewhere, science administrators in government have sought to encourage R&D activities without paying too much attention to the results. As a consequence there are almost no measurements of the national output of R&D. The Senate Committee expects that this data gap will soon be filled by Statistics Canada, in close co-operation with the science and technical information system which will be proposed in the second volume of this report.

On the input side, the available statistical material is more abundant, largely owing to the efforts made by the OECD since 1963. However, even here there is still room for substantial improvement. An important gap that still exists in many countries, including Canada, is the absence of reliable data on expenditures and manpower in the social sciences. This gap is symptomatic of the degree to which these disciplines have been neglected.

Some valuable statistical information about the science activities of several government agencies in this sector is contained in the Committee's proceedings, but it is not sufficiently complete to give a national picture. The Committee reiterates here the hope expressed during its public hearings, that Statistics Canada will give high priority to filling this regrettable gap.

The Committee has also learned from its formal hearings and from its visits abroad that even statistics on other aspects of the national science input are not always reliable. We have been told that in recent years coverage and methods have improved but it is still difficult to measure national trends over a period of years. Moreover, it has been noted that countries do not always use the same definitions or give them the same interpretation. Coverage may be different. Some countries use the calendar year and others their own fiscal year. For these reasons, international comparisons must be interpreted with care. Finally, many countries, including Canada, make a national statistical survey only every two years and publication of the results is considerably delayed. For instance, the most up-to-date figures for most OECD countries are for 1967.

In spite of these limitations, international comparisons are valid and useful, provided they are used only to describe general patterns against which the performance of individual countries can be appraised. Wherever possible the countries selected for these comparisons were chosen because their economic and social structures were similar to Canada's, and because of the intensity and their relations and their competitiveness with Canada, but sometimes the availability of information dictated our selection.

## THE OVERALL R&D INPUT

Statistics on expenditures and manpower devoted to national science efforts have another limitation, which has not yet been mentioned. They are related to R&D only. Expenditures devoted to such programs as data collection, technical surveys, scientific information, testing and standardization, scholarships and fellowships, which are included in the general definition of scientific activities, are not covered by the OECD surveys.

In an appendix to a submission before the House of Commons Committee on Research in 1961, Dr. C. J. Mackenzie presented estimates of R&D expenditures in Canada from 1939 to 1959.[1] Table 1, Chart 1 shows more recent figures of gross R&D. Expenditures were negligible in Canada in the early 1920s, increased slowly until the beginning of World War II, and have since risen rapidly. This upward movement was interrupted temporarily in

*Table 1—Total Gross Expenditures on R & D (GERD) in Canada, 1957-1967, and their Relation to Gross National Product*

| | GNP (millions $)[1] | GERD (millions $)[2] | % of GNP |
|---|---|---|---|
| 1957 | 32,907 | 304.6 | 0.9 |
| 1958 | 34,094 | 329.1 | 1.0 |
| 1959 | 36,266 | 309.2 | 0.8 |
| 1960 | 37,775 | 321.7 | 0.8 |
| 1961 | 39,080 | 392.8 | 1.0 |
| 1962 | 42,353 | 403.9 | 0.9 |
| 1963 | 45,465 | 464.4 | 1.0 |
| 1964 | 49,783 | 561.4 | 1.1 |
| 1965 | 54,897 | 676.6 | 1.2 |
| 1966 | 61,421 | 769.2 | 1.2 |
| 1967[3] | 65,608 | 895.5 | 1.4 |

SOURCES:
[1]From revised tables in *National Income and Expenditure Accounts 1926-1968*, D.B.S., August 1969. P6.
[2]From tables supplied by R. W. Jackson, Science Council.
[3]From special table supplied by H. Stead (D.B.S.), summer 1969, based on revised tables of national income.

1959 by the cancellation of the Arrow program but the acceleration reached its maximum between 1963 and 1967, when the share of GNP allocated to R&D rose from 1.0 per cent to 1.4 per cent. For the entire period between 1920 and 1967, GERD in Canada increased exponentially, that is, by a similar proportion each year, with a doubling time of approximately seven years.

While the pace of the national R&D effort in relation to GNP was thus accelerating, Canada was still behind most other countries at a similar stage of economic and social evolution (Table 2, Chart 2). As can be seen, the GERD in seven of these countries was close to or exceeded 2 per cent of GNP in 1967.

The lower ranks held by Sweden and Japan may be misleading. These two countries, especially Japan, had comparatively large non-R&D activities, in the sector of scientific and technical information in particular, and a highly developed technical know-how, which enabled them to produce innovations quickly and successfully from the *inventions* of others. In Canada the situation has been different; we have been importing *innovations* rather than inventions from the United States. The lesson to be drawn from the Japanese experience fits the Canadian situation well and has major implications for Canadian science policy.

# CHART 1 ILLUSTRATING TABLE 1

TOTAL GROSS EXPENDITURES ON R&D IN CANADA, (GERD), 1957 - 1967, AND THEIR RELATIONSHIP WITH GROSS NATIONAL PRODUCT (GNP)

*". . between 1920 and 1967, GERD in Canada followed an expotential law, with a doubling time of approximately seven years."*

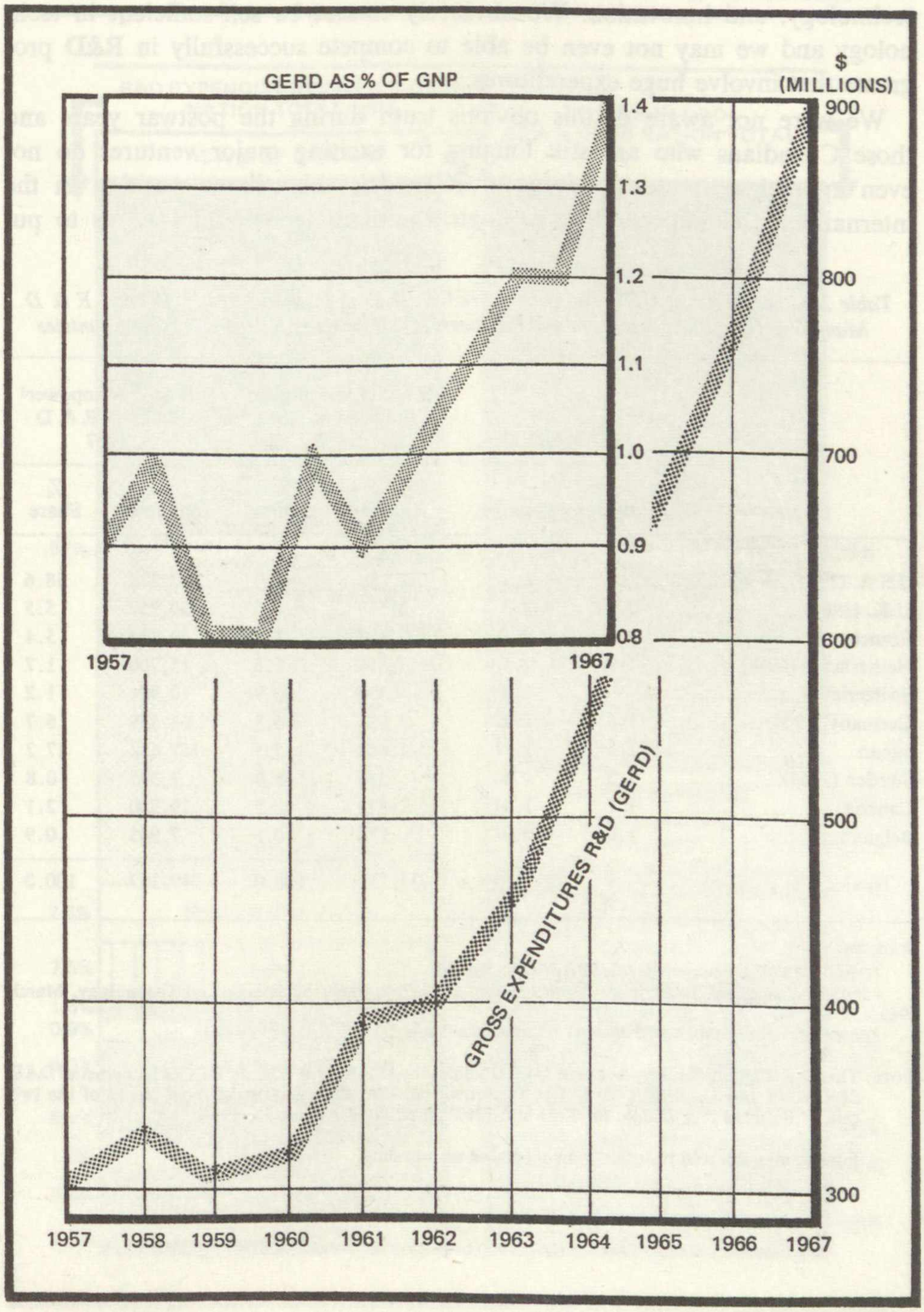


Table 2, Chart 2 shows that in 1967 the aggregate R&D expenditures for these ten countries amounted to slightly more than U.S. $33 billion. This means that the Canadian share was about 2.5 per cent. Although this percentage is more or less in proportion with our scientific labour force, it underlines the fact that Canada plays only a small role in the world arena of science, technology, and innovation. We obviously cannot be self-sufficient in technology and we may not even be able to compete successfully in R&D programs that involve huge expenditures.

We were not aware of this obvious truth during the postwar years and those Canadians who are still longing for exciting major ventures do not even appreciate it today. Moreover, Canada's subordinate position in the international scientific and technological community should lead us to put

*Table 2—Percentage of GNP Devoted to GERD, R & D Expenditures ($US) and R & D Manpower (Qualified Scientists and Engineers, QSE) for Ten Selected OECD Countries*

| | GERD/GNP[1] | | R & D Expenditures[1] (millions of US$) 1967 | | R & D Manpower[1] QSEs in R & D 1967 | |
|---|---|---|---|---|---|---|
| Country | 1963 | 1967 | Amount | % Share | Number | % Share |
| U.S.A. (1964, 1966) | 3.0 | 2.9 | 22,285 | 67.0 | 537,278 | 58.6 |
| U.K. (1964) | 2.3 | 2.3 | 2,533 | 7.6 | 50,350 | 5.5 |
| France | 1.6 | 2.3 | 2,507 | 7.5 | 49,224 | 5.4 |
| Netherlands (1964) | 1.9 | 2.3 | 514 | 1.5 | 15,700 | 1.7 |
| Switzerland | — | 1.9 | 304 | 0.9 | 10,954 | 1.2 |
| Germany (1964) | 1.4 | 1.7 | 2,084 | 6.3 | 61,559 | 6.7 |
| Japan | 1.5 | 1.8[2] | 1,684 | 5.1 | 157,612 | 17.2 |
| Sweden (1964) | 1.3 | 1.4 | 336 | 1.0 | 7,395 | 0.8 |
| Canada | 1.1 | 1.4[3] | 828 | 2.5 | 19,350 | 2.1 |
| Belgium | 1.0 | 0.9 | 176 | 0.5 | 7,945 | 0.9 |
| Total | | | 33,251 | 100.0 | 917,357 | 100.0 |

SOURCES:

[1]OECD, 1970, Document DAS/SPR/70.48, Table I

[2]Japan Science and Technology Agency, Summary White Paper of Science and Technology, March, 1969.

[3]Based on revised tables of National Income (see Table I)

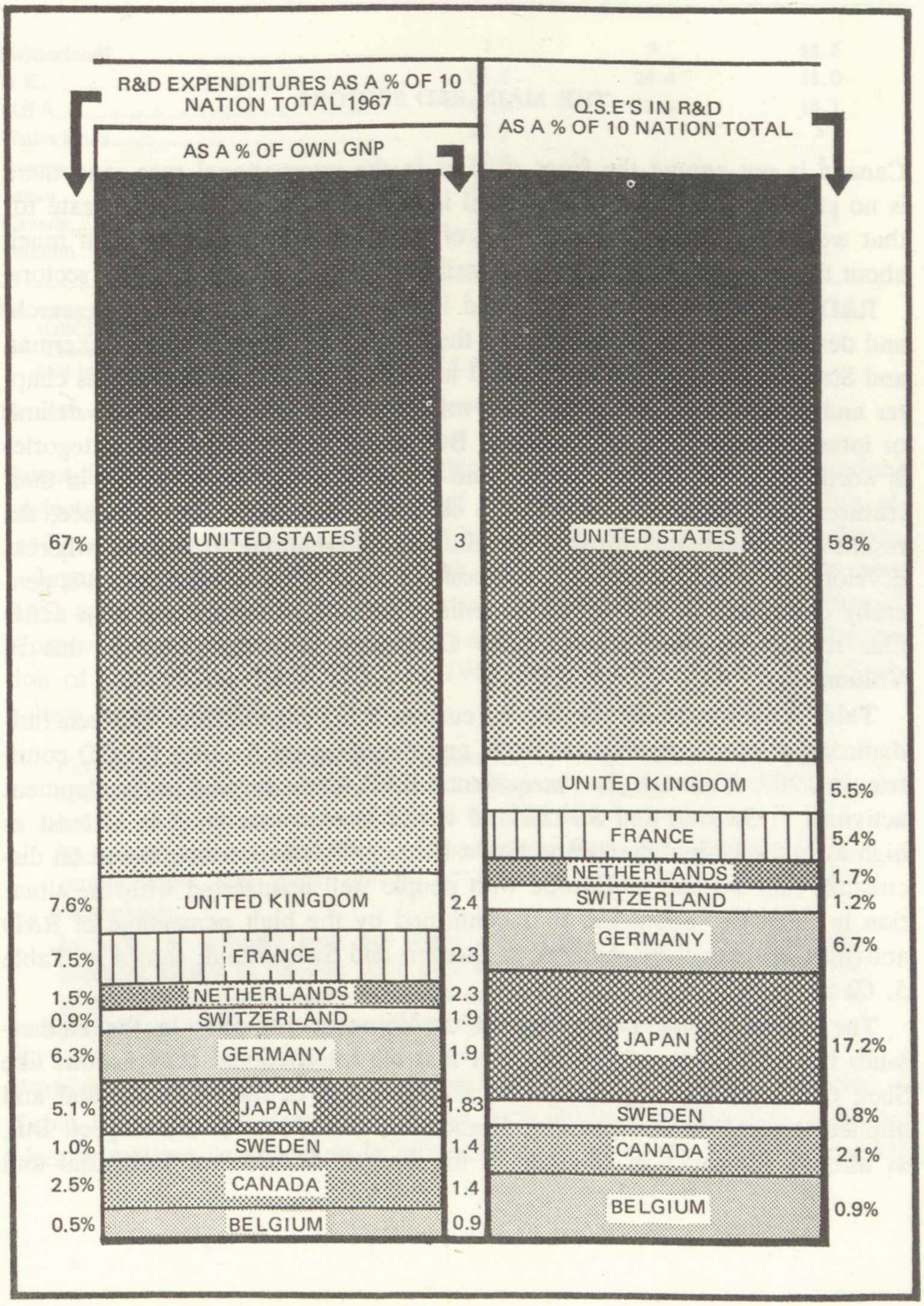
NOTE: There are slight differences between GERD values for U.S.A. and U.K. in OECD Documents DAS/SPR/70.48 and DAS/SPR/70.9. The Document used for this table is the most recent of the two, called "Selected R & D data for 1963 and 1967", and dated August 31, 1970.

Figures may not add to totals shown because of rounding.

# CHART 2 ILLUSTRATING TABLE 2

PERCENTAGE OF GNP DEVOTED TO GERD, R&D EXPENDITURES AND R&D MANPOWER (Qualified Scientists and Engineers) FOR TEN SELECTED OECD COUNTRIES (1967)

*"Canada plays only a small role in the world arena of science technology and innovation."*




Q.S.E.'S - Qualified Scientists and Engineers



99715—9½

much greater emphasis than we do now on the gathering and distribution of international technological information. This would put us in a better position to import knowledge and inventions and innovate ourselves rather than have to rely on imports of innovations and products. The Committee will have more to say later about these important policy questions.

## THE MAIN R&D SECTORS

Canada is not among the front runners in the international race, and there is no effective scientific and technical information system to compensate for that weakness, but that is only part of the story. One can also learn much about the national effort from the distribution of the science input by sectors.

R&D activities are usually divided into basic research, applied research, and development. The definitions of these categories by Sir Solly Zuckerman and Statistics Canada are reproduced in *Appendix 1* at the end of this chapter and Annex A at the end of this volume. It is not always easy to delimit or interpret these different activities. But the effort to define these categories is worthwhile, because they correspond to activities that differ greatly in their features, their requirements, and the objectives they serve. For instance, the results of fundamental research constitute an international free good, whereas development work immediately preceding market-oriented innovations is generally conducted in secrecy and is usually much more expensive than activities related to basic science. The Committee will elaborate on this in Volume II.

Table 3 shows the distribution of current R&D expenditures between fundamental research, applied research, and development for nine OECD countries in 1967. Although the *share* of total R&D funds devoted to development activities in Sweden and Switzerland is not known exactly, it is at least as high as in the United States and Great Britain. This assertion is based on discussions that we had in Europe with people well acquainted with the situation in these two countries. It is confirmed by the high percentage of R&D activities performed by industry in Sweden and Switzerland, shown in Table 5, Chart 4.

The relatively low percentage of development activities in the Netherlands is explained largely by the fact that big international corporations like Shell Oil, Unilever, and Philips do a large share of their fundamental and applied research in that country. France also ranks low in this respect. But, as already indicated in Chapter 4, the French Minister of Industrial and

*Table 3—Distribution of Total National R & D Expenditures by Type of Activity and Country, 1967*

Percentages[1]

| Country | Development | Applied Research | Fundamental Research |
|---|---|---|---|
| Switzerland[2] | [3] | [3] | 14.5 |
| U.K. | 64.6 | 24.4 | 11.0 |
| U.S.A. | 64.3 | 21.6 | 14.1 |
| Netherlands | 48.7 | [3] | [3] |
| France | 47.8 | [3] | [3] |
| Japan | 42.5 | 30.8 | 26.7 |
| Canada | 38.9 | 38.0 | 23.1 |
| Belgium | 37.2 | 42.2 | 20.5 |

SOURCES:
[1]OECD Document DAS/SPR/70.48, Table V
[2]Courtesy Swiss Embassy, Washington, D.C.
[3]No breakdown available between categories of R & D

NOTE: Figures may not add to 100% because of rounding.

Scientific Development views this neglect of development work on mundane projects as a regrettable expression of national *amour propre* and has already taken steps to correct what is, in his opinion, an undesirable imbalance.

Japan represents another untypical case because of its extensive non-R&D activities related to the importation of knowledge, already mentioned. Moreover, the Japanese government is not satisfied with the present distribution of the national R&D effort. In 1969, the Japanese Science and Technology Agency stated:

> Furthermore, the breakdown of investment by three research categories—basic research, applied research and development—shows that Japan is far behind the other advanced countries in the field of development.
>
> The recent trends in introduction of technology from abroad show that it is getting more and more difficult to have an easy access to excellent technology. . . .
>
> In order to compete with big world enterprises, with ample capital and excellent ability to develop their own technology, and to have further improvements in our industry, economy and living standard, it is necessary to develop our own technology, which is the basis for competitive power. . . .[2]

With these explanations and qualifications, Canada's position as shown in Table 3 appears in a clearer perspective. It is obvious that the general pattern already existing or emerging in advanced countries is to devote a relatively

# CHART 3 ILLUSTRATING TABLE 4

TOTAL NATIONAL R&D EXPENDITURES BY SECTOR OF PERFORMANCE IN CANADA, 1957 - 1967.

*"In absolute terms, the rise of the academic sector as a performer of R&D has been spectacular".*

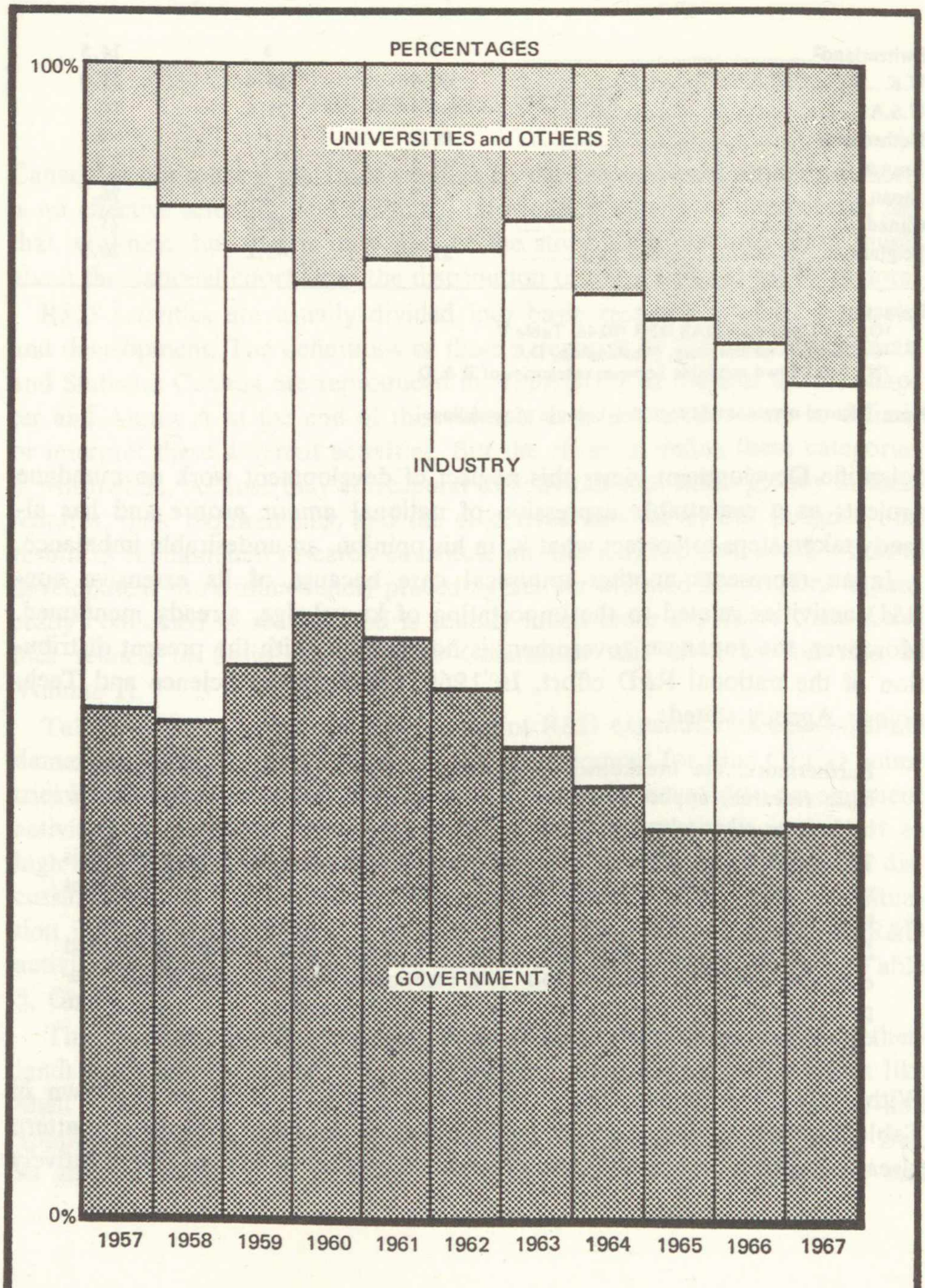


*Table 4—Distribution of National R & D Expenditures by Sector of Performance in Canada, 1957-1967*

($ millions)

| | Government | Industry | Universities | Other | Total |
|---|---|---|---|---|---|
| 1957 | 134.9 | 140.1 | 25.8 | 3.8 | 304.6 |
| 1958 | 141.0 | 150.5 | 33.8 | 3.8 | 329.1 |
| 1959 | 151.2 | 110.3 | 43.3 | 4.3 | 309.2 |
| 1960 | 172.4 | 92.7 | 51.8 | 4.8 | 321.7 |
| 1961 | 199.0 | 130.5 | 57.8 | 5.5 | 392.8 |
| 1962 | 187.9 | 140.3 | 69.6 | 6.1 | 403.9 |
| 1963 | 187.7 | 184.3 | 85.2 | 7.2 | 464.4 |
| 1964 | 207.5 | 237.9 | 108.4 | 7.6 | 561.4 |
| 1965 | 234.6 | 287.9 | 146.2 | 7.9 | 676.6 |
| 1966 | 266.6 | 303.2 | 189.4 | 10.0 | 769.2 |
| 1967[1] | 318.9 | 337.8 | 238.8 | | 895.5 |
| | | percentages | | | |
| 1957 | 44.3 | 46.0 | 8.5 | 1.2 | 100.0 |
| 1958 | 42.8 | 45.7 | 10.3 | 1.2 | 100.0 |
| 1959 | 48.9 | 35.7 | 14.0 | 1.4 | 100.0 |
| 1960 | 53.6 | 28.8 | 16.1 | 1.5 | 100.0 |
| 1961 | 50.7 | 33.2 | 14.7 | 1.4 | 100.0 |
| 1962 | 46.5 | 34.7 | 17.2 | 1.5 | 100.0 |
| 1963 | 40.4 | 39.7 | 18.3 | 1.6 | 100.0 |
| 1964 | 37.0 | 42.4 | 19.3 | 1.4 | 100.0 |
| 1965 | 34.7 | 42.6 | 21.6 | 1.2 | 100.0 |
| 1966 | 34.7 | 39.4 | 24.6 | 1.3 | 100.0 |
| 1967 | 35.6 | 37.7 | 26.7 | | 100.0 |

SOURCES: Science Council

[1]Special table supplied by H. Stead (D.B.S.) summer 1969.

NOTES: (a) Figures may not add to totals shown because of rounding.

small share of their R&D effort to fundamental research and a slightly higher proportion of their funds to applied research and to put the main emphasis on development activities. Canada and Belgium do not fit into this pattern.

## PERFORMANCE AND FUNDING

NRC's plan of 1919 has not only influenced the distribution of our national effort among the main types of R&D activities, it has also to a large extent determined the pattern of performance and funding that has developed. This was at least logical and consistent. Table 4, Chart 3 shows the distribution of Canadian R&D expenditures by sectors of performance from 1957 to 1967. Table 5 gives similar information for 1967 on an international basis.

The trends apparent in Table 5, Chart 4 for industry and government were disrupted by the cancellation of the Arrow program in 1959. If this disturbance is disregarded, long-term movements appear more clearly. They show a downward trend in the shares of R&D activities performed by government and industry in Canada. The big gainer was the university sector. In absolute terms the rise of the academic sector as a performer of R&D has been spectacular, especially since 1964. To a large extent these trends reflect the failure of a few big industrial R&D projects in the late 1950s, as was described in Chapter 4. Industry did not recover its former position in the 1960s. The rapid rise of the academic sector resulted from Canada's persistent emphasis on basic and applied research rather than development work and from a willingness on the part of government agencies to share many of their research activities with universities.

*Table 5—Distribution of National R & D Expenditures by Sectors of Performance and Country, 1967*

(Percentages)

| | Business Enterprise | Government | Higher Education | Private Non-Profit |
|---|---|---|---|---|
| Switzerland | 76.5 | 6.3 | 17.1 | — |
| Sweden | 69.9 | 14.2 | 15.5 | 0.4 |
| U.S.A. | 69.8 | 14.5 | 12.2 | 3.6 |
| Germany | 68.2 | 5.1 | 16.3 | 10.4 |
| Belgium | 66.8 | 10.4 | 21.4 | 1.3 |
| U.K. | 64.9 | 24.8 | 7.8 | 2.5 |
| Japan | 62.5 | 13.0 | 22.9 | 1.6 |
| Netherlands | 58.1 | 2.7 | 17.7 | 21.5 |
| France | 54.2 | 32.1 | 12.9 | 0.8 |
| Canada | 37.7 | 35.6 | 26.7 | |

Source: OECD Document DAS/SPR/70.48, Table IV.
Note: Figures may not add to 100.0% because of rounding.

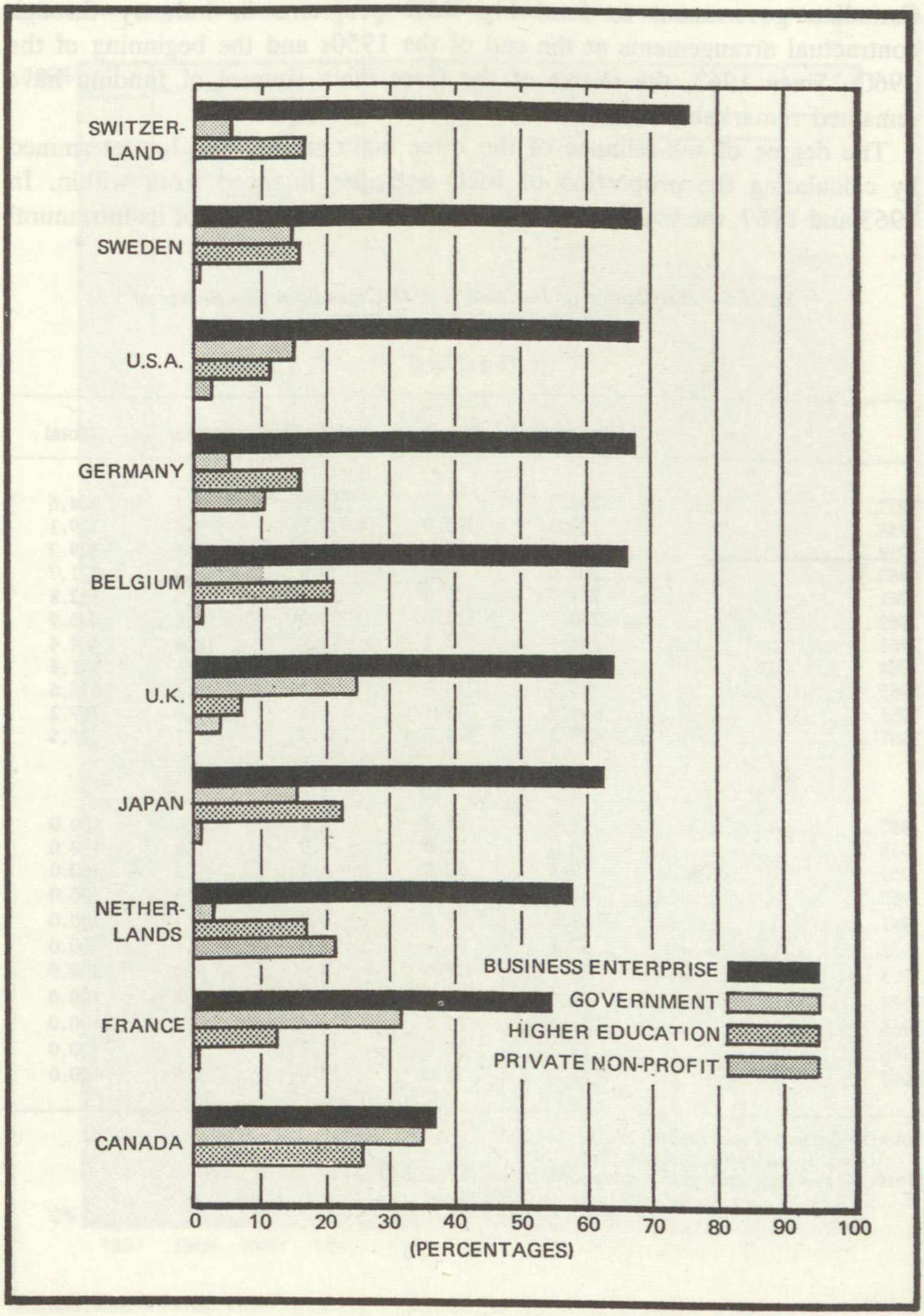
If we look at the international situation presented in Table 5, the uniqueness of Canada's position becomes obvious. Canada is at the bottom of the list as far as R&D performed by industry is concerned, but at the top when it comes to the government and university sectors.

Thus, here again, Canada stands aside in the international race. This originality is significant. Empirical evidence shows that the ideal location for R&D activities is where their results can be used, that is, where the innovation can be developed and introduced. This location, in an economic system

# CHART 4 ILLUSTRATING TABLE 5

TOTAL NATIONAL R&D EXPENDITURES BY SECTORS OF PERFORMANCE AND COUNTRY IN 1967 (PERCENTAGES)

*"Canada is at the bottom of the list as far as R&D performed by industry is concerned, but at the top when it comes to the government and university sectors . . . Canada appears to be on the wrong track."*






99715—10

mainly based on private initiative, is in industry. On that basis, at least, what most other advanced countries are doing seems to be right and Canada appears to be on the wrong track. In the funding of R&D the Canadian situation as it evolved between 1957 and 1967 is also interesting to follow (Table 6, Chart 5). We can observe the attempt and the failure of the Canadian government to fund big R&D programs in industry through contractual arrangements at the end of the 1950s and the beginning of the 1960s. Since 1963, the shares of the three main sources of funding have remained remarkably stable.

The degree of self-reliance of the three main sectors can be determined by calculating the proportion of R&D activities financed from within. In 1963 and 1967, the government financed 99 and 98 per cent of its intramural

*Table 6—Distribution of National R & D Expenditures by Source of Funding in Canada, 1957-1967*

($ millions)

| | Government | Industry | Universities | Other | Total |
|---|---|---|---|---|---|
| 1957 | 208.3 | 78.6 | 14.6 | 3.1 | 304.6 |
| 1958 | 198.3 | 105.2 | 19.3 | 6.0 | 329.1 |
| 1959 | 183.5 | 93.9 | 25.0 | 6.8 | 309.2 |
| 1960 | 205.0 | 77.5 | 30.9 | 8.3 | 321.7 |
| 1961 | 234.7 | 117.0 | 31.6 | 9.5 | 392.8 |
| 1962 | 230.7 | 122.6 | 38.0 | 12.6 | 403.9 |
| 1963 | 246.4 | 153.7 | 45.9 | 18.4 | 464.4 |
| 1964 | 288.5 | 187.9 | 60.2 | 24.8 | 561.4 |
| 1965 | 345.8 | 214.9 | 77.2 | 38.7 | 676.6 |
| 1966 | 409.1 | 215.2 | 101.4 | 43.5 | 769.2 |
| 1967[1] | 478.3 | 277.7 | 107.9 | 31.7 | 895.5 |
| (percentages) | | | | | |
| 1957 | 68.4 | 25.8 | 4.8 | 1.0 | 100.0 |
| 1958 | 60.3 | 32.0 | 5.9 | 1.8 | 100.0 |
| 1959 | 59.3 | 30.4 | 8.1 | 2.2 | 100.0 |
| 1960 | 63.7 | 24.1 | 9.6 | 2.6 | 100.0 |
| 1961 | 59.8 | 29.8 | 8.0 | 2.4 | 100.0 |
| 1962 | 57.1 | 30.4 | 9.4 | 3.1 | 100.0 |
| 1963 | 53.1 | 33.1 | 9.9 | 4.0 | 100.0 |
| 1964 | 51.4 | 33.5 | 10.7 | 4.4 | 100.0 |
| 1965 | 51.1 | 31.8 | 11.4 | 5.7 | 100.0 |
| 1966 | 53.2 | 28.0 | 13.2 | 5.7 | 100.0 |
| 1967 | 53.4 | 31.0 | 12.0 | 3.5 | 100.0 |

SOURCES: Science Council table
[1]D.B.S. special table, summer 1969.
NOTE: Figures may not add to totals shown because of rounding.

# CHART 5 ILLUSTRATING TABLE 6

TOTAL NATIONAL R&D EXPENDITURES BY SOURCE OF FUNDING IN CANADA, 1957 - 1967

*"Since 1963, the shares of the three main sources of funding have remained remarkably stable".*

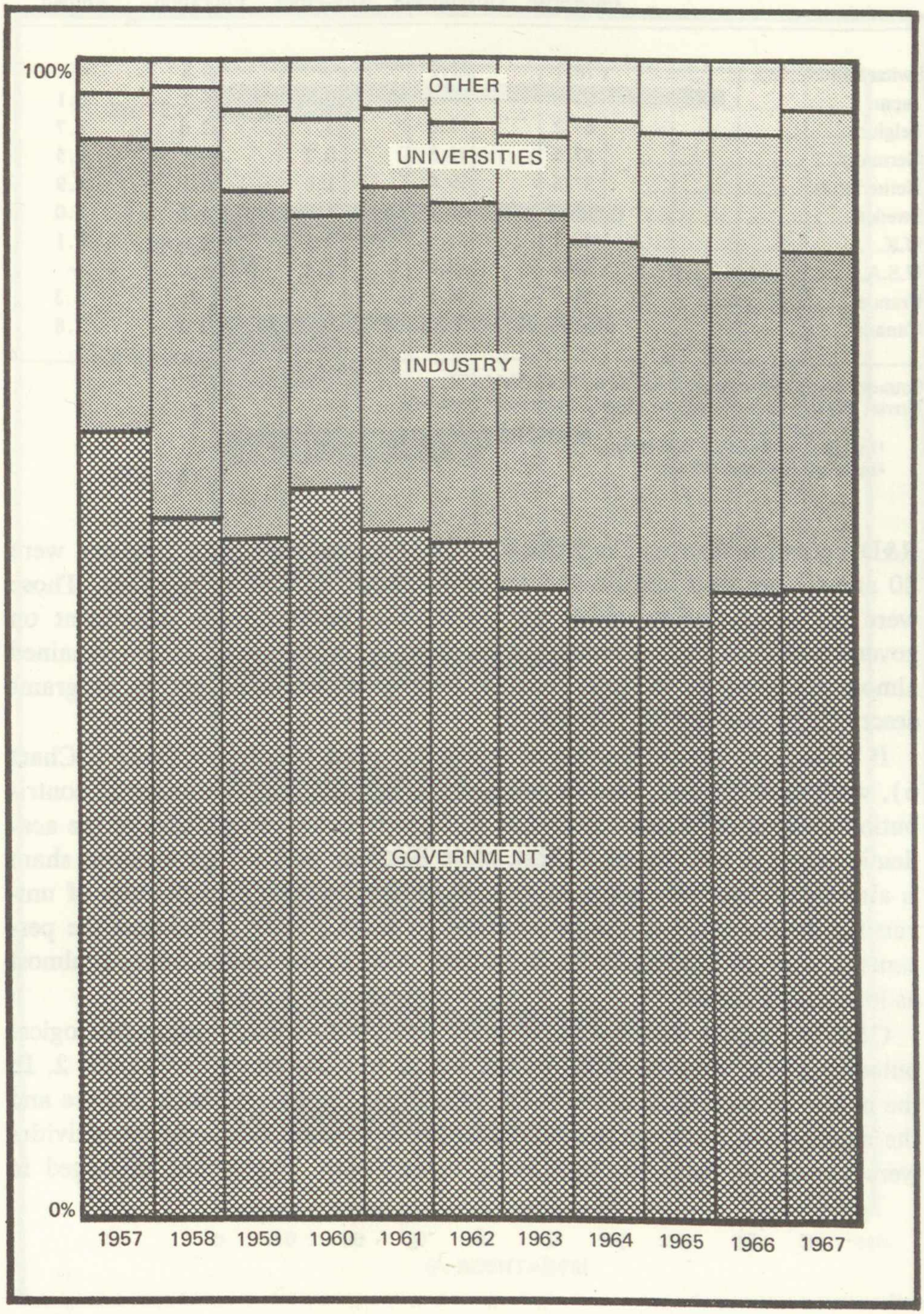


*Table 7—Distribution of National R & D Expenditures by Source of Funding and Country, 1967*

(Percentages)

| | Business Enterprise | Government | Private Non-Profit | Higher Education | Abroad |
|---|---|---|---|---|---|
| Switzerland | 78.1 | 21.1 | — | 0.8 | — |
| Japan | 62.8 | 30.2 | 0.8 | 6.1 | 0.1 |
| Belgium | 61.2 | 18.8 | 3.7 | 12.6 | 3.7 |
| Germany | 57.5 | 41.3 | 0.7 | — | 0.5 |
| Netherlands | 57.5 | 39.0 | 1.8 | 0.1 | 1.9 |
| Sweden | 55.1 | 42.1 | 1.7 | 0.2 | 1.0 |
| U.K. | 42.1 | 51.3 | 2.9 | 0.6 | 3.1 |
| U.S.A. | 32.8 | 62.7 | 1.4 | 3.0 | — |
| France | 31.8 | 64.9 | [1] | [2] | 3.3 |
| Canada | 31.0 | 53.4 | 0.8 | 12.0 | 2.8 |

SOURCE: OECD Document DAS/SPR/70.48, Table III.
NOTES: Figures may not add to 100.0% because of rounding.
—indicates nil.
[1]Included in Business Enterprise.
[2]Included in Government.

R&D activities. During the same period, the percentages for industry were 80 and 82 per cent and for the academic sector 55 and 45 per cent. Those were the years during which the universities became more dependent on government financing, whereas the situation in the industrial sector remained almost unchanged, in spite of the new government incentive programs described at the end of Chapter 5.

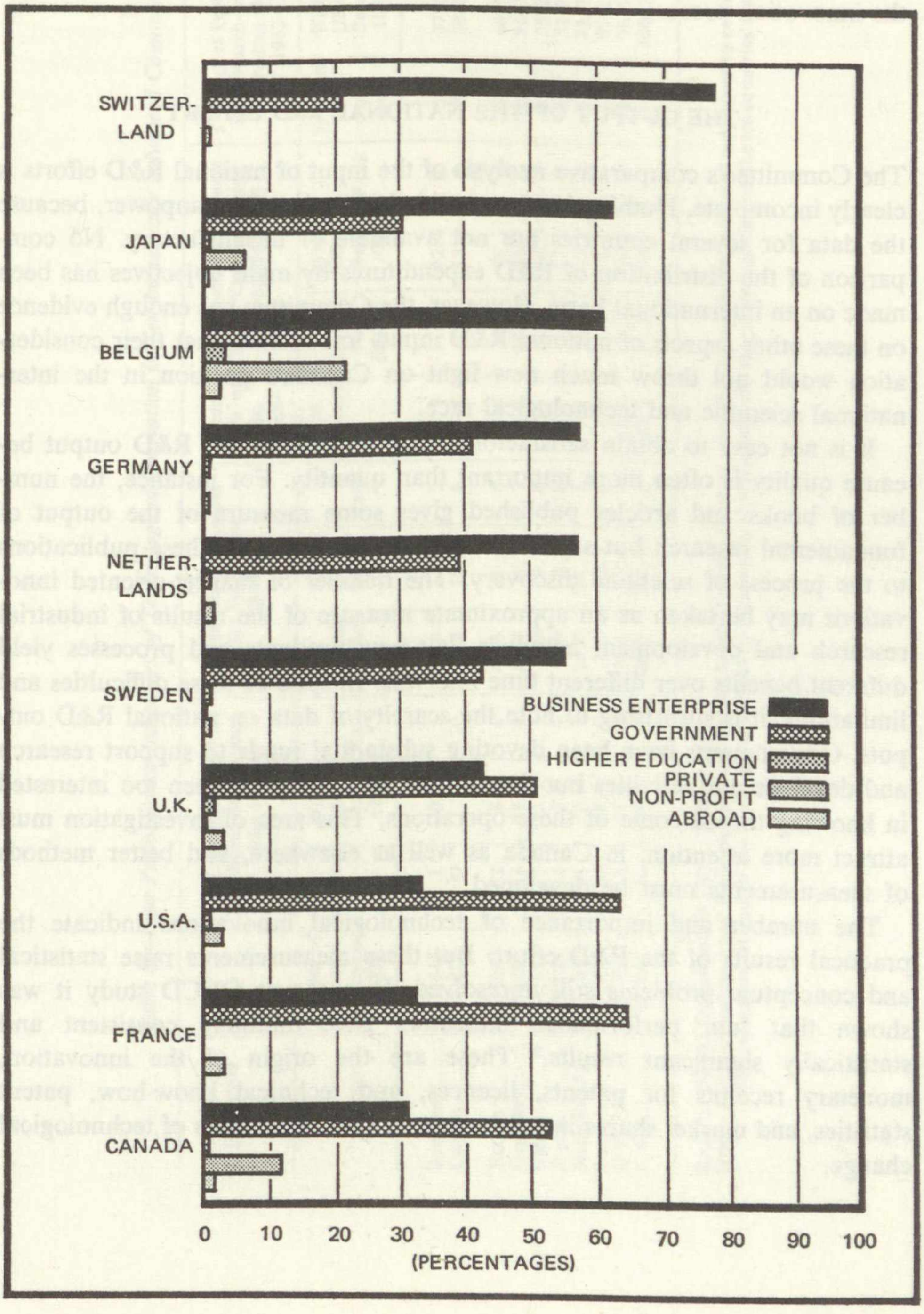
If we look at the distribution of funding in other countries (Table 7, Chart 6), we find again that Canada holds a special position. The financial contribution made by business enterprises in Canada is the lowest, that of the academic sector is the second highest, after Belgium, and the government share is also high, especially when we note that in France the contribution of universities is attributed to the government. It must also be noted that the percentage share of funding by the industrial sector in the United States is almost as low as in Canada.

Canada's unique distribution of R&D effort is to a large extent the logical outcome of the original NRC model which was described in Chapter 2. In the model he presented in 1919, Dr. Macallum emphasized basic science and the necessity to train "an army of scientists", whereas development activities were viewed as being of "ephemeral value" only. The model envisaged in

## CHART 6 ILLUSTRATING TABLE 7

**TOTAL NATIONAL R&D EXPENDITURES BY SOURCE OF FUNDING AND COUNTRY IN 1967 (PERCENTAGES)**

***"Canada not only plays a subordinate role in the technology race but stands aside as well in maintaining a pattern remote from the innovative process."***



1919 still prevails. Canada is contributing relatively generously to the international pool of knowledge, both through government research and university research, but we have neglected to develop our own innovations. In the light of international comparisons, we must conclude that Canada not only plays a subordinate role in the technology race, but stands aside as well from the innovation process.

## THE OUTPUT OF THE NATIONAL R&D EFFORT

The Committee's comparative analysis of the input of national R&D efforts is clearly incomplete. Nothing has been said about scientific manpower, because the data for several countries are not available or unsatisfactory. No comparison of the distribution of R&D expenditures by main objectives has been made on an international basis. However, the Committee has enough evidence on these other aspects of national R&D inputs to conclude that their consideration would not throw much new light on Canada's position in the international scientific and technological race.

It is not easy to obtain satisfactory measurements of the R&D output because quality is often more important than quantity. For instance, the number of books and articles published gives some measure of the output of fundamental research but says nothing about the value of these publications to the process of scientific discovery. The number of market-oriented innovations may be taken as an approximate measure of the results of industrial research and development activities, but new products and processes yield different benefits over different time intervals. In spite of these difficulties and limitations, it is surprising to note the scarcity of data on national R&D outputs. Governments have been devoting substantial funds to support research and development activities but they do not seem to have been too interested in knowing the outcome of these operations. This area of investigation must attract more attention, in Canada as well as elsewhere, and better methods of measurements must be developed.

The number and importance of technological innovations indicate the practical results of the R&D effort. But these measurements raise statistical and conceptual problems still unresolved. In a recent OECD study it was shown that four performance indicators gave mutually consistent and statistically significant results.[3] These are the origin of the innovation, monetary receipts for patents, licences, and technical know-how, patent statistics, and market shares in product areas with rapid rates of technological change.

*Table 8—Four Performance Indicators of Technological Innovation in Ten Industrially Advanced Countries*

| Indicators | | I. Location of 100 Significant Innovations since 1945 | | | II. Monetary Receipts for Patents etc., 1963-64 | | | Percent Share of Ten Coun-tries' Mfd. Exports | III. Number of Patents Taken Out in Foreign Countries, 1963 | | | IV. Export Performance in Research-Intensive Product Groups 1963-65 | | | Com-posite Rank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Country | Number of Industrial Employees ['000] | Absolute No. | With USA Base 100 | Rank | Absolute $ million | With USA Base 100 | Rank | | Absolute No. [000's] | With USA Base 100 | Rank | % share of 10 coun-tries | With USA Base 100 | Rank | |
| Belgium | 1,645 | 1 | 20.6 | 5 | 7.9 | 34.2 | 5 | 5.8 | 1.8 | 12.4 | 10 | 3.0 | 37.6 | 10 | 8 |
| Canada | 2,428 | 0 | 0 | 10 | 6.2 | 18.3 | 8 | 5.5 | 1.9 | 13.9 | 9 | 2.0 | 38.3 | 9 | 10 |
| France | 7,940 | 2 | 8.5 | 8 | 46.3 | 41.9 | 4 | 9.8 | 9.3 | 38.1 | 6 | 6.5 | 48.2 | 8 | 6 |
| Germany | 12,385 | 14 | 38.3 | 4 | 49.4 | 28.7 | 7 | 18.1 | 29.9 | 64.7 | 2 | 21.1 | 84.7 | 2 | 3= |
| Italy | 7,776 | 3 | 13.2 | 7 | 9.9 | 9.1 | 9 | 7.5 | 4.6 | 24.6 | 7 | 5.7 | 55.2 | 6 | 7 |
| Japan | 17,129 | 4 | 7.9 | 9 | 5.9 | 2.4 | 10 | 8.1 | 3.5 | 17.4 | 8 | 5.9 | 52.9 | 7 | 9 |
| Netherlands | 1,847 | 1 | 18.3 | 6 | 26.0 | 101.2 | 1 | 5.9 | 6.4 | 43.6 | 5 | 5.9 | 72.7 | 5 | 5 |
| Sweden | 1,535 | 4 | 88.4 | 2 | 7.1 | 33.3 | 6 | 3.5 | 3.8 | 43.7 | 4 | 4.0 | 83.1 | 3 | 3= |
| U.K. | 11,798 | 18 | 51.8 | 3 | 76.1 | 46.4 | 3 | 13.2 | 15.2 | 45.2 | 3 | 13.9 | 76.5 | 4 | 2 |
| U.S.A. | 25,063 | 74 | 100.0 | 1 | 386.7 | 100.0 | 2 | 22.6 | 56.3 | 100.0 | 1 | 31.1 | 100.0 | 1 | 1 |

SOURCE: OECD Document SP (70) 1, Table A. 1

NOTE: For indicators I and II the ranking was derived by dividing the absolute values by the number of industrial employees to correct for country size. For indicators III and IV the ranking was derived by dividing the absolute values by the percentage share of the ten countries' manufactured exports.

As indicated by Table 8, Canada's performance in market-oriented innovation ranks among ten industrially advanced countries. To the extent that these criteria are meaningful, they justify the "cheap Japanese imitations" argument given to explain Japan's success on world markets. They also substantiate the statement already quoted from the Japanese Science and Technology Agency, that Japan puts too much emphasis on research but "is far behind the other advanced countries in the field of development." The agency's report also states that "while we depended on imported technology, we have been remiss in creating our own original technology, and not exerting fully to develop our technology by ourselves." This criticism applies to Canada also. Canadians also have been imitators but, unlike the Japanese, their imitations have been largely confined to the domestic market.

The low practical output of the Canadian R&D effort is also reflected in the patent statistics shown in Table 9, Chart 7. During the period 1964-70, the average number of patents issued in Canada was 26,170 per year. Of these, 66 per cent were granted to US residents, 29 per cent to residents of other countries and only 5 per cent to Canadian citizens. In the period 1964-69 more Canadian patents were granted each year to residents of Germany, France, Switzerland, and the Netherlands—about 3,300 a year—than to Canadian citizens, who on average received 1,330 a year.

These results are particularly disappointing in the light of the relatively large professional labour force engaged in R&D activities in Canada (Table 10, chart 8). Canada's share of qualified scientists and engineers engaged in R&D, as a percentage of total labour force, is much lower than the American ratio, and probably lower than the French ratio. Nevertheless, this

*Table 9—Canadian Patent Statistics, 1964-1970*

| Year | Number of Patents Issued | Residence of Inventor Granted Patent | | | |
|---|---|---|---|---|---|
| | | Canada | U.K. | U.S.A. | Other |
| 1964-65 | 23,451 | 1,116 | 1,936 | 15,951 | 4,448 |
| 1965-66 | 24,241 | 1,131 | 2,000 | 16,274 | 4,836 |
| 1966-67 | 24,432 | 1,222 | 1,769 | 16,614 | 4,827 |
| 1967-68 | 25,836 | 1,263 | 1,862 | 17,583 | 5,128 |
| 1968-69 | 27,703 | 1,433 | 2,013 | 18,542 | 5,715 |
| 1969-70 | 31,360 | 1,814 | 2,263 | 18,702 | 8,581 |
| Average | 26,170 | 1,330 | 1,974 | 17,278 | 5,589 |
| % Distribution | 100% | 5% | 7.5% | 66% | 21.5% |

SOURCE: Annual Reports, Patent and Copyright Office

# CHART 7 ILLUSTRATING TABLE 9

CANADIAN PATENT STATISTICS, 1964 - 1970

*"On average . . . 66% were granted to US residents, 29% to residents of other countries and only 5% to Canadian citizens."*

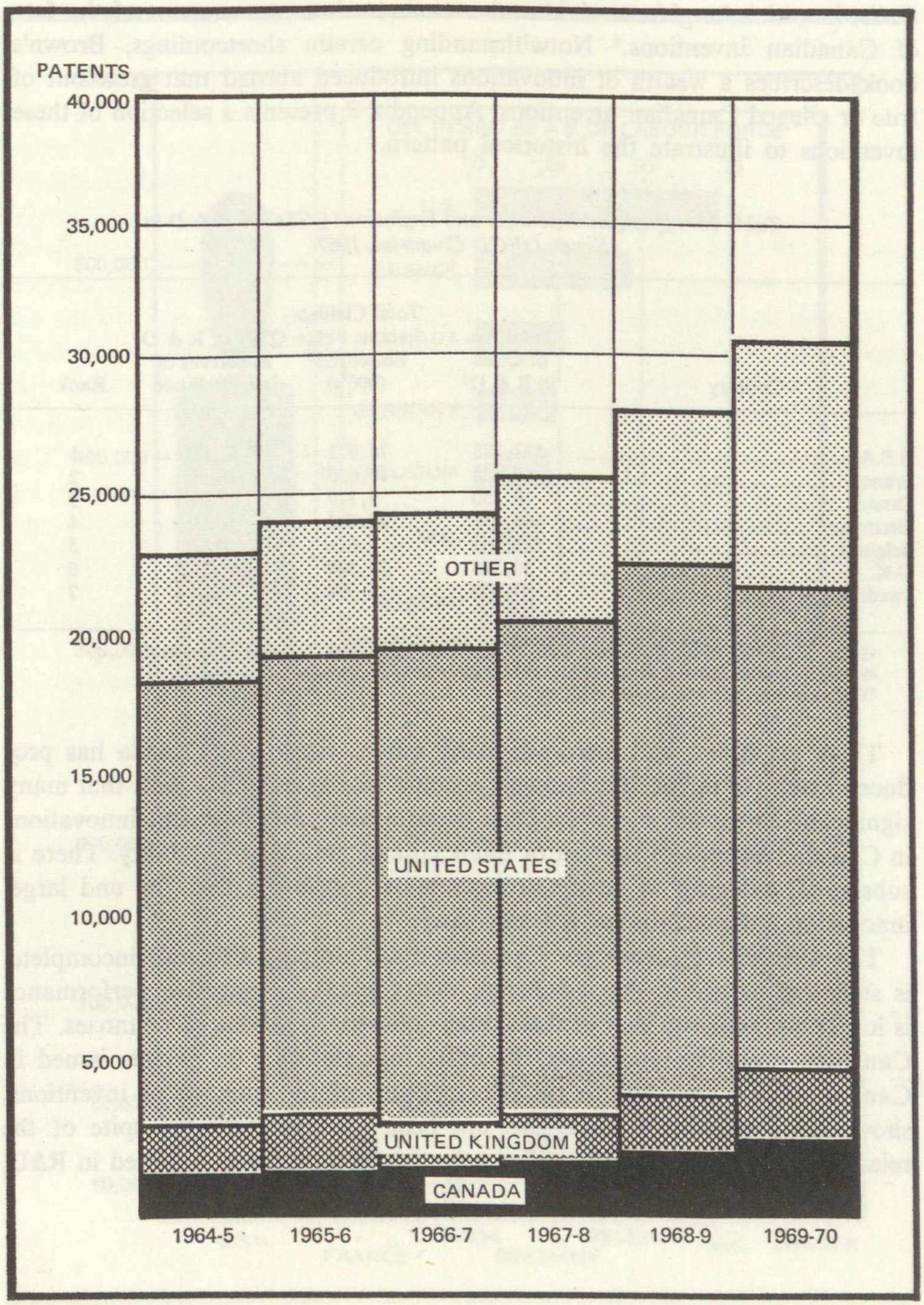


table shows that Canada is among the top three OECD countries as far as the relative number of qualified scientists and engineers engaged in R&D is concerned, yet we are at the bottom of the list when it comes to innovative performance, as is shown in Table 8.

In 1967, J. J. Brown published a book with a suggestive title, *Ideas in Exile*, in which he gives a vivid and sometimes dramatic account of the fate of Canadian inventions.[4] Notwithstanding certain shortcomings, Brown's book describes a wealth of innovations introduced abroad that grew out of true or alleged Canadian inventions. Appendix 2 presents a selection of these inventions to illustrate the historical pattern.

*Table 10—Qualified Scientists and Engineers (QSEs) in R & D in Seven OECD Countries, 1967*

| Country | Total No. of QSEs in R & D[1] | Total Civilian Labour Force Employed[2] (000's) | QSEs in R & D as percent of Labour Force | Rank |
|---|---|---|---|---|
| U.S.A. | 537,273 | 74,372 | 0.72 | 1 |
| France | 49,224 | 10,620[3] | 0.46 | 2 |
| Canada | 19,350 | 7,379 | 0.26 | 3 |
| Germany | 61,559 | 25,803 | 0.24 | 4 |
| Belgium | 7,945 | 3,616 | 0.22 | 5 |
| U.K. | 50,345 | 24,509 | 0.21 | 6 |
| Sweden | 7,395 | 3,734 | 0.20 | 7 |

[1]Source: OECD, 1970, Document DAS/SPR/70.48, Table VIII (full-time equivalent)
[2]Source: International Labour Office, *1969 Yearbook of Labour Statistics*, pp. 292-312.
[3]Estimate only, includes government service.

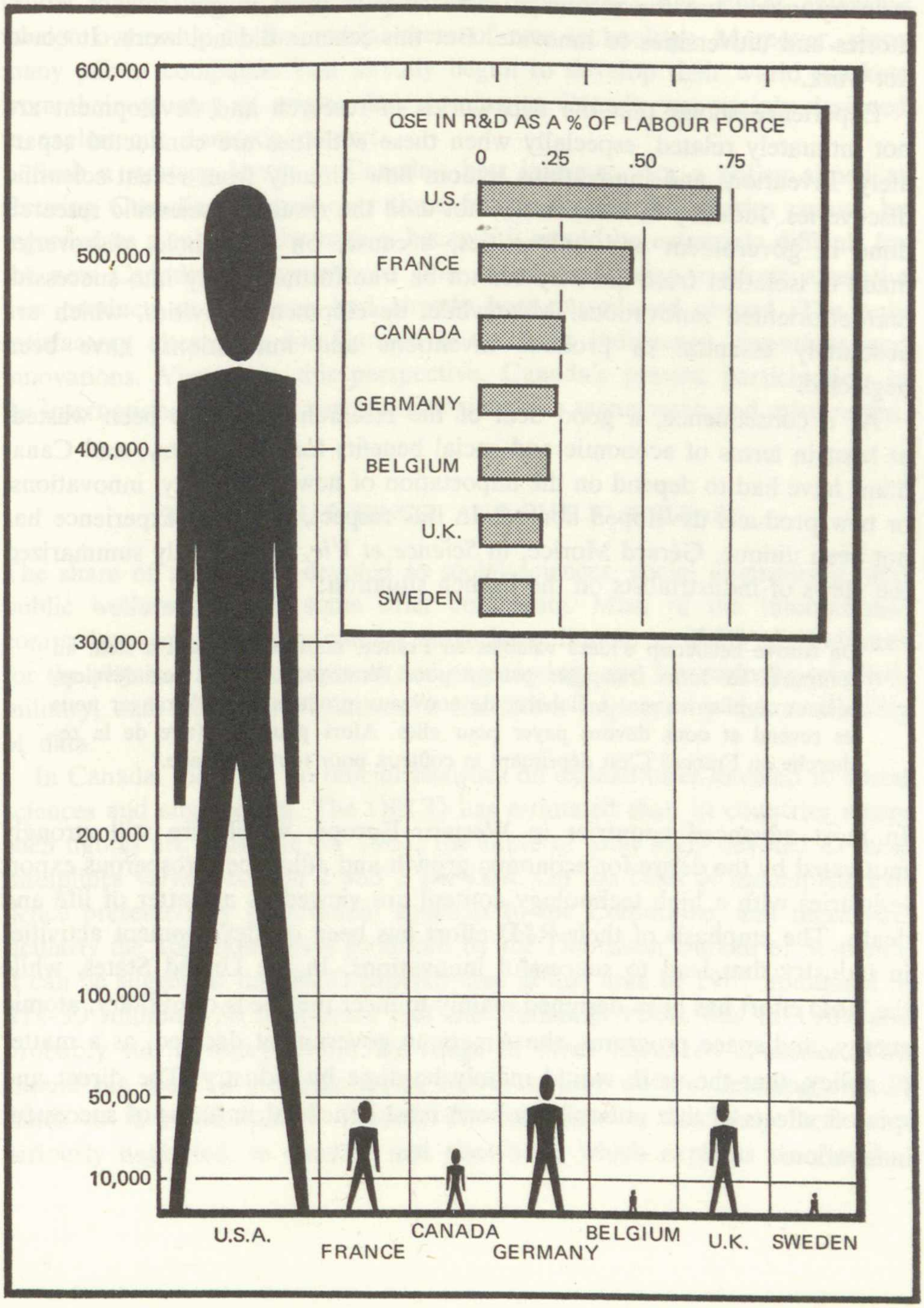
These examples, and there are many others, show that Canada has produced inventive talent. Yet Brown's account leaves the impression that many significant inventions have not been transformed into successful innovations in Canada, for lack of interest or financial and industrial capability. There is substantial evidence to justify Brown's main conclusion that "by and large, innovation in Canada is not a happy story."[5]

The available evidence on Canadian R&D output, although incomplete, is sufficient to justify the conclusion that Canada's innovative performance is low compared with that of most other industrially advanced countries. The Canadian inventive record may be better but statistics on patents issued in Canada, which constitute a reliable measure of the number of inventions, show that even here Canada has not been too successful, in spite of the relatively large number of qualified scientists and engineers engaged in R&D.

# CHART 8 ILLUSTRATING TABLE 10

QUALIFIED SCIENTISTS AND ENGINEERS (QSE) IN R&D IN 7 OECD COUNTRIES (1967)

*"(The) results are particularly disappointing in the light of Canada's large professional labour force engaged in R&D activities . . . We are at the bottom of the list when it comes to innovative performance."*



This situation is not surprising. It simply means that the R&D output is proportionate to the input. The emphasis has been on research in government laboratories and in universities, rather than on development in industry. Innovative capacity cannot be developed under such conditions. The senior government officials who formulated Canada's science policy expected that industry would use the results of research performed in government laboratories and universities to innovate. But this scheme did not work. It could not work.

Experience shows that the two worlds of research and development are not intimately related, especially when these activities are conducted separately. Inventions and innovations seldom flow directly from recent scientific discoveries. Industry in Canada has not used the results of scientific research done in government and universities, because, on the whole, discoveries made in isolation from industry cannot be transformed easily into successful market-oriented innovations. Meanwhile, development activities, which are absolutely essential to produce inventions and innovations, have been neglected.

As a consequence, a good deal of the research effort has been wasted, at least in terms of economic and social benefits for the country, and Canadians have had to depend on the importation of new technology, innovations, or new products developed abroad. In this respect, Canada's experience has not been unique. Gérard Morice, in *Science et Vie,* has recently summarized the views of industrialists on the French situation:

> On trouve beaucoup d'idées valables en France, mais cela ne sert à rien, au contraire: les idées françaises partent pour l'étranger où elles sont développées et où elles servent à élaborer de nouveaux produits, puis l'étranger nous les revend et nous devons payer pour elles. Alors pourquoi faire de la recherche en France? C'est déprimant et coûteux pour tout le monde.[6]

In most advanced countries in Western Europe, which are still strongly motivated by the desire for economic growth and affluence, prosperous export industries with a high technology content are viewed as a matter of life and death. The emphasis of their R&D effort has been on development activities in industry that lead to successful innovations. In the United States, while the R&D effort has been designed mainly to meet the needs of military, atomic energy, and space programs, the American government decided, as a matter of policy, that the work would mainly be done by industry. The direct and spin-off effects of that policy have been most beneficial in terms of successful innovations.

In Japan, where the R&D effort seems to have been misguided, this deficiency was compensated by "cheap imitations" quickly introduced on world markets. Canada too has depended on imported innovations. In many cases, however, they were introduced not by Canadians but by firms already fabricating the new products or using the new processes abroad, especially in the United States. For Canada, this dependence has meant extensive foreign ownership in the crucial areas of new technology. Moreover, since many parent companies had already begun to develop their world markets from their country of origin, their coming to Canada was mainly designed to exploit our domestic market.

Such a strategy is not in Canada's best interests. But a policy aimed at securing Canadian control over these foreign-owned subsidiaries cannot be regarded as a suitable alternative, because it would be extremely difficult for the new Canadian companies to gain access to foreign markets after the new products or processes had already been introduced abroad. The only satisfactory alternative for Canada is to foster indigenous inventions and innovations. Viewed in this perspective, Canada's present participation in the international scientific and technological race seems weak and misdirected.

### THE SOCIAL SCIENCES AND PUBLIC WELFARE

The share of total R&D devoted to social sciences, social engineering, and public welfare deserves some brief comments. Most of the international comparisons made in this chapter have been limited to R&D expenditures for the physical and life sciences and engineering, and for curiosity-oriented, military, and industrial objectives, a limitation imposed by the availability of data.

In Canada, there are no official statistics on expenditures devoted to social sciences and engineering. The OECD has estimated that, in countries where such figures are available for 1967, the share of total R&D devoted to these disciplines varies between 2 and 3 per cent. On the basis of incomplete evidence presented by government agencies to the Committee, and more particularly the approximations produced by the Dominion Bureau of Statistics, it can be suggested that R&D expenditures in this area in 1967 amounted to $24-30 millions. So it appears that the Canadian effort was in 1967 and probably still is today within the range of other advanced countries. This should not lead to the conclusion, however, that we are devoting enough funds to these disciplines. Indeed, the consensus is that they have been seriously neglected, in Canada and elsewhere, which explains their underdeveloped condition and our lack of understanding of the true nature and dimensions of our social problems. The Committee will have more to say about this evident and regrettable gap in knowledge in Volume II.

The same comments apply to the R&D effort devoted to public welfare or to the problems related to the quality of life, such as health, education, urban living, pollution, poverty, labour unrest, leisure, and adaptation to accelerating change. The OECD has just begun to publish data on national R&D efforts in these areas but they are still too incomplete to justify international comparisons. While Canada is probably not in a worse situation than other countries, the tragic fact remains that so-called advanced societies have devoted only a negligible portion of their R&D effort to identifying, defining, and solving these complex problems which threaten their very survival. We are just beginning to realize in the West that collective affluence does not necessarily mean happiness and that collective problems will not be solved satisfactorily simply by spending huge sums of money. A much larger and better organized R&D effort will be needed to provide a more adequate knowledge of these urgent difficulties and more effective solutions. The Committee will also have specific recommendations to make about this vital R&D area in Volume II.

### CANADA'S SPECIAL POSITION AND THE HIDDEN SCIENCE POLICY

International comparisons of various advanced countries' R&D input and output show that Canada is in a special position:

(1) Table 3 shows that Canada devotes 61 per cent to scientific research and only 39 per cent to technological development. The proportions are reversed in the United States, the United Kingdom, Sweden, and Switzerland.

(2) Table 5 indicates that Canada relies more heavily on the academic sector as a performer of research than do other advanced countries —about 25 per cent of total R&D—and as Tables 4 and 6 show, the government directly finances close to half of that effort. This large share of government support, added to substantial amounts devoted to scholarships and fellowships, fits the model intended to produce a growing supply of well-trained scientists.

(3) Table 5 also shows that in Canada the government performs a larger share of R&D than in any other advanced country. The academic and the government sectors perform together more than 60 per cent

of R&D activities while most other countries rely mainly on the business enterprise sector to carry out R&D. The Canadian situation, which is again a reflection of the 1919 model, is logical and consistent; it corresponds to the heavy emphasis on scientific research rather than technological development.

(4) The Canadian government finances a much lower proportion of extramural R&D activities than do most other governments. This is shown in Table 11 and Chart 9, which shows the proportion of government financing to government performance of R&D in 1967. While the Canadian government devotes only one third of its R&D budget to supporting R&D activities in the industrial and academic sectors, in several other countries governments devote two to three times as much to the financing of extramural activities as to the funding of their own intramural programs. Again this corresponds to the Canadian model, which called for the establishment and expansion of government laboratories to provide employment opportunities for the scientists who could not find jobs in universities.

(5) A substantial share of the support given by the Canadian government to extramural activities is allocated to the academic sector. As a result, the industrial sector, which puts the emphasis on technological development rather than scientific research, has had to try to be self-supporting and has remained relatively weak. Its weakness as a performer is clearly shown in Table 5. Its degree of financial self-sufficiency is indicated in Table 12 and Chart 10, where the national ratios of funding to performance for the industrial sectors of the ten countries are presented.

*Table 11—Total Government Funding as a Percentage of R & D Performance by Government, by Country, 1967*

| | |
|---|---|
| Netherlands | 1444 |
| Germany | 810 |
| U.S.A. | 432 |
| Switzerland | 335 |
| Sweden | 296 |
| Japan | 232 |
| U.K. | 207 |
| France | 202 |
| Belgium | 181 |
| Canada | 150[1] |

SOURCE: Tables 5 and 7

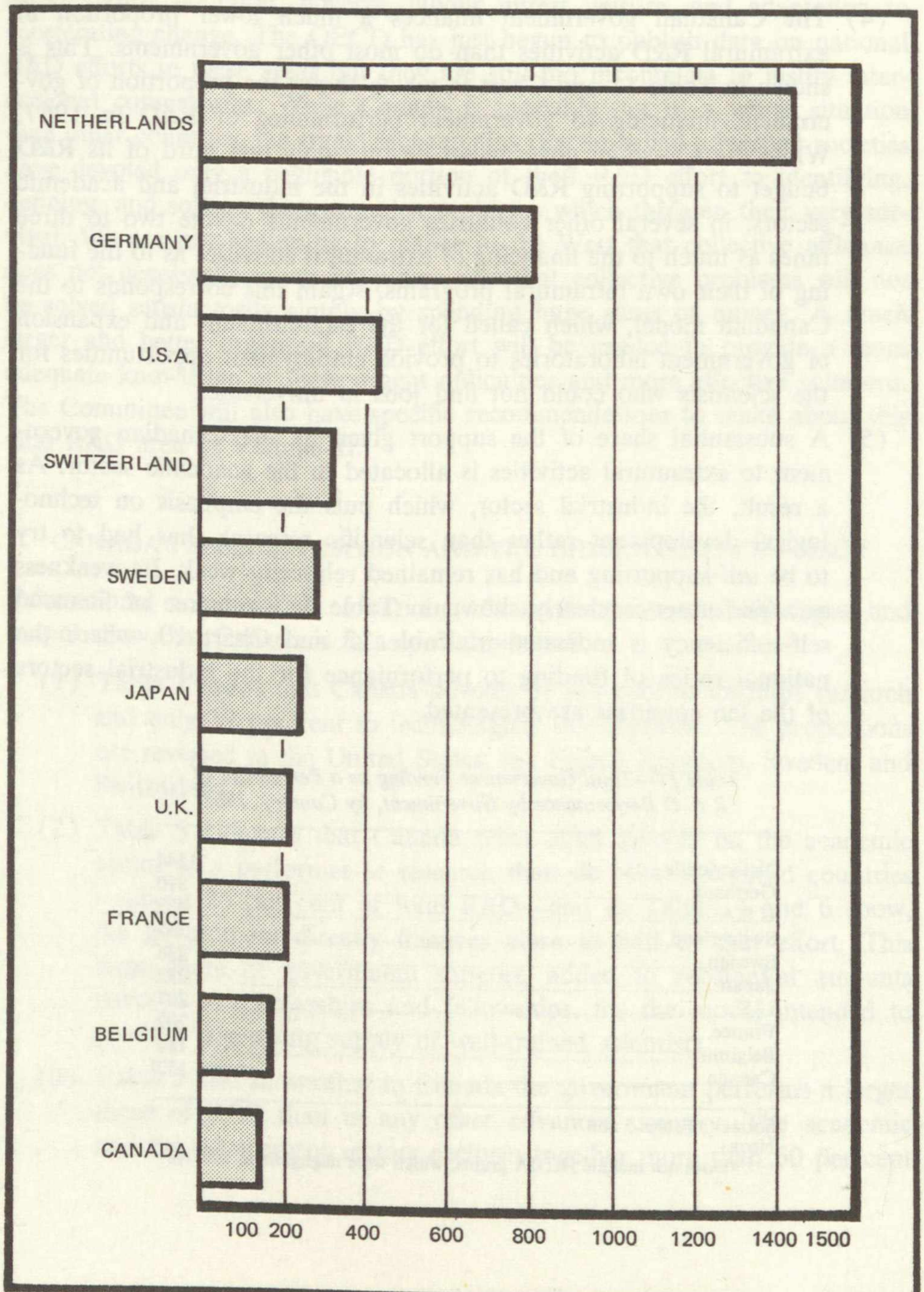
NOTE:

[1]Does not include IRDIA grants, which were negligible in 1967-68

# CHART 9 ILLUSTRATING TABLE 11

TOTAL GOVERNMENT FUNDING AS A PERCENTAGE OF R&D PERFORMANCE
BY GOVERNMENT AND BY COUNTRY IN 1967

*"The Canadian government finances a much lower proportion of extra-mural R&D activities than do most other governments."*





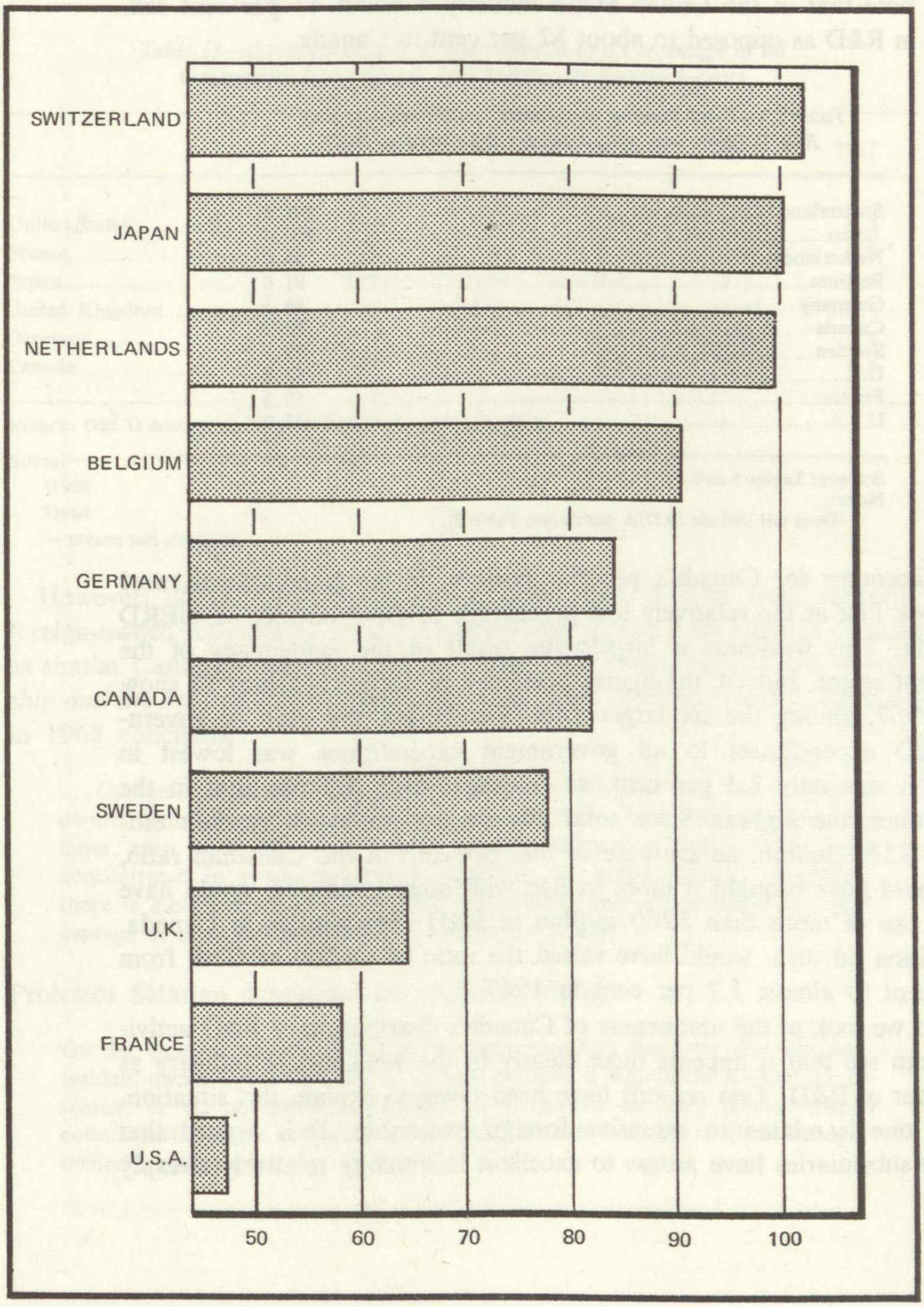

SOURCE TABLES 5 AND 7

## CHART 10 ILLUSTRATING TABLE 12

TOTAL FUNDING BY INDUSTRY AS A PERCENTAGE OF R&D PERFORMANCE

BY INDUSTRY, BY COUNTRY IN 1967

*"Canadian industry pays for the major portion of its R&D activities."*




SOURCE TABLES 5 AND 7

Here Canada appears to be between two worlds. As in the United States and France, the Canadian industrial sector pays for about one-third of the national R&D effort, as shown in Table 7. But in contrast with these two and as in other countries, Canadian industry pays for the major portion of its own R&D activities. This is indicated by Table 12, Chart 10. It is interesting to note that in the United States industry is about 47 per cent self-sufficient in R&D as opposed to about 82 per cent in Canada.

*Table 12—Total Funding by Industry as a Percentage of R & D Performance by Industry, by Country, 1967*

| | |
|---|---|
| Switzerland | 102.1 |
| Japan | 100.4 |
| Netherlands | 99.0 |
| Belgium | 91.6 |
| Germany | 84.3 |
| Canada | 82.2[1] |
| Sweden | 78.7 |
| U.K. | 64.8 |
| France | 58.6 |
| U.S.A. | 47.0 |

SOURCE: Tables 5 and 7
NOTE:
[1]Does not include IRDIA grants (see Table 2).

What accounts for Canada's peculiar position in the international race? Let us look first at the relatively low percentage of GNP devoted to GERD in Canada. This weakness is largely the result of the inadequacy of the government sector. Indeed, the figures presented in Table 13, Chart 11 show that in 1967, among the six larger OECD countries, the ratio of government R&D expenditures to all government expenditures was lowest in Canada. It was only 2.3 per cent, as compared with 5.7 per cent in the United States, the highest. Since total government outlays were then estimated at $21.1 billion, an increase of one per cent in the Canadian ratio, which would have brought it more in line with other countries, would have meant a rise of more than $200 million in R&D expenditures in Canada. This addition, in turn, would have raised the ratio of GERD to GNP from 1.4 per cent to almost 1.7 per cent in 1967.

Now, if we look at the uniqueness of Canada's distribution of R&D activities, we can see that it appears most clearly in the weakness of industry as a performer of R&D. Two reasons have been given to explain this situation. The first one is related to extensive foreign ownership. It is argued that Canadian subsidiaries have access to excellent technology relatively cheaply from their parent companies and therefore do not need to sustain a large R&D effort of their own. Professor A. E. Safarian of the University of Toronto has shown that in 72 per cent of the Canadian subsidiaries he studied, "spending on research and development as a percentage of sales was considerably less than in their foreign parent firms."[7]

*Table 13—Government R & D Expenditures as a Percentage of all Government Expenditures, by Country, for Specified Years*

| | 1959 | 1961 | 1963 | 1965 | 1967 |
|---|---|---|---|---|---|
| United States | 5.9 | 6.0 | 6.5 | 6.6 | 5.7 |
| France | 2.2 | 2.6 | 2.8 | 3.6 | 3.9 |
| Japan | 2.7[1] | 3.0 | 3.0 | 3.7 | 3.5 |
| United Kingdom | — | 4.2 | — | 3.4[2] | 3.1 |
| Germany | — | 1.7 | 2.0 | 2.3 | 2.4 |
| Canada | 1.8 | — | 1.8 | 2.1 | 2.3 |

SOURCE: OECD document, DAS/SPR/70.31, August 17, 1970

NOTES:
[1]1960
[2]1964
— means not available

However, all the available evidence shows that at least until recently, foreign-owned subsidiaries spent proportionately as much on R&D in Canada as similar Canadian companies, if not more. The report on *Foreign Ownership and the Structure of Canadian Industry* (The Watkins report) published in 1968 concluded:

> . . . Comparisons of the research performance of foreign-owned and Canadian-owned firms suggest that the former do relatively more research than the latter, even when allowance is made for the tendency of foreign firms to be concentrated in research-oriented industries. By broad industry groupings, there is clear evidence of a positive relationship between research as a percentage of sales and the degree of foreign ownership.[8]

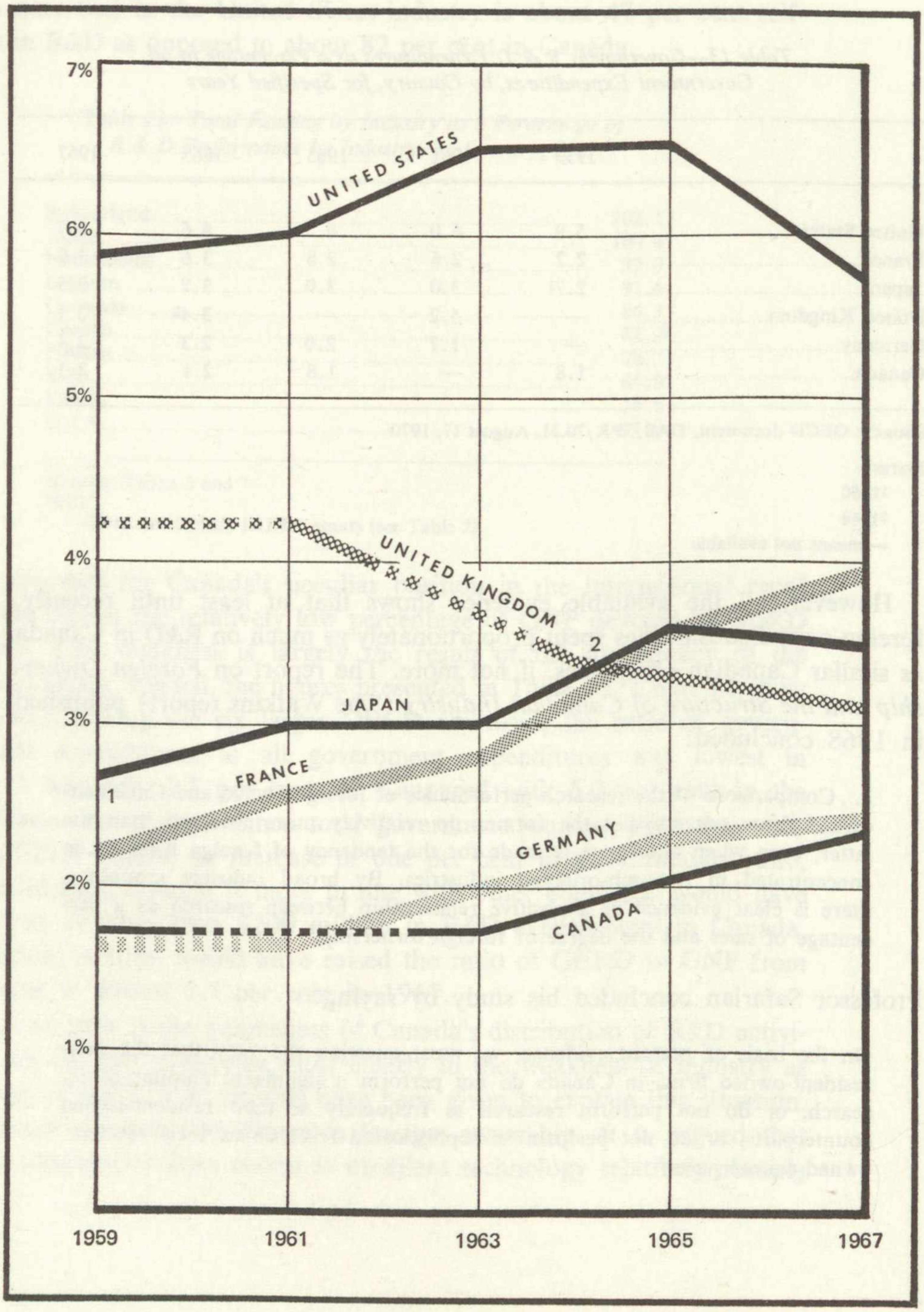
Professor Safarian concluded his study by saying:

> On the basis of present evidence, we must question the view that the non-resident-owned firms in Canada do not perform a significant amount of research, or do not perform research as frequently as their resident-owned counterparts, or do not perform as sophisticated research as their resident-owned counterparts.[9]

# CHART 11 ILLUSTRATING TABLE 13

GOVERNMENT R&D EXPENDITURES AS A PERCENTAGE OF ALL GOVERNMENT EXPENDITURES, BY COUNTRY FOR SPECIFIED YEARS

*". . . the relatively low percentage of GNP devoted to GERD in Canada . . . is accounted for in large measure by the inadequacy of the government sector."*






1) 1960
2) 1964

And the OECD report on Canada's science policy compared the 100 most important firms in Canada and concluded:

> The R&D expenditure can be expressed in a series of ratios: in relation to turnover, to assets and to profits. These three ratios agree. Firms under non-Canadian financial control quite definitely spend more on R&D than the Canadian firms. Secondly, there is hardly any difference between the behaviour of firms under United States control and those controlled by other non-residents. Both of these categories spend something like one-sixth of their profits on R&D as against only one-thirteenth in the case of Canadian firms.[10]

More recent and complete statistics covering 326 foreign firms tend to show, however, that this situation is now changing. They are presented in Table 14. By subtracting the estimated total R&D expenditures of foreign subsidiaries from the national totals reported in DBS Catalogues 13-527 and 13-532, we can also deduce that R&D outlays by Canadian firms have been multiplied about 3½ times recently, from approximately $32 million in 1964 to approximately $113 million in 1968.[11]

*Table 14—Research Intensity in Canada by 326 Foreign-Owned Subsidiaries: R & D Expenditures as a Percentage of Sales*

| | 1964 | 1967 | 1968[1] |
|---|---|---|---|
| | (millions of dollars) | | |
| Total Sales | 15,342 | 20,742 | 22,484 |
| Current Expenditures on Research and Development (excl. salaries and wages) | | | |
| —Total | 98 | 120 | 109 |
| —Abroad | −10 | −14 | −15 |
| —in Canada | 88 | 106 | 94 |
| R & D salaries and wages in Canada[2] | 90 | 128 | 111 |
| Total R & D in Canada Current Expenditures | 178 | 234 | 205 |
| Research Intensity in Canada | | | |
| —excl. salaries | 0.58% | 0.51% | 0.42% |
| —incl. salaries | 1.16% | 1.13% | 0.91% |

SOURCE: Department of Industry, Trade and Commerce, 1970: Foreign-owned Subsidiaries in Canada, Summary Tables 2, 6 and 17.

[1]Courtesy Department of Industry, Trade and Commerce, Corporation Returns Division.

[2]Estimated from ratios of total current expenditures and wages derived from DBS Catalogues No. 13-527 and 13-532. Some of the reported R & D expenditures may already include salaries and wages. The total figures shown in this table are therefore approximations only.

We would like to know the causes of these two recent and opposite developments. Are they attributable to the discriminatory aspects of the new government incentive programs, which require that the results of publicly supported projects be used in Canada? If so, that would also explain why these programs do not seem to have induced any increase in R&D funding by the industrial sector as a whole. In any case, the significant decline in the research intensity of Canadian subsidiaries in 1968 cannot account for the weakness of industry as a sector of performance before 1968.

It has been argued as another explanation of this situation that Canada has remained less industrialized than other countries and that Canadians have chosen an extensive rather than intensive growth pattern, based on the exploitation of natural resources. Such a pattern, it is claimed, calls for relatively more government effort. This contention can be referred to as "the hewers of wood and drawers of water" argument.

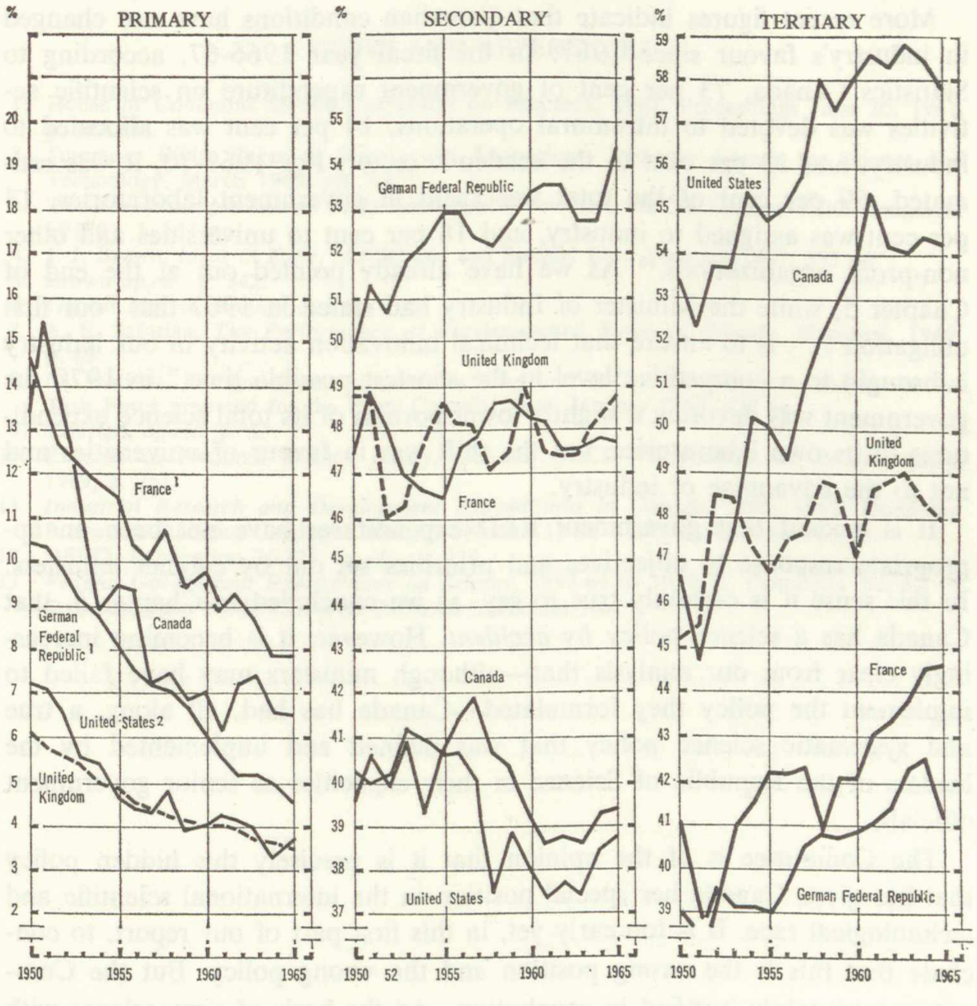
Such reasoning, even if it gave a true description of Canada's development, is not supported by our relative emphasis on fundamental research and the great importance of the academic sector as a performer and a source of funding of R&D, as compared with other advanced countries. But even the description on which this argument is based is no longer true. There is a revealing graph in the OECD report on Canada's science policy.[12] It shows the evolution between 1950 and 1965 of the contributions made by primary, secondary, and tertiary industries to the gross domestic product of the United States, the United Kingdom, France, West Germany and Canada.

In the shares of primary industries the Canadian pattern is not remarkably different from that of other countries. The same is true to a lesser extent for secondary industries and tertiary industries. As far as these two are concerned, however, the Canadian situation is more similar to that of the United States; it appears more "advanced" than the economy of the three European countries, and we may postulate that Canada has already reached the "post-industrial" era in which services begin to predominate. Thus, the argument that rests on an extensive resource-based growth, while perhaps valid in the past, cannot explain Canada's unique distribution of R&D performance and funding between the three main sectors.

We are left with the model first proposed by NRC in 1919 and restated since by most senior science managers in the public service. That pattern, which has been described in previous chapters, put the emphasis on basic science and fundamental research and denigrated development activities as being of "ephemeral value". It called for government assistance to help

## ORIGIN OF GROSS DOMESTIC PRODUCT AT FACTOR COST (at current prices)

IN PER CENT OF TOTAL




NOTE. 1. At market prices.
2. Net Domestic Product.

universities expand their research and education facilities in order to produce a growing number of well-trained pure scientists. It involved the creation and expansion of government laboratories to provide job opportunities for the increasing supply of scientists and to carry on R&D activities that would, it was hoped, prove useful to the industrial sector. Statistical evidence shows that this pattern has been followed faithfully in Canada.

More recent figures indicate that Canadian conditions have not changed in industry's favour since 1967. In the fiscal year 1966-67, according to Statistics Canada, 73 per cent of government expenditure on scientific activities was devoted to intramural operations, 14 per cent was allocated to industry, and 13 per cent to the academic sector. For 1969-70, it was estimated, 69 per cent of the total was spent in government laboratories, 13 per cent was assigned to industry, and 18 per cent to universities and other non-profit organizations.[13] As we have already pointed out at the end of Chapter 5, while the Minister of Industry had stated in 1967 that "our first obligation . . . is to ensure that technical innovation activity in our industry is brought to a competitive level in the shortest possible time," in 1970 the government was devoting a slightly lower portion of its total science expenditures to its own laboratories, but the shift was in favour of universities and not to the advantage of industry.

It is evident that government R&D expenditures have not been an appropriate response to objectives and priorities set out by cabinet ministers. In this sense it is certainly true to say, as we concluded in Chapter 5, that Canada has a science policy *by accident*. However, it is becoming increasingly clear from our analysis that—although ministers may have failed to implement the policy they formulated—Canada has had, all along, a true and systematic science policy that was defined and implemented by the leaders of the Republic of Science in their capacities as senior government officials.

The Committee is of the opinion that it is precisely this hidden policy that has given Canada her special position in the international scientific and technological race. It is too early yet, in this first part of our report, to conclude that this is the wrong position and the wrong policy. But the Committee is certainly justified in concluding—on the basis of comparisons with other advanced countries—that the Canadian situation is strange and that Canada's de-facto science policy is unique, to say the least. This does not necessarily mean that other countries are right and that they are satisfied with their present orientation. On the contrary, the committee has already indicated in this volume that Great Britain, France, and Japan, in particular, are not satisfied with their own R&D effort. Statements to that effect made by Mr. Wedgwood Benn in the United Kingdom, by Mr. Ortoli in France, and by the Japanese Science and Technology Agency are clear. However, they all indicate that these countries intend to move further away from the Canadian position. This should be an additional source of concern for Canada.

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## APPENDIX 1

### SOME DEFINITIONS FROM STATISTICS CANADA

1. *Scientific activities* comprise all activities concerned with the creation or acquisition of new knowledge in engineering or the natural and social sciences, or with new applications of scientific knowledge to useful purposes. Five classes of activities are to be distinguished: research and development (R&D), data collection, scientific information, testing and standardization, and education in the sciences and engineering.

1.1 *Research and Development* [*R&D*].

(a) *Research* is investigative, experimental and generally original work undertaken for the advancement of scientific knowledge (i.e. scientific information when arranged in logical systems or theories). Research is *basic* when it has no immediate specific practical application (although it may be oriented towards an area of interest to the performer); it is *applied* when it is directed towards a specific practical application.

(b) *Development* is the use of knowledge derived from research in order to produce new materials, devices, products and processes, or to improve existing ones.

1.2 *Data Collection* refers to the routine and continuous collection and arrangement of data on natural and social phenomena. It includes geological, topographical, hydrological and oceanographic surveys and mapping, collection of meteorological data, collection of social and economic data, and the gathering and arrangement of human, biological, entomological and zoological specimens and data.

1.3 *Scientific Information* refers to the dissemination of scientific and technological information, including any necessary preliminary work such as recording, classifying, translating or coding. Expenditures attributable to this activity include the costs of libraries of scientific and technical publications, the costs of national patent offices and government scientific and technical information services, the costs of scientific conferences or displays, and the costs of publishing information acquired as a result of some other scientific activity.

1.4 *Testing and standardization* refer to work directed towards the establishment of national standards for materials, devices, products and processes, the calibration of secondary standards and non-routine quality testing, separately identifiable from R&D, which may be required to identify the characteristics of materials, devices, products and processes.

1.5 *Education* refers to education and training in engineering and technology or the natural and social sciences at institutions of higher education. The Federal Government's direct participation in this activity is mainly through scholarships and fellowships intended to assist students with their educational expenses.

2. *Intramural*—done within the reporting organization, i.e. agency or unit.

3. *Capital expenditures*—expenditures on land, buildings and non-expendable research equipment used for R&D and other scientific activities. In the case of multipurpose facilities, capital expenditures should be apportioned between scientific and non-scientific activities (or between R&D and other scientific activities) on the basis of proportion of time devoted to various activities.

4. *Personnel classifications:*

4.1 *Professionals:* personnel with at least one degree from a university or college plus those without such formal qualifications who are in job classifications for which such qualifications are normally required, (i.e. research scientist, statistician, economist).

4.2 *Technicians:* technically trained personnel who assist professionals engaged in scientific activities. Normal qualifications are certification by provincial education authorities or by scientific and engineering associations (provincial and national). Also included are personnel who do not have such certification but who are in job classifications for which such qualifications are normally required (e.g. technical officer).

4.3 *Workers:* skilled craftsmen or unskilled help who assist professionals and technicians in their work (e.g. machinists and electricians).

4.4 *Other supporting personnel:* administrative personnel such as clerks, typists, accountants and storemen. (Do not include persons only indirectly involved in scientific activities, such as janitors, cafeteria workers and security guards, or persons engaged in the construction of facilities for scientific activities.

5. *Agency and unit*

(*a*) *Agency* is the term used for organizations under the jurisdiction of the Federal Government such as Departments, Crown Corporations, Commissions or Boards.

(*b*) *Units* denote groups (e.g. sections or divisions) operating within an Agency.



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# APPENDIX 2

## THE HISTORY OF TECHNOLOGICAL INNOVATION IN CANADA

### *A Narrative*

In 1967, J. J. Brown published a book with the suggestive title "Ideas in Exile", in which he gives a vivid and sometimes dramatic account of the fate of Canadian inventions. Notwithstanding certain shortcomings, the book describes a wealth of innovations that grew out of true or alleged Canadian inventions. Following is a selection of some of these inventions to illustrate the historical characteristics of technological innovation in this country.

The major technological innovations in Canada started in the "railway age" which Brown places between 1849 and 1877. During this period there was a flood of inventions designed to improve the safety, comfort and efficiency of railway transportation. However, for a variety of reasons, the signal and safety systems that came into use on the Canadian railways were of European origin, whereas such innovations as the safety block system, the Westinghouse brake and the Pullman car were all American. Canada's most important contribution to railroading is probably the rotary snowplow, an invention that permitted midwinter operations in mountainous terrain.

The basic patent of the rotary plow was taken out in 1869 by J. W. Elliott, a Toronto dentist, and was later improved by Orange Jull and the Leslie Brothers of Orangeville, Ontario. In 1888 the CPR built eight of the Elliott-Jull snow ploughs and the implement was soon put to use "with spectacular success" on many of the world's railways.

The age of mass communication came about with the telegraph, the telephone, the phonograph and vast improvements in printing techniques. The most famous "Canadian" invention is of course the telephone, invented in 1876 by Alexander Graham Bell, and patented in the United States during the same year. Alexander Graham Bell was undoubtedly Canada's greatest inventor in terms of the size of the resulting industry and the social significance of his discoveries.

However, the business side of the Bell telephone did not develop in Canada, but in the United States where the National Bell Telephone Company was founded in 1876. George Brown, editor of the Toronto Globe and Mail, had bought the Canadian telephone rights for $25 per month for six months, but he was unable to carry through his commitment. The rights were then offered to the Dominion Telephone Company, which declined the offer. Meanwhile the Canadian government had begun to levy import duties on telephone equipment which meant that Melville Bell, who still owned the Canadian rights, could not supply his Canadian subscribers with telephone receivers and transmitters at the original price. Finally, in 1879, the National Bell Telephone Company took over the American and Canadian rights and the Bell Telephone Company of Canada was formed in 1880.

With respect to new printing techniques, Brown mentions two important Canadian inventions, neither of which produced commercial results in Canada. In 1869 George E. Desbarats established the Canadian National News which used half-tone reproduction of photographs. Although Desbarats was also the founder of the "Canadian Patent Office Record", his half-tone photographic process was not patented and went unnoticed for nearly a decade. The half-tone process was finally patented by Ives in the United States in 1878.

The well-known Kodak developing tank was invented in 1899 by a Canadian named Arthur McCurdy. The invention was patented in Canada and the United States and subsequently sold to the Eastman-Kodak Company in Rochester.

Two other Canadian inventions pertain to the area of mass communication. Stephenson's wire pictures and Rogers' radio tubes. In 1921 William Stephenson developed a system to send pictures by wire, but according to Brown, Canadian newspapers and electrical companies were not interested in this invention. Stephenson obtained a British patent in 1923 and transformed his invention into a commercial success in Great Britain.

Towards the end of 1924, Ted Rogers of Toronto developed the alternating current radio tube which enabled radio receivers to operate without batteries. In 1927 the batteryless idea had been extended to radio transmitters and the Rogers invention is still commemorated in the call letters of CFRB in Toronto, where CF stands for Canada, and RB for "Rogers' Batteryless".

Concomitant with the development of electronic communications, was the further development of mass transportation. In this field were some significant Canadian innovations also. For instance, James T. Wright of Toronto overcame the problems of underground short-circuits in electric trams, by developing the electric trolley pole and overhead wires which he demonstrated successfully at the Canadian National Exhibition in 1883. Although the system spread quickly to all major cities of the world, it is not known to what extent Canadian industry benefitted from Wright's innovation.

The earliest experiments with aircraft in Canada were done at Baddeck, N.S. by Bell's Aerial Experiment Association which was organized in 1907. The association consisted of two Canadian engineers: John McCurdy and Casey Baldwin; and two Americans: Glen H. Curtiss, a motorcycle manufacturer, and Lieutenant Thomas Selfridge, an aeronautics expert with the U.S. Army. Towards the end of 1907, the first man-carrying kite, the Cygnet, was towed along Baddeck Bay, carrying Selfridge to a height of 168 feet. In order to tow the experimental kites at greater speed, Bell and Baldwin developed also the principles for the hydro-foil but the project did not reach full success until 1919 when more powerful engines had become available. Out of the kite experiments grew Canada's first airplane, the Silver Dart, which flew on February 23, 1909; powered by a Curtiss engine and with John McCurdy at the controls.

In terms of industrial success, the first Canadian aircraft company was a subsidiary of the Curtiss Company of Hammondsport N.Y. The Toronto plant was called "Curtiss Aeroplanes and Motors" and was managed by McCurdy. The factory made a number of two-seater J. N. Curtiss trainers some of which were used by Canada's first flying school, the "Curtiss Aviation School" at Long Beach near Toronto.

Another important contribution to the development of aircraft was made by Wallace Rupert Turnbull with his invention of the variable pitch propellor which was a propellor that gave optimum thrust for all conditions of flying. Turnbull sold his patent rights to aircraft manufacturing companies, chiefly to Curtiss Wright in the United States.

With respect to organizational innovation, one could say that Alexander Graham Bell invented the concept of the "research team", when he organized the Aerial Experiment Association. During the First World War the idea of using a research team to examine broad or narrow questions of technology took a firm hold. In 1924, Parliament provided The National Research Council with money for temporary laboratories and for research programs on a specific topic. The test topic—the utilization of magnesium limestone for refractories used in furnaces —turned out to be successful and resulted in the establishment of a new Canadian firm, Canadian Refractories Ltd. in Montreal which is still in existence.

Provinces and universities also formed research teams and an example of product innovation by a university research team, is the development of a commercial electron microscope by members of the Physics Department at the University of Toronto in 1938. According to Brown (op.cit. p. 217), the three scientists who worked at this successful project all emigrated to the United States. At the time of his writing they were employed at the Massachucetts Institute of Technology, at the Ohio State University and at RCA in Princeton, N.Y. The electron microscope itself is manufactured in the United States.

During the Second World War, Canadian scientists contributed to a number of military innovations such as Goodeve's invention of "degaussed" ship hulls to ward off magnetic mines, Arnold Pitt's proximity fuse and several contributions to radar technology.

After the Second World War, Canada saw innovative activity in several fields, two of which will be taken as examples: off-road vehicles and cartography. With the widespread exploration for oil and minerals in Canada, came the requirement for terrain vehicles. The pioneer developer of this type of transportation was Armand Bombardier who developed the first snowmobile in 1926, and later the Bombardier muskegg tractor. Following Bombardier's ultimate success, a dozen or so Canadian companies started to manufacture snowmobiles and a considerable competence developed in this field. Not only snowmobiles proved to be a successfull innovation, but Canada became the world leader in many types of all-terrain vehicles, such as the Amphicat, the Tiger, the Multimobile, the Gyp-Sea, the Skipper, the Argo, the Beaver, the Sur-trek and the Lobo.

The technological success in these areas of specialization has led to a rapid growth of these industry sectors. The Department of Industry, Trade and Commerce (private comm) estimates that the manufacturers of snowmobiles, all-terrain vehicles, tracked vehicles and forest-harvesting equipment employ more than 12,000 people and produce of the order of $440 million in factory shipments per year. These industry sectors are characterized by rapid growth, a high percentage of exports, a high rate of obsolescence and therefore a large demand for further innovation. As a result of their technological success, however, many of the major companies have been purchased by American firms, which is an aspect of technological innovation in Canada that will be discussed later in this paper.

In view of Canada's vast territorial expanse, it seems natural that a number of Canadian inventions pertain to aerial cartography, such as the narrow-beam altimeter which was developed in 1946 by the National Research Council to measure the distance from aircraft to ground. The original instrument was manufactured by Electronic Associates of Canada. In subsequent years the instrument was improved by the National Research Council and the present version is manufactured by Leigh Instruments.

Another Canadian development for scientific cartography was the Gamble plotter, developed in the early fifties by S. C. Gamble. About ten of these instruments were manufactured in Canada, but the instrument has become obsolete and has generally been replaced by more modern plotters such as the Swiss Wild V-8 plotter. In the 1960's, Mr. Helava at the National Research Council developed the Helava analytical plotter which enabled the interpretation of non-standard aerial photographs. The instrument proved to be invaluable for the interpretation of reconnaissance photographs. Rights to the Helava plotter were originally sold to the Nistri Company in Italy which later transferred them to Bendix in the United States. An undisclosed number of Helava plotters have been made for the U.S. Air Force where they have been used—among other things—to evaluate the Ranger moon photos. There are four Helava plotters in Canada: one at Laval University, one at the University of New Brunswick, one at the National Research Council and one at the Army Survey Establishment.

G. L. Hobrough developed the Stereomat, which is an automatic contour and profile-tracing instrument. The Stereomat has a number of U.S. patents and is now produced by Raytheon Corp. of Alexandria, Virg. and by Wild Heerbrugg Ltd. in Switzerland. From 1961 to 1967 Hobrough continued his research in the United States, but he returned to Canada in 1967 for the commercial development of the Gestalt photomapper which is a radically new instrument for the automatic production of ortho photographs.

All of these examples demonstrate that Canada has never been short of inventive talent. Yet, Brown's account leaves the impression that many significant inventions have not been used to Canada's economic benefit, either because of insufficient intellectual interest, or because of insufficient financial or industrial capability, and, we must agree with Brown's main conclusion (op.cit.p.342) that: "By and large, innovation in Canada is not a happy story".

SOURCE: *Technological Innovation in Canada.* Report by the Economic Development Division, Department of Finance, October 1970.

# 7

## A REVIEW OF THE EVIDENCE BEFORE THE COMMITTEE: THE FEDERAL GOVERNMENT SECTOR

The evidence presented before the Committee by government agencies, other organizations, and individuals has been most useful, not only to us, but to a great number of other interested people in Canada and abroad. That evidence now stands by itself as a valuable source of information. It constitutes an unprecedented record of the current national R&D effort, mainly of the science activities carried out by government agencies. It is not the Committee's intention to sum up the descriptive content of the briefs. The OECD report on Canada's national science policy, published in December 1969, contains a recent and comprehensive description of the R&D activities and duties of government institutions and a general account of conditions prevailing in Canadian universities and industries, and there is no need to duplicate that effort.

We have made a critical analysis of the Canadian scene, both historically and internationally. Volume II of this report will contain a set of proposals designed to improve it. But first it is important to extract from our proceedings the criticisms and constructive proposals we have received from Canadian individuals and organizations most directly concerned with national science activities and policy. This review of the evidence may appear to overemphasize the criticism. The Committee wish to underline again that its mandate is precisely to detect the weaknesses of the Canadian situation and try to correct them.

This review does not cover minor aspects of science policy. It does not include the trivial criticisms and proposals nor those that have already been acted on (For instance, the Programme of Assistance to Industrial Tech-



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nology (PAIT) administered by the Department of Industry, Trade and Commerce was strongly criticized by a number of firms but has now been changed to meet the objections.) Our analysis of the evidence also tries to minimize tedious repetitions of the same views presented by different organizations. For these reasons, but also because of the difficulty involved in extracting all significant comments from more than 10,000 pages of evidence within the limits of three chapters, we have not been able to quote extensively from all the briefs presented, and for this we apologize in advance to all those individuals and organizations who helped us so much in our work. We will refer to them again, of course, in Volume II as we develop our own recommendations.

The Committee's review falls naturally into two main parts. This chapter covers the views submitted by representatives of federal government agencies. Chapters 8 and 9 outline the assessment presented by provincial agencies and the private sector, including universities, industry, professional organizations, and learned societies. The two groups approached science policy issues differently and did not emphasize the same points, as was to be expected.

## SCIENTIFIC AND TECHNOLOGICAL INFORMATION

It has been repeatedly pointed out to the Committee that an efficient scientific and technological information system is a basic requirement for any country wanting to maximize the benefits it can derive from R&D activities conducted at home and abroad, if gaps, duplication, and imbalances in the national R&D effort are to be detected and corrected.

The chairman of the Economic Council, Mr. Arthur Smith, stressed the importance of knowing what goes on abroad:

> We do not really have any good studies that I know of in Canada dealing with the use of scientific and technical knowledge as it affects economic activities.... Much of the knowledge that we are going to need to use effectively in Canada in innovation is going to have to come from abroad.[1]

To improve the situation, the Economic Council has already suggested that "our commercial counsellor service in Canada might be used more effectively to keep a watchful eye for new things that were developing in other countries. . . . Some of our most successful innovations in Canada in recent years have come from abroad."[2]

Mr. J. H. Warren, deputy minister of the Department of Industry, Trade and Commerce, stated that Canadian industry was inadequately supplied with technological information originating abroad:

> The Branches (of the Department) do what they can; but that, I would say, is a poor substitute for a proper information system for scientific and technological information such as could be envisaged for Canada.[3]

Dr. O. M. Solandt, the chairman of the Science Council, underlined by implication the need for another type of information system for science policy: "Clearly, the first thing is to ask 'Where are we now?' We have to answer that question because whatever policy we adopt has to start from where we are today. . . . The next thing is to know what resources we have available."[4]

In view of the basic need for an effective information system, what the Committee was told about the Canadian situation was not encouraging. Dr. Roger Gaudry, vice-chairman of the Science Council and Rector of the University of Montreal, stated that "the statistics as to expenditures on R&D have been too old to permit us to make rather rapid and precise recommendations as to needed changes or trends."[5]

Mr. Jean Boucher, then director of the Canada Council, complained about the lack of information on the national effort in the social sciences and the humanities. He said: ". . . There is no comprehensive census at the moment of the amount of support given to the social sciences and the humanities, from all sources."[6] And he went on, referring to the Canada Council:

> At the moment, we do not have the total picture. We do not know what our position is in the market. We do not know what our competitors are. We do not know what we are stealing people from. We do not know what we are losing them to. We do not have the total picture, and, not having the total picture, we cannot define exactly the financial dimensions of the role that we ought to be performing. But I am not quite sure that the natural scientists do not have that too. . . .[7]

Mr. Boucher then referred to research grants distributed to university teachers and stated that "Canadian universities do not know how much money their own staff are making in this way."[8]

Dr. F. R. Hayes, then director of the Fisheries Research Board, indicated that the board had to make isolated decisions about research grants to universities because it did not know what other granting agencies interested in related fields were doing. He concluded that "it would be useful to know what is happening elsewhere."[9]



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Mr. E. L. Hewson of the Department of Transport admitted that the department did not know what was spent on R&D activities and that "a total, meaningful figure for the department would take some examination and investigation to produce."[10]

Dr. L. G. Cook, who was then Délégué général at the National Research Council, generally and not specifically of NRC, recognized that ". . . the greatest weakness that we show is not doing adequate technical audits."[11]

Dr. J. B. Bundock of the Department of National Health and Welfare, referring to the department's brief to the Committee, said: ". . . this is the first time we have done this total analysis of the scientific aspects of the department."[12]

He later stated:

> Much research is being done, with attempts to develop a system, but as long as we do not have a total system of information relating to the management of science on a nationwide basis, I would suggest, Mr. Chairman, that there is no hope of really taking the kind of decision that we are discussing now—this is, how to apportion funds as between various sciences . . . because we do not know where the gaps are or where the research is taking place. At the moment, there is no agency or capability for this work. That is the reason why we are so strong in our brief in making a specific recommendation for a beginning by establishing a central agency which will have the capabilities to store the kind of information which will lead to proper decision-making.[13]

The brief of the Department of National Health and Welfare recommended that "all federal agencies supporting research and development should be directed to maintain comprehensive, up-to-date indexes of their own current research and development efforts."[14]

Mr. Walter E. Duffett, who was then Dominion Statistician, asserted that "the Statistics Act gave us the responsibility for co-ordination without powers."[15] His brief contained the following comment: "Government accounting records are not in a form which permits automatic identification of resources devoted to scientific activities. It might be noted that there seem to be substantial discrepancies in some cases between the departmental estimates prepared for this committee and those supplied to the DBS."[16]

Mr. M. Archer, vice-president of the Canadian National Railways, recommended a transportation data bank for gathering information and avoiding duplication by knowing what others in the field were doing.[17] More generally, the brief presented by the governor of the Bank of Canada, Mr. Louis Rasminsky, made the following recommendation:

> The time would now seem to have arrived to carry the development of the nation's information systems further by undertaking (perhaps through the

Bureau of Statistics) new initiatives to ensure that Canadians will in fact be able to benefit from the greatly improved access to economic and other information which the computer puts technically within our grasp.

> There would seem to be some urgency in this matter. If the economies of scale possible through system-sharing are not pursued urgently they may be lost through the proliferation—at enormous overhead costs—of overlapping and incompatible data files and programmes at a number of separate research centres across the country, each trying to develop large-scale facilities of its own. Means should also be studied of reducing the existing degree of incompatibility among the various types of computer hardware and communications links offered by competing suppliers, since this creates much difficulty and expense for users who want the advantages of system-sharing.[18]

On the basis of these comments, the Committee finds that Canada suffers from a serious information gap in science and technology and science policy issues. Under such conditions Canadians cannot get maximum benefits from R&D activities conducted abroad. Moreover, government people responsible for science policy do not have the information required to arrive at rational decisions on budgets and programs. If the government has not succeeded in co-ordinating information on scientific activities, how can it be expected to co-ordinate the science effort of its various agencies effectively?

## THE NATIONAL R & D EFFORT:

## THE NATURE OF ITS DISTRIBUTION AND ITS AGGREGATE LEVEL

An issue that is still hotly debated in scientific circles is whether modern societies should have a policy for science or use science for policy. To a large extent this is a false issue, as Dr. W. G. Schneider pointed out in NRC's brief, because both are needed. However, Dr. Solandt expressed the prevailing views of senior science managers in the government when he put the emphasis on the mobilization of science to serve social and economic goals:

> We are now in a period of transition from what might have been called, to oversimplify it, the period in which we thought of science primarily for science. We are now entering a new phase in which, as expenditures for science increase and also as the possibilities for using science to solve economic and social problems become more obvious and more important, science policy at the national level must be concerned far more with how we use science to solve social and economic problems rather than with how we develop science.[19]

This emphasis on the practical utilization of science was not new. Dr. Macallum in 1919 had underlined industrial development as the objective to justify the creation of NRC's laboratories. But 50 years later, Dr. Solandt stressed the importance of development activities rather than the need for fundamental research:

> "... [the United States] puts 12 per cent into basic research, as opposed to our 22 per cent; 22 per cent into applied research, as opposed to our 41 per cent; but 66 per cent into development as opposed to our 37 per cent. This indicates that the United States has, as I think everyone who has studied the matter will agree, a better balanced mix.[20]

Dr. C. M. Isbister, then deputy minister of the Department of Energy, Mines and Resources, agreed with this assessment: "All the evidence that has so far been gathered points to the fact that the development side of R&D is the component in Canada that has not been pushed as it has in other countries."[21] Dr. Schneider of NRC also shared this view:

> Generally speaking, the applied sciences and engineering disciplines are as yet not as highly developed as the pure science disciplines. This is largely attributable to the fact that research in engineering schools is expensive, cannot flourish without a favourable industrial climate and has had a much later start although it is now developing rapidly.[22]

Dr. Isbister proposed that "Fundamental research should normally represent only a small part of the total effort of a mission-oriented organization, and should not be justified on the ground only that it satisfies the curiosity of the investigator. The application of this restriction will go far toward deciding what kind of research should be done by a given agency."[23]

When it came to the distribution of the national R&D effort by main areas of scientific and engineering disciplines, it was generally agreed that imbalances had developed to the disadvantage of the life sciences and social sciences. Dr. Hayes of the Fisheries Research Board complained about the situation of the life sciences in his broad area of interest:

> Of course, the levels of support, for reasons that I do not always altogether understand, in the renewable natural resources, fisheries, forests and agriculture, have simply been in the joke column compared with what is available in other branches of sciences; I do not know why that is so, but it is very difficult to get it rectified.[24]

About the support given to the medical sciences, Dr. G. Malcolm Brown, Chairman of the Medical Research Council, had this to say:

> Canada now spends at least $2.8 billion annually on health care. The extramural money going into medical research in universities and hospitals, to take the largest component of health science research, is $44 million. The ratio is wrong and it needs examination in its social, financial and scientific aspects.[25]

Dr. R. J. Uffen, then chairman of the Defence Research Board, referring to the estimates of $80 million for R&D expenditures by the Armed Forces and the Defence Research Board, said:

> This is about 5 per cent of the defence budget. So, one thing I would like to have recognized is that we are at the bare minimum threshold of a reasonable investment in R&D from the point of view of national defence.[26]

There was a general consensus that more support should be devoted to the social sciences. Mr. Jean Boucher of the Canada Council referred to the preferred treatment given to the natural sciences:

> While the Government's response has been quite encouraging and has now brought the Council's budget up to the level where the NRC-MRC budget stood only six years ago, it has at the same time improved the position of natural scientists considerably; whereas the Canada Council can now support almost 10 per cent of its universe of career scholars, nearly two out of three natural scientists are being supported.... The Council remains of the view that while its position has been quite remarkably improved over the last five years, the recovery operation, by which the gap between the natural and the social sciences would be gradually reduced, has made very little progress.[27]

Dr. Solandt stated that the "... [Science] Council would support all efforts to promote expansion of the nation's activities in these [social] sciences."[28] Dr. Arthur Smith, on behalf of the Economic Council, deplored the long tradition of neglect: "In Canada we have simply had an underdeveloped state in the social sciences for quite a long time, one that stretches all the way back into the education system."[29] The brief submitted by the Department of National Health and Welfare stressed that the natural sciences and social sciences were complementary. The brief declared:

> ... That a great many of Canada's most perplexing problems require extensive co-operation between the social and natural sciences and that it is essential that any policy for science in Canada be conceived broadly enough to encompass an appropriate development of the social sciences and humanities along with the natural sciences.[30]

The Department of Agriculture made a sad comment about its economic research in referring to a remark contained in the Glassco Report:

> In other words, there is too little correlation between the important and the urgent. For example, the Glassco Commission commented on the situation (1963) in the Economic Branch as follows:
>
> > "In the Department of Agriculture, with the largest economic analysis organization in the government, the pressure of ad hoc projects is so great that virtually no economic research is done, although the agri-

> culture economy has undergone profound change in recent times and a fundamental understanding of the process is absolutely vital."
>
> While this is an overstatement of the problem, it is nevertheless accurate in principle. Unfortunately, there has been no appreciable improvement in the situation since that time.[31]

But the social sciences were not the only area that had been seriously neglected. Dr. Schneider, the president of NRC, deploring the fact that engineering disciplines were not as developed as the pure science disciplines, also believed that the whole area of technology had not been sufficiently encouraged:

> As a nation we must make a much greater commitment to new technology. With limited resources, we cannot of course hope to challenge on all fronts. But by being selective and concentrating our efforts we can become preeminent in those areas where we have a favourable base or special advantage. As part of Federal government policy these areas should be identified and given special support and encouragement on a priority basis. Possible areas which should be considered include transportation, telecommunications, building materials and building technology, environmental pollution, metal physics and metallurgy, marine sciences, food technology, energy and power technology, northern development and specialized computer technology.[32]

It would be interesting to compare Dr. Schneider's list of programs with those presented by two of his predecessors, Dr. Macallum to the Cronyn Committee in 1919 and General MacNaughton to the Rowell-Sirois Commission in 1938. There may be doubts about Canada's capability to launch some of these high technology programs in view of our experience in the 1950s, which has been described in Chapter 4. Professor Louis-Philippe Bonneau made much the same point when he spoke about his proposed program on metal physics and metallurgy:

> There is no way of constructing a good autonomous, autochthonous technology without that basic reserve of scientists who know something about metals and other matters important for technology. But above this foundation, a structure must be built: in this respect Canada at the present time has next to nothing.[33]

It would seem that today we are in about the same position in this field as we were in the early 1950s with nuclear energy. We have a reserve of good scientists but no technological know-how. Does this mean that engineers and designers will once more have "to learn on the job", as Dr. Steacie advised in the 1950s and as they have been doing for almost 20 years in the construction of nuclear power stations? The strategy did not seem to meet with Dr. Solandt's approval because he said that "If we do design, development and innovation based on somebody else's research this is just as good and, in fact, may be better."[34]

Some of the underdeveloped areas identified by Dr. Schneider were also mentioned by others. Mr. Hewson of the Department of Transport stated that "the proportion of total research effort devoted to seeking solutions to transportation problems in relation to the national cost of providing transportation leaves room for acceleration of research activities by a number of agencies."[35] Mr. R. R. Cope, vice-president of the Canadian Transportation Commission, added:

> 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. We agree that this has been the situation in Canada and regrettably so.[36]

Mr. Cope went on to say that the target R&D budget of the commission for 1973 should be around $15 million instead of $3 million, as was first proposed to the Treasury Board in 1969.[37]

Mr. H. W. Hignett, president of Central Mortgage and Housing Corporation, commented on CMHC's housing and planning research:

> It can be said, I think, that there has been a plan for developing a programme of institutional support and training support, but beyond this, there has not been a preconceived overall program plan. But special efforts have been made for finding and encouraging people to work on topics that interest them and have significance within the very wide range of our interests in housing and planning affairs.[38]

The evidence CMHC presented to the Committee showed that its intramural R&D activities were merely designed to provide information needed to support decision-making. Although the funds devoted by the corporation to extramural projects had increased in recent years, only $10 million had been spent for that purpose in the last 14 years. Of this total, 42 per cent had been provided for institutional support, 31 per cent for training and education, and 27 per cent for R&D proper.[39] Thus, in the last 14 years, the main agency of the Canadian Government involved in housing and urban planning had spent only $2.7 million for research and development, without "a preconceived overall program plan."

Mr. J. A. MacDonald, the deputy minister of Indian Affairs and Northern Development, expressed the view that R&D requirements in the North were being satisfied "subject only to some unforeseen event which will reveal in retrospect that we ought to be doing something."[40] This "rear-view mirror" approach to R&D problems in the North has not satisfied other agencies, such as the Science Council and NRC, which are proposing a major R&D program for that last huge Canadian frontier.

In space research, Prof. G. N. Patterson asserted that Canada had developed a relatively high science capability but he added that "Until we get a space agency and a national space program, universities will not know where they are going. Universities have got on their horse and are galloping off in all directions at the same time. There is no policy there and we need someone to help us formulate one."[41]

Dr. Schneider expressed the growing concern of many representatives of the government sector when he implied that the Canadian R & D effort had neglected the wide public welfare area. He said:

> National policy must concern itself with the application of science to social and economic problems and to improving the human environment. . . . They include, for example, conservation, pollution and other environmental problems, housing and urban problems, fire protection, law enforcement, public health and public safety.[42]

He went on to add the problems of regional disparities, national unity, and inter-cultural relationships. The Science Council has already drawn the attention of the government to several of these gaps in the Canadian R&D effort.

The views of the representatives of government agencies about the distribution of the national R&D effort by type of activity and objective can be easily summarized. They favour putting greater emphasis in future on:

(1) engineering and technological development rather than basic science and fundamental research;

(2) the life sciences, and especially the social sciences, rather than the physical sciences;

(3) social and economic objectives, particularly those related to public welfare, rather than curiosity-oriented discovery and scientific achievement.

No representative of the government sector suggested that these proposed shifts in emphasis should be made by cutting activities and programs. The implication, therefore, was that these re-adjustments should be effected by increasing the aggregate level of R&D. This recommendation became explicit when Dr. Solandt stated:

> Our real problem is that the scientific community must make the case for more money for science. Our total expenditure on science and scientific research is less than the optimum amount.[43]

On another occasion he said that "The majority of the Council are firmly convinced that we will be spending a good deal more than the present target of two per cent of GNP on what could be called research and development, certainly before the end of the century."[44]

One of the major objectives set out by Dr. Macallum in 1919 was to produce an "army of scientists." Dr. Schneider told the Committee about a study on scientific manpower in Canada that had just been completed:

> While we have had a continuing shortage of highly trained research manpower in the past, . . . this picture is likely to change rapidly because of the expansion of our universities and particularly university graduate training in recent years. . . .
>
> In round figures the annual output of new Ph.D.s has increased from over 200 in 1959 to a projection of around 2,000 per year in 1973. (These figures do not include Ph.D.s in the medical sciences). The annual number of new employment positions has increased from somewhat over 400 to nearly 1,000 and is not expected to increase greatly beyond this figure. . . .
>
> The total average number of Ph.D.s employed in all sectors was 4,300 for the period 1959-63 and is projected to rise to 11,500 in 1973. . . . The university sector will take up an increasing proportion of the total Ph.D. graduates, increasing from 53 per cent in 1960 to about 70 percent in 1973. The corresponding figure for government laboratories will be halved from 33 per cent to 17 per cent, while there will be virtually no relative change in the industrial sector . . . [these figures] have implications which should be kept in view in respect of shaping national policies and programs.[45]

Dr. Schneider made certain qualifications that may tend to reduce the projected gap between supply and demand. Dr. Solandt even questioned the forecast that a surplus would develop. But NRC's projections, showing that in 1973 we would produce twice as many Ph.D. graduates as we need, cannot be so far wrong as not to portend a substantial overall surplus. Thus, even if these are rough estimates, Dr. Schneider is certainly justified in warning policy-makers about the undesirable market situation that is likely to emerge soon.

While there may be disagreement about the size of the overall surplus, there is a general consensus about the imbalances that already exist in the supply of scientific manpower in Canada. Dr. Schneider also had something to say about these distortions:

> It also must be admitted that in the face of a rapid university expansion in the recent past, industrial laboratories have not competed successfully for their share of top scientific and engineering talent. It is sometimes claimed that today's graduate is too strongly academically oriented and not interested in industrial research and those that are frequently look to industries in the United States in the belief that industrial research opportunities are lacking in Canada.[46]

The clear implication here is that the emphasis on pure scientists may have helped universities to satisfy their needs but has not met the requirements of Canadian industry. As a result, the "army of scientists" may become a "reserve army", to use Karl Marx's reference to the reservoir of unemployed. This strong academic orientation also made Mr. Maurice Archer of the Canadian National Railways wonder: "To what extent are those in the universities prepared to do some railway research? I am not sure."[47]

A number of government agencies complained about shortages of qualified R&D manpower in their fields of interest and underlined their difficulty in recruiting the staff they needed. In its brief, the Department of Agriculture stated: "There are inadequate training opportunities at Ph.D. level in Canadian universities in specialized fields: pesticide chemistry, natural products chemistry, soil chemistry, soil microbiology and agricultural economics. The shortage of agricultural economists is especially critical."[48]

The shortage appears most acute in the social sciences. The Department of Manpower and Immigration contended that the major difficulty it was facing was a manpower problem: "The chief hindrance, both current and foreseeable, is shortage of qualified staff to perform the research functions required. A substantial number of the research positions established in the Department have remained vacant, because of such conditions as the inadequate salary levels offered and a general shortage of adequately qualified personnel in certain fields, such as cost-benefit analysis."[49]

Mr. R. B. Bryce, then the deputy minister of Finance, noted: "Like other departments we have real difficulty in finding experienced and well-trained economists and statisticians. There is an overall shortage of such people in Canada. There must still be scores, if not hundreds of vacancies for such people in Ottawa and new positions for such work granted by the Treasury Board are essentially hunting licences—and much of the hunting is done within the public service itself. Our work suffers from this shortage as does that of others."[50]

The Dominion Bureau of Statistics confirmed that view: "The greatly increased need for highly trained professional staff, the severe shortage of such talents and the keen competition for people with similar skills among federal government departments, provincial governments and industry, confronts the Bureau with a difficult resource situation."[51] The Department of Labour experienced the same difficulty: "The major hindrance to the effective performance of scientific functions and responsibilities [in the Economics and Research and Legislation Branches] is the inadequate supply of highly-trained staff."[52]

Similar complaints were presented by other agencies. The Department of Transport stated: "The major hindrance to the effective conduct of our research and development activities is the difficulty experienced in attracting suitable personnel."[53] The Department of Fisheries and Forestry: "The long-standing shortage of competent professional staff is, perhaps, the outstanding hindrance encountered by the Department in the pursuit of its objectives."[54] The Department of Indian Affairs and Northern Development: "Obtaining additional staff is not merely a matter of having the authority to hire. Trained wildlife biologists and ecologists are at a premium."[55]

This long but incomplete list of complaints has been presented to show that, according to the evidence before the Committee, there is something fundamentally wrong about the scientific manpower situation in Canada. We are apparently producing undesirable surpluses in certain areas and tolerating serious gaps in others that are paralyzing important research functions in government. The chairman of the Public Service Commission, Mr. John L. Carson, held the universities partly responsible for this situation:

> Because the universities are consumers of their own products, there is the possibility that they can become the centre of a self-sustaining supply and demand cycle. The "ivory tower syndrome" may manifest itself in out-dated courses providing training which finds little application outside the university and represents, potentially, a severe wastage of human and material resources.[56]

Mr. Carson also detected a "too much too late" syndrome that inevitably leads to surpluses. Finally, he mentioned the lack of co-ordination of manpower management in government:

> The location, identification, selection, recruitment, development and retention of first-rate talent requires a unified approach that is rational and coherent in both its design and its operation. This has not been achieved, nor is it likely to be achieved until the total staffing function is integrated into a national priority and policy network. At the moment, responsibility is divided between too many agencies to permit an effective overall program of manpower management.[57]

The lack of a coherent policy on scholarships and fellowships and the lack of co-ordination between the several government granting institutions have also been responsible for some of these imbalances in the supply of scientific manpower. This point was mentioned by Mr. Jean Boucher of the Canada Council and will be underlined later.

In previous chapters dealing with the historical development of Canadian science policy, we have indicated that the conventional wisdom did not attach great importance to industry as a performer of R&D. In 1919, Dr. Macallum had claimed that industrial research was "of ephemeral value". Dr. Schneider stated in 1968: "Accordingly, our minimal industrial R&D effort has concentrated for the most part on short-range programs likely to produce a more immediate return. More often than not, this is concerned with minor extension or elaboration of existing technology rather than with the development of promising and entirely new technology . . . . Our deficiencies in these respects today will increasingly compromise our economic potential ten or twenty years from now."[58] This weakness of the industrial sector had become a serious source of concern:

> It is clear that while we have made great strides in our scientific development during the past two decades, our present development with respect to the application and utilization of science is alarmingly unbalanced. We have not achieved a sufficient rooting of R&D in the industrial sector, nor has existing industrial R&D developed a sufficient momentum for growth to assure the future welfare of advanced industrial technology in Canada.[59]

Dr. Schneider elaborated the point later: "We are not doing sufficient research in industry. This is the thing that has to be corrected. I do not think you are going to solve the problem or improve the situation by tearing down what strengths we have in order to do this. I think what we have to do is build new strengths in the deficient areas."[60] Noting that NRC probably had "the best machine shop in the country",[61] Dr. Schneider added, however, that "the council's laboratories don't need to grow too large."[62]

Dr. Solandt explained the predominance of the Canadian government as a performer of R&D: "Traditionally, in most developing countries, the government naturally has to take the lead in building up research—but as a country gets larger there is every reason to believe that this dominance by government ceases to be a good thing and that there should be a wider distribution of activity into the universities and particularly into industry. We are just at the transitional point now."[63] Dr. Solandt described what should be the new role of the government:

> This concept of a gradual change in the role of the federal government from being an agency that does research to being an agency which fosters, stimulates and guides research throughout the whole nation is taking place now and this is something we must encourage.[64]

To enable the government to fulfill its new role effectively, Dr. Solandt 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."[65]

The representatives of the government sector did not put great emphasis on the role of universities as performers of R&D. Dr. Schneider underlined a new approach to the support for academic research: "Science generally in Canada has now developed a reasonably broad foundation and considerable strength, though somewhat diffusely based in a considerable number of university laboratories. The most immediate needs for the future will be to develop greater depth and concentration in important selected areas. The Council's recently established program of negotiated development grants is intended to aid this objective."[66] Thus, a new and more active approach to university research grants is being developed by NRC.

However, universities were criticized on various grounds. Dr. Louis-Philippe Bonneau, a member of NRC's board and vice-rector of Laval University, stated: "There are whole areas in which the universities do applied research for non-existent industries with the result that the projects are too impractical. Herein lies the tragedy, I feel, if we want to call it that."[67] He also noted that "the link between industry and the university is still extremely small and, in certain cases, non-existent."[68]

The brief presented by the Department of Fisheries and Forestry mentioned another difficulty:

> The greatest scientific obstacle is that the government approach to science tends to be interdisciplinary, built around environmental problems or objects such as fisheries, pollution, water, etc. These do not interact naturally with the traditional university departments of chemistry, physics, etc. Canadian universities differ enormously in their readiness to experiment with interdisciplinary science and only a minority are likely at present to find administrative and faculty support for working out such ventures.[69]

In fact, most of the emphasis was put on the need to strengthen industrial R&D. Dr. J. L. Gray, president of Atomic Energy of Canada Limited, presumably on the basis of his experience at AECL, warned that "Unless our industries take some initiative to implement programmes they feel are important to their future and to support them technically, personally and, to some extent, financially, all the government support in the world for "industrial research" will be an exercise in futility.[70] Dr. B. G. Ballard of Canadian Patents and Development noted: "We have had only small success in acquiring licenses among the larger industrial organizations and most of our patents are put into production by smaller firms."[71]

Mr. William M. Gilchrist, president of Eldorado Nuclear Company Limited, stated: "We recommend a greater use of industrial research and development facilities by federal government departments in their long-range scientific and technological programmes . . . . Direct financial assistance . . .should be based upon total expenditures by the Company rather than only on the annual increase in expenditures as is the case at present."[72] In the same vein, Dr. C. M. Isbister said, on behalf of the Department of Energy, Mines and Resources: "Departments such as ours could make more use of development contracts to produce instruments, plans, and working procedures from ideas developed during research programs."[73] Dr. Schneider pointed out that total support provided by NRC under the Industrial Research Assistance Program (IRAP) "only compares in personnel and budget with that of a medium-sized industrial laboratory in the U.S.A."[74] Referring to all government incentive programs, he said:

> The results of these programs have been encouraging but they are as yet modest programs and fall far short of what is needed. Some well planned and integrated programs are necessary to generate the momentum necessary in this area.[75]

And later he added:

> Finally, if our limited scientific resources are to be developed and deployed in the most effective manner, a much closer interaction and collaboration between university laboratories, government laboratories and industrial laboratories than now exists must be given strong encouragement.[76]

Referring to government incentive programs to industry, Mr. J. H. Warren, of the Department of Industry, Trade and Commerce, stated: "I would hope that they could be improved and this flows from our basic recognition of the priority that has to be given to innovation if we are to maintain our position as a manufacturing nation and a trading nation."[77] Mr. David B. Mundy, of the same department, believed that these programs were not too effective in promoting industrial research: "I think the conclusion that could be reached is that in terms of business judgement, they are not attractive enough for them to enter into the very degree of risk into which they have to enter."[78]

One would have expected that these incentive programs would have been developed after careful study of the causes of Canadian industry's weakness as a performer of R&D. But Mr. Warren asserted that no such comprehensive analysis had been made, although he indicated that "the process of study and evaluation of the strength and weaknesses of our industry is going on all the time."[79]

On behalf of the Science Council, Dr. Solandt summarized these various proposals:

> 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 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.
>
> (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; and then, finally, we recommend that the Government should use its procurement contracts to upgrade the competence of industries.[80]

Thus the message that the Committee received from representatives of the government sector was pretty clear: the R&D activities performed by industry in Canada need to be greatly reinforced. The recommendation was not new. The theme has been developed in Canada on several occasions, notably by the Glassco Commission in 1963. But coming this time from senior government officials themselves, it also contained a good deal of self-criticism. This was the first time the Canadian model put forward by NRC in 1919 had come under such an attack. The Committee also noted with concern that close interaction and collaboration between government, university, and industrial laboratories did not exist in Canada.

## GOVERNMENT LABORATORIES AND GRANTING INSTITUTIONS

The briefs presented by government agencies were mainly devoted to a detailed description of their role and activities, as the Committee had requested. Although these presentations contained much valuable information and a number of success stories representing notable achievements, our intention in this chapter, as indicated earlier, is not to summarize this material but to underline the deficiencies, the hindrances, and the recommendations that were submitted to us.

The absence of coherent and integrated policies on scientific and technological information and manpower management, and the isolation of the government sector from universities and industry, have already been noted. In addition to scientific manpower shortages, some departments with important laboratories criticized the working conditions under which they had to operate. The Department of Energy, Mines and Resources presented the most elaborate comments on this situation:

> However, the concern of Treasury Board and the Public Service Commission appears to be principally with job classification procedures, and they have required the staff of this Department to become heavily involved in such procedures. The unfortunate effect is to encourage personnel to relate themselves to an artificial system controlled from outside the Department, rather than to the tasks that have to be done and to the colleagues with whom they work.[81]

The brief suggested that "mission-oriented departments should have the maximum possible amount of control, particularly over hiring, reclassification and promotions in scientific and technical positions. That more decentralization of personnel administration is possible in government is shown by the relative freedom that is enjoyed by those government agencies that are not under the aegis of the Public Service Commission."[82]

Another major theme that developed was co-operation and co-ordination between government agencies. This problem was familiar to anyone who had followed the development of Canadian science policy. Decade after decade, co-ordination had remained the forgotten function, although everybody talked about it. Dr. Schneider seemed to be satisfied with the present situation:

> At first glance, the scientific activities of federal government agencies may appear to an outsider to be wholly unco-ordinated, and Ottawa to be a scientific jungle. This is not the case. In general, it has become accepted that any federal department or agency with a mission should be responsible for the research essential to its mission. This leaves certain fields of applied science as the territory for one single agency or department. Much of the co-ordination which exists is a direct outcome of good personal relationships between deputy heads of agencies and heads of scientific subdivisions.[83]

This ideal situation described by Dr. Schneider does not always seem to correspond with the facts. In the field of nuclear energy, for instance, Dr. J. L. Gray of AECL said:

> I do not know how much influence we have in the overall planning. In our own program we try to plan at least five years ahead and generally to have this forwarded to the Government every year, indicating what we think should be done to keep atomic energy programs viable. But we do not know how this is co-ordinated with other programs of NRC and other Government departments

and agencies—other than the Treasury Board, the procedure of which we understand.[84]

Dr. Gray mentioned that AECL had recommended an overall review of the related field of radiobiology, "so that the various government departments and agencies working in this area may be satisfied that their present and proposed programs fit reasonably into an overall program."[85] "Good personal relationships" did not seem to be sufficient there.

Indeed, Dr. G. C. Laurence, chairman of the Atomic Energy Control Board, whose function is to control nuclear and radioactive materials and nuclear energy equipment, said: ". . . What their [NRC's Division of Radiobiology's] present program is, I do not know."[86] However, although the board is a regulatory body, Dr. Laurence described it also as "one of the agencies through which the federal government gives support to atomic energy research in the universities."[87]

In the field of air pollution, the Department of National Health and Welfare claimed that "there is a plan which is being designed to provide the department with the authority to deal with the overall national problem of air pollution control."[88] At the same time, Mr. D. P. McIntyre of the Department of Transport asserted: "We have received from the Treasury Board authority to operate within a certain field in the sphere of air pollution; that is, certain areas of activity are ours by rights, so to speak. No government department has complete authority in the field of air pollution."[89] We hope that Mr. McIntyre was right when he added: "There is no formal, overall co-ordination for everything, but whenever problems which go across those boundaries come up, then everybody knows the right people so that they move in and carry out the proper conversations."[90]

In the area of water pollution, the main responsibility has been given to the Department of Energy, Mines and Resources but Dr. A. W. H. Needler of the Fisheries Research Board concluded: "In viewing these requirements, particularly respecting anti-pollution research, the base of the board's responsibilities must be broadened—beyond the sole consideration of fish and fisheries—to include a large and active share of the responsibilities for water resources generally."[91]

The situation in the sector of national defence seemed not to be ideal. The brief presented by Dr. R. J. Uffen stated: "The separation of the responsibility for research and preliminary development (DRB) from that for development (CTS Branch of Armed Forces and DOI) and procurement (DDP) presents some problems. It has been unusual in the Western Alliance."[92] Thus Major-General D. A. G. Waldock, who was Director-General of the Defence Forces'

Canadian Armament Research and Development Establishment (CARDE) from 1955 to 1959, was asked about the Department of Industry's attempt to persuade the Americans to adopt the counter-mortar radar developed by the Department of National Defence during his appointment with CARDE and answered: "Frankly, I am not aware of the details of that particular project; and what happened when we tried to sell it to the United States, I do not know."[93] He added: "Another hindrance is a result of the government designation of a separate department as the purchasing agent for the Department of National Defence. This imposes a middle man between the DRB (the Defence Research Board) and the seller and often creates serious delays in purchasing of urgently needed equipment and beginning contract research in industry and universities."[94] General Waldock concluded: "So long as DDP (the Department of Defence Production) or its successor retains the authority for defence contracting, its relations with DND (the Department of National Defence) will be complex."[95]

We have previously mentioned the fact that Mr. Cope of the Canadian Transportation Commission described transportation research in Canada as being "fragmented" because nobody was "looking at Canada's total needs." Dr. Solandt found the same situation in the space field: ". . . Space involves many different departments, each one operating a departmental space program, but none attempting to put them together into a national space program."[96]

Dr. C. M. Isbister seemed to refer to a general situation when he said: "At present, we can send scientists abroad on technical aid missions more easily than we can exchange them among governmental and private agencies."[97] Dr. B. G. Ballard of Canadian Patents and Development gave the impression that government laboratories were not co-operating very effectively with his agency when he suggested initiation of a government policy "which would enable and generally encourage government research laboratories to enter into contracts with CPDL to do preliminary developments on such patentable products of research as in CPDL's opinion merit such development."[98]

Mr. John L. Carson, of the Public Service Commission, commented on the lack of co-ordination and co-operation between different departments in the scientific fields: "Once you grant autonomy to people, there is a preciousness—I think all of us have preciousness in this respect—about preserving autonomy."[99]

Social and economic research in government also suffered from lack of co-operation. Mr. Harry J. Waisglass, of the Department of Labour, confided: "I am much more concerned, at this stage anyway, about the gaps than I am about overlapping."[100] Questioned about the relations between the Department of Labour and the Department of Manpower and Immigration, which seemed to have similar research problems, Mr. Waisglass commented: "They do not tell us what they are doing and we do not tell them what we are doing, not because there is any secret. Usually we are all so doggoned busy minding our own shops that we just have not got the time to mind other people's business."[101]

A similar comment came from Dr. W. R. Dymond of the Department of Manpower and Immigration: "Our problem at the moment in this area of research gaps is perhaps that we are too inward looking . . . ."[102] When he was told of the lack of co-ordination in this field of economic and social research, he added: "I think I would say I would not disagree with that remark."[103]

When Mr. Louis Rasminsky, the governor of the Bank of Canada, was asked if there was an inter-departmental mechanism for looking at the overall effort in the field of economic research and trying to detect gaps or undesirable duplication, he replied: "There is no formal interdepartmental agency of the type that you refer to, that I know of."[104] But Mr. Waisglass described the activities of the interdepartmental committee on social and economic research which he chaired when he was in the Privy Council Office:

> What we tried to rely on to a large extent was voluntary co-operation of research between voluntary agencies; there was no mandate, no requirement or authority requiring them to integrate these things. . . . This kind of thing is possible; it requires a great deal of faith, a great deal of time and a great deal of patience, but it is very slow until you have some authority commanding integration and co-ordination.[105]

Co-ordination does appear to be a very painful process. The fragile interdepartmental committee was short-lived. According to Mr. Waisglass, "It ceased functioning some time after I left [the Privy Council Office]. It may have had one or two meetings since then."[106]

Without effective co-ordination within this broad sector, it is difficult to see how the various discipline areas can be brought closer together. And yet, speaking from the point of view of the natural sciences, Dr. Schneider suggested that "in certain research areas, stronger links and co-operation with social science disciplines must be established."[107] The Department of National Health and Welfare raised the same problem:

> At the interdepartmental or inter-agency level, problems of co-ordination between organizations working on complementary problems need to be resolved. With the continuing growth of scientific activities and the greater use of multi-

disciplinary groups to undertake major programs, it is [necessary] to ensure a broader outlook at problem areas than can be accomplished by any single department and to ensure that the particular interests of the various departments do not result in biased governmental programs in various scientific areas.[108]

The department asked for "guidelines for co-ordination of effort" that would avoid "the two extremes of a chaotic jungle at the one end and over-centralized control at the other."[109]

The lack of co-ordination was also apparent among the government granting agencies. Dr. Roger Gaudry, of the Science Council, referred to the numerous departments involved in the support of research:

There has been over the years a large number of departments in the federal government that have been supporting research. They have been supporting basic research and little science mainly in the universities without any co-ordination whatsoever between all these various departments in the methods of granting, in the levels of granting, in the areas which should be supported and how much, and so on, and some of these ad hoc decisions made at the departmental levels have created great problems in the universities.[110]

This is a very strong statement, and yet it seems to be supported by Mr. Jean Boucher of the Canada Council: "Whether or not all aid to university research comes under a single Minister, the various agencies of the Government that share this responsibility will have to develop closer and closer liaison in order to ensure complementarity between services and consistency between programmes and in order to foster interdisciplinary undertakings."[111]

The lack of co-ordination was not limited to the area of academic research support. It seemed to extend to the government incentive programs aimed at the encouragement of industrial R&D too. Indeed, the Department of Industry, Trade and Commerce, which sponsors several of these programs, stated in its brief: "The effectiveness of the government's activities in the areas of science and technology as they relate to industrial development would be improved through greater co-ordination of the various programs involved."[112]

NRC, which also sponsors one of these incentive programs to industry and supports academic research as well, warned that if it were "to be isolated from university and industrial research activities, it would soon become ineffective as a national science body."[113] It viewed the suggestion that the granting function should be removed from the council as "a serious mistake". But Dr. Solandt told us: "The National Research Council, as a council, has not dealt effectively with the laboratories, because the members of the council are drawn from among those who have been receiving grants from the NRC for support of their research and so they were not free to be critical of the council's work."[114]

Dr. J. B. Bundock, of the Department of National Health and Welfare, described the situation in the area of medical research: "There is in existence an interdepartmental committee that meets twice a year, composed of the four major granting agencies at the federal level, namely our own department, the Medical Research Council, the DVA (the Department of Veterans Affairs) and the Medical Research Board, although there is no statutory authority for their meeting."[115] Dr. Gordon Josie of the same department stated: "There is a whole series of special committees dealing with the allocation of grants and approval of particular projects and there is a general co-ordinating committee which is set up by the Dominion Council of Health."[116]

This is confusing. No doubt there are many committees; but is there effective co-ordination? One thing is certain: according to Dr. Brown, the Medical Research Council is not consulted on what the National Research Council is doing in the field of medical research.[117]

The need for effective co-ordination of government R&D activities has been a constant theme in discussions on Canadian science policy since 1916. It was underlined again more recently by the Massey Commission in 1951 and by the Glassco Commission in 1963. But this need appears to be even greater today. It probably originates from the government decision in 1964 to accept Dr. C. J. Mackenzie's advice that the new central machinery for science policy should not be allowed to infringe upon "the rights and privileges" of existing agencies.

## CENTRAL MACHINERY AND OVERALL SCIENCE POLICY

The decision then taken by the Canadian government appears to have been respected. As we saw in Chapter 5, Dr. R. J. Uffen, the director of the Science Secretariat, described his institution as "a service agency whose primary task is to assist government departments and other agencies in getting their proposals before the cabinet in an orderly manner."

Dr. Solandt stated, on behalf of the Science Council, that "in the field of science policy, we are the major agency advising the Government."[118] However, in his view, the council had a limited role: "One of our most important continuing functions is not looking at specific projects within areas of expenditure, but looking at broad areas of expenditure in order to see that the trends of expenditure are in the right direction."[119] He had emphasized the same point earlier: "We have to be careful to keep the Science Council out of recommending on relatively specific programs."[120] He saw another limitation: "The Council has decided itself that it can be most effective in dealing not so much with long-term as with broad strategic goals—and these, of course, of necessity usually are longer-term."[121]

Dr. Solandt also indicated that the social sciences were not specifically included in the terms of reference of the council: "I was unable to get any mention of social science put in, but the act just says 'science'; so by the Act, we are permitted to deal with social sciences problems. There has been strong resistance by almost everyone consulted to putting social scientists on the Council."[122] The council's chairman regretted this exclusion: "My feeling is that the social sciences must be represented at the national policy level, and social sciences must be considered in formulating national policy on an equal footing with natural sciences."[123]

The Department of National Health and Welfare also recommended "that the Science Council of Canada include in its membership adequate representation from the social and behavioural sciences."[124] Mr. Boucher thought this inclusion was premature: "In any instance, before the mandate of the Science Council is expanded to embrace concern for the direction taken by the social sciences, or before a parallel Social Science Council is established, it might be wise to wait and see what the present Science Council can do for the natural sciences. The courtship has barely started between two scholarly communities equally richly endowed with prejudices. It should be neither interrupted nor rushed."[125]

Dr. Solandt saw other problems facing the Science Council: "I do not think there is any doubt whatever that the work of the Council would operate better with a full-time chairman and probably with a full-time vice-chairman."[126] There was another much more serious difficulty: "We have to find a mechanism by which we have access to the decision-making powers of the government"[127] Dr. Solandt had alluded to this gap earlier: "We have begun to see that one of the major problems which the Council will face is the coupling of its recommendations with the political action in the Government. There is no use in the Science Council making representations, if nothing happens."[128] He referred to the decision that the council should report to the Prime Minister and said: "This was a good arrangement in every way, except that the Prime Minister does seem to have other preoccupations! This was something we had not quite envisaged."[129]

Dr. Malcolm Brown of the Medical Research Council also recognized that difficulty: "The most difficult part of the problem is at the centre, at cabinet level. Its solution would seem to lie in confidential and intimate scientific advisors who, on the one side, have open and free lines of communication with the Science Council and other bodies and who, on the other, communicate with the politicians with a freedom which only mutual confidence can bring. This is the most difficult part of the whole problem to organize. It is also its most essential part."[130]

This vacuum left the Treasury Board practically alone at the centre. But, according to the Honourable C. M. Drury, who was about to become its president, "the Treasury Board in the past has not been much of a generator of new policies or new ideas: it is rather more co-ordinator and controller than it is a generator."[131] And Dr. Solandt was not satisfied with the way the board exercised its function in the area of science policy.

> The President of the Treasury Board would like to have a list with every scientific activity in order of priority with a running total of expenses down the column, and when he decides how much to spend, he takes a pair of scissors and cuts the list off at that point.... But this is a totally unreal idea, because obviously so many of the projects in science are inter-dependent, and if you are not going to do this one, then it is not worth doing that one.[132]

For Mr. Simon Reisman, then secretary of the Treasury Board, "the national science policy really comprises a series of policies with respect to sectors. There is a policy in respect to pollution, a policy in respect to nuclear energy, a policy in respect to fisheries, a policy in respect to industrial research and development, divided into two, civilian and military defence. You also talk about a national science policy in the sense of comprising all those features. Together, they make up a national science policy."[133]

Once national science policy had been reduced to the mere sum of specific sectoral policies, Mr. Reisman believed that individual departments and agencies could be left with the responsibility of determining these particular science policies within the financial constraints imposed by general budgetary considerations. The brief of the Department of Energy, Mines and Resources appeared to support that view: "The department or agency has the responsibility of allocating its funds in various ways, among them being support for research. To deny a department or agency its power to control its funds is to deny the department or agency its ability to discharge its function."[134]

The Senate Committee, as seen previously, has heard strong criticisms of this decentralized system under which government science activities have developed in Canada. Other objections have also been mentioned. Dr. Arthur Smith, chairman of the Economic Council, stated: "We have been moving with a lot of bits and pieces at the moment and what we are really



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talking about here is how eventually we conceive of putting this together as something that really becomes a coherent science policy."[135] Dr. Solandt referred to the space program:

> Each one of these (DRB, NRC, DOT, EMR) has a real genuine interest in something connected with space. But if you ask any one of them to enunciate a national space program and ask how it should be organized, I think each one of them would say, "That is easy, just give it to me, I will look after it." And they will look after it, but they will produce a program which is conditioned by departmental interests rather than national interests. What we need is something that will make it possible to plan and organize a structure which will evolve a program on a national basis rather than on a departmental or regional or sectional basis.[136]

Later on, quoting from Report No. 4 of the Science Council, Dr. Solandt said:

> 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.[137]

And he went on: "It is amazing how often these things are not stopped; they keep on drifting away from their original mission-orientation towards being more broadly-based research in the same field but not really properly planned."[138] Mr. Carson of the Public Service Commission also regretted the lack of effective planning within the present system:

> Because of the lack of good long-range planning about the kind of direction in which scientific activity is going to go in the federal government, we are not in a position to give the sources of supply [of manpower] adequate lead time to be able to produce the kind of product we are going to need at the moment we need it. We are constantly engaged in crash recruitment programs to obtain a new kind of person that nobody envisaged in adequate time. It is hit or miss . . . . We do not have enough lead time in our information on departmental needs. Departments, of course, do not have enough lead time in terms of being able to do their own long-term planning.[139]

Thus, an overall science policy had to be developed, not by accident as the mere aggregate of specific policies, but in a coherent and systematic way to provide a general framework for the planning, co-ordination, and reconciliation of such specific policies in the light of national requirements. Dr. Solandt stated: "The real problem we face is one of co-ordinating the efforts of the research community and the scientific community throughout the country . . . . The federal government will be more and more concerned, not with the execution of research but the planning, co-ordinating and financing of research programs which will be widely spread throughout the scientific community, some by government, some in the universities and some particularly in industry."[140]

Mr. D. P. McIntyre, of the Department of Transport, indicated that the "... lack of a clear-cut science policy is one of the major hindrances that we are faced with. The better the science policy, the more easily we will be able to operate and the more easily we will be able to sell our programs."[141] Quoting from Report No. 5 of the Economic Council, Mr. Arthur Smith asserted: "What is required is the development of a coherent strategy which co-ordinates and blends the scientific, technological and innovative capabilities of government, the scientific community, the business sector and the universities."[142]

Dr. Solandt defined overall science policy as "a broad strategy for the use of science by the entire scientific community in support of the national goals."[143] According to Mr. Boucher such a policy "must provide a rationale for the apportionment of government funds between ministries and research councils on the one hand, and on the other, between development budgets, research contract budgets and research grants budgets . . . ."[144]

But there was the uneasy feeling that somehow a vacuum existed at the centre which prevented the formulation and implementation of such an overall policy. Dr. Schneider admitted that this vacuum was a cause of confusion: "I think the outside world is confused. I was at a meeting of the pulp and paper industry which is currently being held in Montreal and they asked a similar question, 'If we have some idea on science policy, or prepare a brief or something about, let us say, industrial research, who should we go to? Should we go to this Senate Committee or should we go to the Science Council or to any department or the NRC? We want to make an input; where should we make it?' I think there is a confusion here. Of course, at the moment, things are rather confused, we will admit."[145]

Dr. Whitehead of the Science Secretariat indicated that "there is perhaps lacking a linkage between the expenditures in Government which on the same subject go to industry, to universities and within Government. Often these decisions are made by totally independent bodies, and I think one of the very important things in the future is to obtain a mechanism by which the policy for the conduct of research can be linked in these three sectors . . . ."[146] Dr. Solandt also noted the vacuum:

> The truth of the matter is that there is no central mechanism for co-ordination except the cabinet, and the cabinet cannot deal with the level of detail that we

are talking about. The problem that faces the country is a fundamental one of Government organization, and the Science Council has hesitated to recommend a complete re-organization or a complete change . . . but maybe we should."[147]

Dr. Solandt had raised the same point on an earlier occasion: "[Science] pervades all sorts of agencies, and certainly the Science Council . . . in the future is going to be producing a series of recommendations that are going to require some adjustment of organization and some changes in organizational pattern."[148] He saw some difficulty in finding a practical solution: "It is very hard to find a Cabinet Minister who is interested in science to be Chairman of this Committee [The Privy Council Committee on Scientific and Industrial Research, now abolished] who is not himself responsible for one of the departments that is a major contender for funds, or the present situation where you have the President of the Treasury Board in this position and he is the major stopper of funds for everybody."[149]

However, Dr. Isbister, then deputy minister of the Department of Energy, Mines and Resources, was more specific when he stated: "So I have in this [brief] argued against putting all the science in one departmental bundle. I have, however, associated myself—and I think the senior officers of the department—with the idea of a ministry that would do far more than has been done in the past to look at government support of science in a co-ordinated integral fashion. Government must decide today what fields to select to back and what are the relatively less important fields."[150]

Dr. Roger Gaudry, of the Science Council, referred to the possibility of having a minister without portfolio "to look after science" and added: "I think more and more, personally, that this could be a good solution."[151] Dr. Solandt preferred the title of minister for science policy. However, both the chairman and the vice-chairman of the council were careful to add that they were not proposing this arrangement on behalf of the Science Council. At the end, all that Dr. Solandt would say about this alleged vacuum at the top was: "I feel sure that the government is very hopeful that your committee will include recommendations on this in your report, because it is a very difficult problem and one in which your wisdom would be most helpful."[152]

## CONCLUSION

The Committee does not want to leave the impression that the representatives of the government sector only expressed dissatisfaction about what they were doing. On the contrary, most of them showed pride in the achievements of their agencies. The Committee was impressed by these senior public servants, who are so dedicated to their missions and so anxious to serve Canada better. If they had not been so dedicated, they could have painted a rosy picture of the current situation without underlining its weaknesses and the need for improvement.

We must accord a great deal of attention to their critical assessment of the Canadian scene not only because it came from devoted and knowledgeable people but perhaps even more because it contained a dose of self-criticism. It must also be emphasized that many comments were not so much a criticism of the past as they were constructive suggestions for the future. And the Committee was impressed by the great similarity of views presented by the spokesmen for the government sector. Such unanimity adds a great deal of authority to the recommendations made to us.

In summary, and if they are considered in the light of a historical perspective, these views lead to the inescapable conclusion that the Canadian model for the national science effort, which was first presented in 1916 and still to a large extent survives today, does not fit the Canadian conditions and requirements of tomorrow. In other words, the hidden or informal but real science policy which has been implemented up to now has been found wanting by a most impressive group of high public servants. The conventional wisdom can no longer serve Canada's national objectives, if it ever did.

In the light of these new views, what should be done?

The Canadian government should develop an integrated and effective system of scientific and technological information to supplement the national R&D effort and to enlighten science policy. The national effort itself must be intensified if Canada is to participate actively in the international scientific and technological race.

The new wisdom prescribes that the additional R&D effort be devoted to the life sciences and social sciences rather than the physical sciences, to engineering and development activities rather than scientific disciplines and fundamental research, to economic and social objectives rather than curiosity and discovery. It recommends the strengthening of industry as a performer of R&D. To attain this objective, it assigns a bigger role to the government in the funding of R&D, a function that should be fulfilled through more R&D contracts and more effective, better integrated incentive programs.

Senior government officials want a more coherent and effective scientific manpower policy, which implies the revision and greater co-ordination of scholarship and fellowship programs. This need for more effective co-ordination applies not only to the various granting agencies but also to all intramural R&D activities in the government sector.

Finally, the new wisdom concludes that these proposed changes are so substantial and pervasive that they cannot be effected without the formulation of a coherent overall science policy and the creation of a central machinery to implement it. What this machinery or these new central mechanisms should be, however, is carefully not defined. Judged in the perspective of the conventional wisdom, the set of proposals presented to the Committee by the government representatives was nothing less than a revolution.

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61. Ibid p. 3059
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# 8

## THE UNIVERSITIES AND PROVINCIAL RESEARCH ORGANIZATIONS: OBSERVATIONS FROM THE EVIDENCE

Unlike briefs from the federal government sector, those from the private sector and provincial agencies were not in direct response to a detailed questionnaire. The Committee simply requested that the individual or organization give whatever advice and information on science policy he considered important. It was hoped therefore that these briefs would represent specific experience and concerns from knowledgeable people with day-to-day responsibility for carrying out the many activities connected with science policy. In effect the Committee asked: "From where you sit and on the basis of your responsibility, knowledge, and experience, what advice do you wish to give us?"

The evidence received by the Committee from the academic sector and from provincial research foundations was quite different, as was to be expected, from that submitted by representatives of the federal government sector. Universities stressed their various roles but more particularly their mission as centres of basic science and fundamental research. The provincial research foundations, on the other hand, described themselves as promoters of new industrial technology and complained about the lack of recognition and co-operation they had received from federal agencies.

### THE UNIVERSITIES

Ever since Canadians first began to think about science and the need for a science policy, the universities have figured large in plans and policy proposals. They still do. The university is where a man starts to become a



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scientist or technologist. Whether he then builds a university career or works outside the academic world, his university education will have been a significant influence on the whole country's relations with the world of science and technology. If Canada moves ahead in the international science and technology race, the universities will deserve much of the credit. If we fall behind, or if the population comes to consider the scientist as an ivory-tower isolationist and science as a sinister force, the universities will have to accept much of the blame.

In the course of our hearings we received many comments on the universities from scientists and technologists outside the universities; industrialists, officers of provincial research councils, and others. So far, it appears that there is no set or single attitude. Many in industry are concerned that the universities prepare their graduates poorly for life outside the academy. More than one witness left the strong impression that the Canadian universities' attitude toward science education is like that of British universities in Victorian times: an attitude of distaste for work of a practical or technological nature. More practical researchers and industrialists are disdainful of what they regard as academic solitude and impracticality. Others, it became clear, consider the universities well capable of carrying out research that will be valuable and useful to industry and to the nation at large.

Dr. Max Tishler, first vice-president of research, Merck Frosst Laboratories, told the Committee:

> The thing we need from universities is a motivation to go into industry, this is a thing that has been lacking . . .
>
> We have to break down . . . the social barriers that exist . . . [We] are not getting these top-flight people because of these . . . social barriers. The universities have to point this out to their students, and industry has to help, making students realize there is a good research career in industry.[1]

Dr. W. N. English, head of the division of applied physics at British Columbia Research Council, commented:

> I must say that they are not so motivated in some engineering faculties in the universities towards industrial research. The really good ones are motivated towards becoming university professors.[2]

Mr. A. D. Fisher, vice-president of the planning, engineering and research division of the Steel Company of Canada, added:

> . . . In teaching methods, too, we feel that there is too much of a theoretical approach and that we are generating people in the graduate area who are not well oriented on those problems of industry and who are not as well assimilated in industry, as a result.[3]

Imperial Oil Limited, on the other hand, regarded universities as good sites for specialized research institutes, though the company gave one qualification:

> We favour the establishment and maintenance of institutes oriented to specific missions or set up to provide exceptionally high cost facilities for common use. Such institutes frequently can be associated with universities. We are somewhat concerned, however, at the establishment of university institutes intended for general contract research, unless a real need for such services can be demonstrated. We would urge that existing provincial research institutes, which are available and anxious to provide such service, and the universities should work together more closely.[4]

## THE UNIVERSITY VIEW

All universities and colleges were invited to present viewpoints and recommendations to the Senate Committee and all but a few responded to this invitation, either by submitting written briefs or by giving evidence during "university week". Representations to the Committee did not always claim to be a university consensus. Individual briefs were received from a university president, a vice-president, and a dean of science; from various science faculties, a number of engineering faculties, a faculty of arts, and a faculty of administration, as well as from departments of religion, computer sciences, physiology, and geological sciences, and from several university research boards. Together they form a useful and important sampling of how the universities perceive their role in Canada's scientific affairs.

All university submissions dealt with matters that are of direct interest to the university sector: the roles and responsibilities of universities, the nature of university research, government grants for university research, and the interaction between universities, government, and industry. Several submissions included general considerations on R&D conducted in industrial or government laboratories, and many contained suggestions for elements of a national science policy.

The purpose of this section is to present a synthesis of the varied opinions and ideas that were presented to the Committee by members of the university community and to recognize whatever trends and patterns emerged from these submissions.

According to the evidence presented to the Committee, universities—either explicitly or implicitly—recognize three roles. Two of these, teaching and basic research, are accepted by all universities. The third is not universally accepted, but was recognized and advocated in more than half of the university submissions. That is the university's role as a collector and disseminator of information—the university as a regional consultant.



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### 1. *The teaching role*

Because of the Committee's concern with science policy and thus with universities' research activities, most of those submitting briefs discussed this subject and ignored, or played down, their teaching role. Most of them undoubtedly consider teaching their prime function. Some specifically said so; for instance, Acadia University:

> Under proper circumstances, there can be no doubt that society has the right to expect that the universities which it supports be cognizant of and responsive to community, regional and national interests. In so doing, however, it is essential that the prime function of the university, that of educating students, be not neglected. The prime function of the university is then to educate young men and women.[5]

Yet it is obvious that the relationship between teaching and research is significant. At the postgraduate level, certainly, the two appeared to be almost synonymous in some briefs. In some universities, research almost seems to replace teaching as the prime function. This of course influences what the student is taught and how he is taught it.

The university is often credited with "socializing" the young scientist or engineer—making him aware of the society around him and responsive to the needs of that society. Some universities emphasize this aspect of a student's education more than others. Some university professors even regret that the student is not made more aware of society's needs. It was in that spirit that Professor W. I. Schiff, dean of the faculty of science at York University, said:

> We start inculcating in our students right from freshman year on in our science programs that pure science is the only pursuit; that it should not be polluted or contaminated; and in what we are teaching little relevance to society ever gets into our discussions...
>
> We then point out to the students that the honours degree is certainly the only degree and that the ordinary degree is a consolation prize; and, furthermore, if they are good, they must go on to get their Ph.D.s. And then, at the Ph.D. level, the more esoteric the thesis subject, the more value it is considered to have.
>
> What we are doing then, is producing carbon copies of ourselves, because, after all, we have turned out so well, the best thing we can do for the students is to make them over in our own image. [Graduates] find themselves faced with two difficulties... getting jobs, [and] an even worse one is the fact that frequently they do not want jobs outside. They want jobs in the university. So we have helped to create this monster ourselves.[6]

Reading the many university submissions, we must conclude that Professor Schiff may have identified an important characteristic of Canada's higher education. For instance, the calendar of the University of Alberta states:

> The essential requirement for the doctorate is the planning and carrying out of research of high quality leading to an advance in knowledge in the candidate's field of study.[7]

The Alberta submission notes:

> The candidate's chances of meeting this requirement are greatest if the research project is fundamental in nature or has fundamental aspects.[8]

### 2. *The research role*

Teaching through research underlies many of the university recommendations. For instance, Dr. J. W. T. Spinks, president of the University of Saskatchewan, said:

> One of the main objectives in teaching at the university is to inspire the student to work and think for himself. Who can do this better than the man who is still actively contributing to the production of new knowledge?[9]

Dr. John Hart, Lakehead University, added:

> The research function is necessary to a university because without the continuous challenge of the research laboratory, a scientist ceases to be a scientist and becomes a conveyor of dull facts . . . If all research were carried out in non-teaching institutions, there would be no passage by which the expertise of the scientist could be conveyed to the younger generation, and what a tragic loss that would be.[10]

Nevertheless, there is some agreement that a talent for teaching and conducting research is not always found in one man:

> . . . Most deans would say that in forming a faculty they have to balance these functions as best they can . . . by hiring faculty members who are primarily teachers, faculty members who are primarily research workers, and they will hope to obtain the rare paragon who is a mixture of both.[11]

Professor P. B. Waite, chairman of the Humanities Research Council of Canada, told the Committee:

> . . . Research does not necessarily produce good university teaching. It is commonly held that research and teaching go hand in hand, but often you find that a professor is hidden in his own research and research papers, and

he would be far better off doing research on the lecture he is planning to give the next morning rather than the paper he is going to deliver to the Canadian Historical Association next June.[12]

As mentioned earlier, most universities accept the close teaching-research relationship without much question. Several points arose during the hearings that seem to call for further inquiry:

(a) Are the teaching and research functions necessarily concomitant at all levels of learning?

(b) If not, when should one or the other function prevail?

(c) Does the performance of both functions at times detract from the successful performance of one or other role?

(d) Should talented teachers be freed from research commitments or pressures ("publish or perish")?

(e) Should good researchers be freed from "the burden of teaching"?

We should point out that nearly all the universities assumed that teaching had to be supplemented by research; only those already quoted implied that there might be justification for freeing teachers from research pressures.

The university's need—indeed its right—to do "basic research" as an end in itself is advocated, defended, reiterated, emphasized, and explained in almost every university submission. For instance, the faculty of science at York University, stated:

The universities should continue to be accepted by Federal and Provincial Governments as the most important source of pure science in the country.[13]

Dr. Spinks of Saskatchewan declared:

. . . Nowadays the universities have as one of their major aims the extension of the boundaries of knowledge . . . Universities have proved . . . to be ideal places for doing fundamental research; they provide time to think, and opportunity to work and talk with keen minds in other disciplines, the stimulus of contact with bright students, the lack of being prodded to some close and fixed goal.[14]

The faculty of science at the University of New Brunswick said:

As it is impossible to predict through foresight which basic research will have a useful application at a later time, the continued investigation of basic problems in universities is utterly vital and invaluable to research in its broadest sense and to the eventual success of applied research.[15]

The University of Guelph's research advisory board commented:

The university setting is ideal for fundamental research aimed at extending the theoretical background for scientific and technological progress as well as

> for the advancement of knowledge in general... The university campus in Canada should be a major source of the new fundamental knowledge produced in Canada in most areas.[16]

St. Francis Xavier University added:

> We believe that the university should be responsible for the greater part of fundamental research that is basic to all Research and Development.[17]

There was an even stronger expression of university opinion on the value of "basic research" for its own sake. The University of Calgary, for example, stated:

> Universities have traditionally guarded their right to the unencumbered pursuit of knowledge for knowledge's sake with such fervent jealousy that even the hint that Canada's National Science Policy will swing heavily in favour of mission-oriented research raises every academic hackle in sight... Enthusiasm for fundamental enquiry is a frail flower difficult to nurture but easy to destroy. We urge that any statement of Science Policy... establish beyond any doubt that no form of research can thrive without the continued healthy growth of unencumbered fundamental inquiry...[18]

The research board of the University of Manitoba said:

> ... Assigning to a single granting agency the task of supporting both uncommitted and committed research... is dangerous... For example, with the present emphasis on mission-oriented research, one might find this consideration beginning to colour all grants. Thus, the nation might lose the high quality of fundamental research which it now possesses, and which is essential to underpin most of the applied activity.[19]

These opinions are representative of the university attachment to basic research. Further evidence lies in the fact that none of the university submissions suggested a reduction in the funding for basic research. On the contrary, some witnesses feared that the need for more applied research and technological development might jeopardize the future of basic research, and there were many requests for increased funding of university research.

The Canadian Association of Graduate Schools, for instance, said:

> We urgently recommend that there be an increase in the federal funds for university research and scholarship programs for the year 1970-71.[20]

Dr. Spinks of Saskatchewan said:

> Greatly increased federal research support, both operational and capital is required.[21]

The faculty of administration at the University of Saskatchewan declared:

> More money must be generated in the area of R&D in general and in academic research in particular.[22]

The University of Alberta commented:

> Any science policy on a national scale must provide adequate funds for university research which is basic in character.[23]

The intense need for money seemed to overshadow many other considerations. It was impossible to escape the impression that many universities considered "research for its own sake" so important that teaching had become secondary. However, the problem of the ever growing demand for funds was recognized by some universities. The research and liaison office of Notre Dame University in Nelson, B.C., wrote:

> For academic and economic reasons even this type of research cannot be independently and autonomously engaged in to an unlimited degree . . . Even this work needs to be coordinated in its organizational and financial aspects (1) always and in the first instance by the universities themselves, and (2) if necessary, with discreet "encouragement" from the respective levels of government, acting in concert.[24]

And the University of Calgary stated:

> The freedom to engage in fundamental enquiry . . . frequently finds itself extended to mean freedom to research on anything at any time by anybody anywhere. It goes without saying that adoption of this policy quickly produces astronomical projections for future costs . . . It is not unreasonable for those who foot the bill to expect at least a modicum of efficiency in the manner in which their dollars are spent.[25]

Some suggested measures to avoid the whimsical use of resources, and several universities thought the federal government might take the necessary action. Memorial University of Newfoundland declared:

> Co-operation between universities in making use of costly facilities is essential. Federal grant-giving agencies . . . can force would-be expensive prima-donnas to orchestrate their efforts.[26]

And Dr. Spinks commented:

> From what has been said about the important role of the universities in the total research picture, it becomes equally urgent to develop policy with respect to research in the universities. Here coordination is required (a) at the Provincial level to see that there is no unnecessary or wasteful duplication of effort

and that major Provincial needs are met and (b) at the national or inter-provincial level to see that again there is no overall unnecessary or wasteful duplication of effort and that major national needs are met. All of which is equivalent to saying that there should be a systems approach to research in the universities. As senior partner in the operation, it would seem advisable that the Federal government take the lead in fostering such a systems approach.[27]

Some universities felt that much basic research could be encouraged to fit into "missions" or would automatically do so, once priorities were assigned to national problems and goals. In view of the strong university preference for basic research, the Committee was interested in their view of "mission-oriented research". Most university briefs favoured an increase in mission-oriented and applied research either within the university or in university-affiliated "institutes", with the proviso that the increase should not be made at the expense of basic research support. The Universities of Laval, Montreal, and Sherbrooke, in a joint brief, said:

> It is essential that our science policy concentrate on selected areas that are compatible with Canadian individuality. Thus, research in such fields as transport, communications, water use and conservation, northern development and intercultural relations would enable Canada to meet her own special needs.[28]

The University of Waterloo recommended:

> That the universities be encouraged and given the support to assume more responsibility in the pursuit of research generated by problem recognition.[29]

The Association of Universities and Colleges of Canada reported a resolution:

> That the AUCC encourage increased support for applied research in universities as a means of raising national productivity.[30]

The research advisory board at the University of Guelph stated:

> Applied research of a mission-oriented nature should be conducted in the university to the mutual advantage of the university and the nation.[31]

The Canadian Association of Graduate Schools felt, however, that little applied research should be undertaken in universities:

> This brief... puts forward the view that most, but not all, pure (i.e. basic) research should be done in a university setting and most, but not all, university research should be free of specific applied goals.[32]

Most of the 20-odd university submissions that discussed the types of research universities might undertake, however, looked for support and encouragement for mission-oriented research in universities; and most of the briefs that considered mission-oriented research related it to the third role of universities; the role of regional consultant.

3. *The need for decentralization and centres of excellence*

A number of universities told us that they wanted their community role recognized alongside of their teaching and research responsibilities. Most thought this expansion of their activities would be valuable to the nation as a whole. For example, B. W. Currie, vice-president (research) on the Saskatoon Campus of the University of Saskatchewan, said:

> The current discussions on a science policy for Canada are failing to recognize the responsibilities and the potential capabilities of our universities for research and consultative services related to the needs of the community or the Province in which each is located . . .[33]

The Memorial University of Newfoundland had this to say:

> We believe that developments of regional or local interest should be encouraged by providing help to establish, at specific universities, institutes whose research activities would be of importance to provincial development . . . Examples may be cited:
>
> The creation of an institute, suggested by the construction of a large phosphorous plant at Long Harbour, Newfoundland, devoted initially to research in phosphorous and silicon chemistry. This might well help to stimulate the growth of secondary phosphorous-using industry in the region. In time, there might develop a centre for extensive studies in the chemistry of numerous non-metallic elements, for example, nitrogen and arsenic . . .
>
> The geographical location of Newfoundland in relation to important fishing grounds in the North Atlantic and existing Marine Sciences Research Laboratory suggest the development of a regional institute of cold-water marine biology.
>
> Ocean-orientated research should cover much more than marine biology. Marine aspects of civil engineering provide and outstanding example, as also does marine geology and under-water research techniques. Here research activities can be expected to stimulate future industrial development.[34]

A number of universities recommended specialized research institutes dedicated to the development of new knowledge and technology or "centres of excellence" intended to focus regional research and development efforts. The University of Guelph's research advisory board suggested:

> Canada cannot provide enough funds for fundamental and applied research to permit the luxury of the dispersion of these limited funds to a multitude

> of small research centres. It would seem desirable to consolidate research by maintaining only research units of a size which assures viability in modern research. The primary units that need to be supported to the level to make them strong are the universities because of the dual role they perform for Canada—the training of the scientific personnel and the production of research results. Science in Canadian Universities has not been adequately funded to allow the universities to discharge these functions at the level necessary.[35]

And the University of Saskatchewan's Dr. Spinks said:

> A long-range program for the orderly development of centres of excellence in Canadian Universities is long overdue.[36]

However, the suggestion of creating "centres of excellence" was often qualified. Memorial University, for example, wrote:

> In arguing that the allocation of research funds should take into account... the necessity to think, to some extent, in regional or provincial terms, we are not arguing that any attempt should be made to create an important research centre at every university in Canada..."[37]

In the final analysis, however, a number of universities appeared to be pessimistic about the regional role of the university in view of the "excellence" criterion that is applied by many federal granting agencies. Some of the briefs referred to Dr. Dugal's minority report,[38] which stated:

> ... their philosophy [the Macdonald Group] ... is that the policy of granting awards must be based on the criterion of excellence only, the 'High Merit' which is repeatedly stressed ... This is not a realistic policy because it does not take into account the present state of university affairs in Canada. I would agree with such an ideal policy if all universities enjoyed the same favourable conditions for attaining the desired excellence; the fact is that for many reasons, desirable or minimal excellence is not reached at the same time by every individual or organization. Many research scientists, laboratories, and institutes today enjoy a level of excellence they certainly did not have when they received their first awards. Had they been subject to the same policies as are now proposed, they would not have been eligible for the awards they received, often very large, which enabled them to attain their present level of excellence....

Dr. John Hart, dean of science at Lakehead University, agreed with this viewpoint:

> Dr. Dugal appears to predicate his minority report on the problems of French Canada, but I would like to reassure him that English speaking universities do have the same problem. The policy of granting awards, which must be

> based on the criterion of excellence, is not a realistic policy because of the rapidity with which the country is growing . . . The Macdonald report and the recommendations appear to me to be very much a report by the establishment.[39]

The Memorial University of Newfoundland also endorsed the criticism:

> Certainly, success must be supported and centres with developed facilities for effective research must not fail to receive support . . . But neither must we, as we so frequently now do, adhere rigidly to the biblical injunction that 'to him who hath much, much shall be given.' For such a policy will not only retard developments in areas where they ought to be taking place, but will be self-perpetuating.[40]

As science and technology, and especially their influence in innovation, are very dependent on inter-personal communication it is obvious that Canada's geography and population distribution will present regional opportunities to research groups, as well as problems. In addition to the witnesses previously quoted, the French-language universities in Quebec told the Committee about some of the specific problems and opportunities they face. The Committee is grateful to the French-language universities of Quebec for taking the pains to produce a joint brief. It was presented by Dr. Maurice L'Abbé, vice-rector (research) of the University of Montreal, and Dr. Larkin Kerwin, vice-rector (research) of Laval University, on behalf of Montreal, Laval, and the University of Sherbrooke (the University of Quebec did not exist when this brief was being prepared). This joint brief assisted all those concerned with science policy by producing a unified view.

Dr. L'Abbé told the Committee: "We are aware that the French-speaking universities have developed more slowly", for reasons which he described, but, he said, "now, from the point of view of quality, the major Quebec universities have attained standards and a development in several areas whereby they compare favourably with their English counterparts in the rest of Canada".[41] "Our research workers", he added, "can now openly compete with their colleagues in the major federal agencies."

Nevertheless this late start led to a disparity that the joint brief discussed:

> One thing is certain: Quebec's share of the benefits flowing from such federal institutions is minimal insofar as the development of research within the province is concerned. Thus, not only have Quebec's taxpayers contributed their fair share to the establishment of federal government laboratories in Ottawa, they have also subsidized regional research activities with federal funds that are spent more generously elsewhere than they are in Quebec . . . The total paid by the federal government in subsidies to Quebec's French-language universities reveals a basic problem. The figures for 1967-68, for

example, show that out of a national total in federal subsidies of $72,481,000 the three French-language universities in Quebec received $8,046,000, or 11.1%.[42]

In view of the recently improved development of the French-language universities, the brief continued, they were "ready to experience the growth in scientific activity that occurred in several English-language universities thirty years ago, at a time when the roots of a number of large growth centres were being laid down. We therefore recommend that the federal government use its offices to capitalize immediately on this opportunity for expansion in Canadian scientific activity."[43]

Dr. L'Abbé told the Committee: "We hope that there will be an overall policy . . . [but] it must not block either regional differences or our attitude in cultural differences, which perhaps do not have repercussions on science itself, since science is universal, but which do have obvious repercussions on research workers and scientists."[44]. In other words, it is science policy that guides the activities of scientists and research workers; the policy must take account of their motivations and aspirations, as well as of R&D activities.

The submission of the three universities pointed out some of the problems French-speaking scientists face. The French-language universities receive a smaller proportion of federal research grants than their population would justify, even though their present abilities could usefully absorb this money. Then, federal government departments and agencies have apparently shied away from building research laboratories in Quebec. As the brief put it:

> Moreover, the federal government has established an impressive number of regional laboratories or research institutes throughout Canada. Capital investment has been vast, and operating costs are considerable. These regional research centres are a valuable asset for universities located in their vicinity, either through actual co-operation between federal laboratories and universities, through the outlets they provide for students during their vacations, or through their researchers' participation in graduate teaching.[45]

Dr. Kerwin told the Committee: "In Canada, we have approximately 30 large-scale federal laboratories. These laboratories are scattered here and there and are fortresses of strength for both the recruiting and the marketing of scientists. However, only one of the 30 laboratories is somewhat bilingual. That is the Defence Research Board laboratory in Valcartier."[46] Dr. L'Abbé also commented on the fact that this "improving number of regional laboratories or research institutions" established by federal departments or agencies were mainly "located in an English milieu, with the result that access for French-Canadians and, particularly, French-speaking persons of other countries, is most difficult."[47] Dr. L'Abbé also said: "It is impossible to imagine a French-speaking person arriving at the National Research Council and not speaking English and even, in my opinion, at Valcartier where administration is still unilingual . . . . There is some talk now about making it [DRB's Valcartier laboratory] into a unilingual centre, which would be normal in order to compensate for the Anglo-Saxon unilingual centres which exist and which will not change".[48]

The witnesses indicated that the absence of French-speaking research institutes and regional laboratories in Quebec aggravated an already difficult recruiting problem, because such laboratories would provide a reserve upon which the universities could draw. Dr. Kerwin spoke to the Committee about the problem of recruiting skilled scientists. For English-speaking institutes the source is the vast North American labour market. But "our situation in French Canada is very different. We do not have the same recruitment possibilities at all and our recruitment problems are much different from that of English-speaking universities. Consequently, that cultural difference which makes itself known by a recruitment problem must be reflected in science policy by the creation of appropriate frameworks for such a situation. That is a specific example where science policy must demonstrate itself through . . . forms of structure of policy which take into account the needs and the cultural situation of the two language groups."[49]

The joint brief included a recommendation:

> That the federal government use its offices to capitalize immediately on this opportunity for expansion in Canadian scientific activity. Laval University, the Universities of Montreal and Sherbrooke must be the sites for the establishment, within five years, of several large laboratories or research centres; in a few special cases, this could be done preferably through the medium of inter-university or university-government installations. Appropriate precedents currently exist in French Canada, and our recommendation, in essence, is that the present policy be applied on a broader scale. We further recommend that the federal government establish unilingual French-language research laboratories in Quebec, and that close ties be developed between such laboratories and the universities.[50]

Thus it was obvious to us that all Canadian universities placed a high value on basic research, as a teaching mechanism and as an end in itself. Many professors, in fact, considered basic research their prime function. All the universities wanted to continue this function, preferably on a larger scale than before. There was, however, a growing tendency to direct much of this research to national needs and opportunities and there was a consensus that more specifically mission-oriented and applied research was necessary, provided it did not jeopardize basic research. Many universities would welcome recognition or expansion of their role as regional consultants; many recommended affiliated research institutes to deal with specific local problems. A number of universities feared, however, that they did not meet the current criteria for most federal grants. They urged that a "centre of excellence" policy should be designed, not only to reinforce existing "excellence" but to help create more "excellence" in, for, and about Canada's distinct regions.

### THE SOCIAL SCIENCES

In this volume we have concentrated on the physical sciences and the engineering and technology associated with industrial innovation. This is because the volume is primarily concerned with the development of Canadian science policy during an era when that was what science policy—the "first generation science policy"—had to deal with.

Now we are moving to new concerns in science policy. There is a declared concern for "science for society's sake", a need to develop "technology with a human face", in the sense that the problems of day-to-day living must be taken into account. Most of our witnesses felt this. It was suggested by Acadia University, for example, that "if we are to reap and to enjoy the fruits of our research and development in the realm of science and technology, it is patently obvious that comparable advances must be made in the humanities and social sciences."[51]

This implies that the situation of research in the social sciences and humanities is not too bright at present. As Acadia concluded: "It must surely be recognized that by any standard of comparison our record of support for the latter [the social science and humanities] has been abysmally poor". Only by correcting this imbalance, Acadia's brief said, "can we look forward with confidence to an improvement in the quality of our life."[52]

The Social Science Research Council of Canada commented in a similar vein: "It is unnecessary to elaborate further on the inadequate research support for social science research in Canada. And yet, how can we in Canada expect our governments to confront successfully the wide variety of social problems without a significant increase in knowledge in the social sciences, which is to say, increased research in these fields?"[53]

Some indication of the demands that will face the social sciences was given in the University of Waterloo's brief, which called for studies "in the relation between research and social benefit." The university claimed that "the support of research by any government must make economic sense and yet insufficient knowledge is available at this time to assure this."[54]

The broad impact of science and technology on society also needed fresh study, according to McMaster University's department of religion:

> Insofar as the scientist has been only a scientist and has not also been a philosopher (in the broad sense of lover of comprehensive wisdom) he has not been adequately aware of the limits and potentially dehumanizing effects of his discipline. . . . Whatever the shortcomings of the scientist, the rest of us must bear part of the responsibility for the unfortunate influences of science in the modern world, for we have been content to be so ignorant of even the most elementary aspects of the scientific enterprise that we have not known how to assess, appreciate and complement the scientist's work.[55]

Division II of Carleton University's faculty of arts listed some of the complex problems of contemporary life:

> Canada is currently faced with a multitude of problems in the areas of mental health, transportation, housing, the economy, environmental pollution, northern development, foreign policy, the use of our natural resources, regional disparities, urban growth, and national unity, to mention only a few problem areas. The social scientist, given adequate facilities, has much to contribute to the solution of these problems.[56]

A vital Canadian problem was mentioned by the Social Science Research Council of Canada:

> The extensive (and expensive) research carried out by the Royal Commission on Bilingualism and Biculturalism served to point out clearly the appalling lack of basic research on one of the major Canadian phenomena. Important work still needs to be done on a myriad of problems and situations that have not yet been forced to public and political attention.[57]

Dr. Kerwin of Laval University made a remark to the committee that reinforced the council's comment. It seemed to him, he said, "that Quebec clearly stands out as one of the important research centres in bilingualism and biculturalism and that applies also on the international scale. We know that there are perhaps 12 large-scale centres in the world. There is no reason why Canada should not rank with them one day."[58] The joint brief of Laval University, the University of Montreal and the University of Sherbrooke stated that "it is essential that our science policy concentrate in selected areas that are compatible with Canadian individuality."[59]

An important research area in the social sciences was identified by the University of Alberta:

> Education has a very important role to play in bringing about changes in our social structure. It is, in fact, a social science of greatest importance.

> Policies in Canada have resulted in very little support for research into elementary and secondary education.... A science policy that neglects this area will neglect one of the most important channels for educating people to accept and contribute to the social changes that will be required.[60]

Research on education would inevitably involve research in child development. The Canadian Psychological Association noted that this was one of the areas of research that must be conducted in Canada:

> It is ironic that those fields of Psychology which have been relatively underdeveloped in Canada are precisely the fields in which it is not possible to rely completely on the results of research done in other countries. To the highly developed areas of physiological and experimental psychology, it is a matter of indifference whether studies are conducted in laboratories situated in Montreal or in Boston or Tokyo. But where it is a matter of establishing norms for the psychological development of children or of applying social psychological techniques to human problems in industrial or community settings, it is always necessary to do local research before the relevance of findings reported from other countries can be assessed.... If the country is to obtain an appropriate benefit from the funds invested in psychological research it is necessary to give more encouragement to those areas of behavioural science which impinge more directly on human problems in a Canadian context.[61]

The Canadian Council for Research in Education suggested "that one per cent of the total expenditure on education be allocated for research and development, and that the federal government contribute half of that amount."[62] Based on 1968-69 expenditures of $5,931 million, one-half of one per cent would be approximately $30 million. The council recommended suitable areas for federal contribution "which would not infringe on provincial control of formal education within provincial territory;"[63] these included "the utilization of modern communication devices in education and training," "the development and most effective use of modern media (hardware and software) including computer assisted instruction, television, films," and "basic research in the field of cognitive, emotional and motor behaviour related to learning, memory and such."[64]

The faculty of administration of the University of Saskatchewan's Regina campus stressed the need for more research into administration: "Several of our faculty have been thwarted and frustrated in their attempts to secure funds for study in the areas of public, business, and health administration." The brief stated that a $500,000 grant from the Ford Foundation was the main support for "the one institution in Canada which has gained a national reputation for innovative research in the area of administration. . . ." Regarding management education, the brief noted that for the 1967-68 academic year U.S. universities granted 490 Ph.D. degrees as compared to one in Canada.[65]

The Social Science Research Council of Canada noted the need for increased support for the social sciences, which would "contribute to increased confidence and ability within our community in the future."[66] It drew attention to the danger that mission-oriented research might pose for basic research and went on to comment:

> Indeed, it would be futile, as Dr. Michael Oliver has pointed out, and contrary to the public interest to resist the demand that part of our social science research capacity be devoted to the analysis of those problems that interests outside the scholarly community regard as the most important.... But the dangers of community-generated research over balancing scholar-generated research are clear and disturbing and they are the greatest where government and business concerns coincide.[67]

Those concerned with research in the arts and humanities must inevitably view any increase in funding of the social sciences as a potential threat to their own fields. The brief of the Humanities Research Council of Canada pointed out that "the more the Humanities remain under-nourished, the more the national interest suffers.... Too often we see the Humanities short-changed, and not only at the national level. Through its funding of practical, mission-oriented research, largely in the social sciences and natural sciences, the government actually and relatively has been causing a reduction of support for the Humanities. Over the last fifteen years a situation, disappointing in 1951, has been allowed to grow worse."[68] The brief added: "We note with some envy and apprehension that in 1967-68 the National Research Council committed some $40 million to the support of research and development in universities".[69]

Witnesses pointed out the need for interdisciplinary or multi-disciplinary research in the face of contemporary problems. One example was the recommendation of the Canadian Mental Health Association:

> Particular emphasis should be placed on the value of multi-disciplinary research teams which bring the biomedical, sociological and psychological professions and disciplines together in a concerted attack on the seemingly vague and so-called 'soft' areas of mental health research. Such areas... would include problems relating to cultural, social and emotional impoverishment and deprivation.[70]

Among the other requirements of the social sciences and humanities, a large increase in library and information retrieval facilities was recommended in a number of submissions. Professor F. Ouellet of the Canadian Historical Association said:

> A good archival organization is vital for the progress of the [history] profession .... Provinces' archival institutions ... sometimes are not very well organized .... Improvement is necessary .... There is need for ... a much more systematic program of acquisition of private papers, ... not only the papers of the political men, but also the papers of the business firms and the papers of various institutions. Economic and social history can't develop without that.[71]

Dr. Roy Wiles of the Association of Canadian University Teachers of English stated:

> In order for reputable, respectable research to be done ... we must have available all the texts. These are increasingly difficult to procure and increasingly expensive .... Massive increases in library holdings should be provided at expense which will be very considerable.[72]

The Canadian Economics Association commented:

> Canadian university libraries—while generally adequate for undergraduate teaching (aside from pressing shortages of space)—are notoriously second-rate from a research point of view. Few libraries are adequate to support intensive scholarly, historical, or institutional research on other than a very narrow range of Canadian topics.[73]

That was the background of a comment from the Social Science Research Council:

> If Canadian researchers are to be aided in their work, libraries must be encouraged to keep pace with the rapid technological developments taking place in the concepts of information retrieval. This Council recommends that concentrated efforts be made to establish a nation-wide information retrieval system centered on Canadian libraries. Related to this is the Council's present investigation of establishing a computerized bank of social science data and information.[74]

Other facilities are also needed for social science research. The council said:

> The demands of modern research involve such necessary tools as data banks, computer centres, survey centres, information retrieval centres, and similar aids. Large sums of money will be needed to establish these facilities, and their major support should come, in our opinion, from the Federal Government. There should be a considerable number of these centres (at least five) across the country in order to provide that infra-structure which has now become necessary for work.[75]

Many universities favoured the idea of "regional bibliographical" or "regional information" centres, not only for the physical sciences, but particularly for the social and human (or behavioural) sciences. In many instances, such a suggestion was among the measures recommended to ensure effective performance of a university's regional role.

Several witnesses warned that the social sciences would be in danger if all funds came from the federal government. Some witnesses also wanted federal support to be decentralized. The Canadian Political Science Association stated:

> It seems to us short-sighted and unwise, that on grounds of "efficiency", there should be any rigid centralizing of the grant structure by which federal money finds its way to political science research. We oppose the principle of a single agency or channel, and instead endorse a variety of methods, and "buffers" between government and universities, and above everything else, we endorse more funds.[76]

The Canadian Association for Education in the Social Services claimed that "a counterpart of the medical research council is urgently needed for the field of social research. An adequately funded body aiming to promote knowledge, through research, of social problems, policy and interventions needs to be brought into existence. Such a body would complement the research interests of the mission oriented agencies by providing support for welfare research as an end in itself."[77]

We have reported the claim that universities were producing too many Ph.D.s but scanting the demand for scientists and engineers. Witnesses suggested that there was a danger that the growing interest in the social sciences would increase the imbalance. For example, Dr. L'Abbé of the University of Montreal told the Committee: "There is a craze for social sciences and letters which may be to the disadvantage of the social disciplines."[78] Dr. L'Abbé reflected that as a result of this trend toward social sciences the University of Montreal had, at that time, 2,000 students in the Department of Social Sciences. These students would not easily find jobs, Dr. L'Abbé said; steps were being taken to create "a second degree, a second cycle which would be much more professional; for instance, a doctorate in communications which would be available to graduates of quite specialized disciplines, such as political sciences or sociology, or linguistics, etc. I think that we have failed in not creating this type of a more professional degree. . . . At the moment our graduates, after a first specialized degree, are a little narrow in their knowledge and not too generalized, and thus must often retrain themselves in order to benefit from their first training . . . [and to] enter the labour market with a more professional bias."[79]

Dr. Kerwin of Laval University noted that "until very recently, the labour market has been able to absorb all the graduates in social sciences that we could produce. Now, this is changing and there are a great deal fewer positions available, and the first reaction of the students who are unable to find work is to remain in graduate school, which is not logical, but which creates problems for us."[80]

The points made by Dr. L'Abbé and Dr. Kerwin parallel the situation in several European countries, which was described to us during our visit. These problems appear paradoxical, because many witnesses have told us that the new problems arising today will require expansion of the social sciences. To avoid imbalances, it seems, it will be necessary to find techniques by which the social scientists can contribute their insights.

Some witnesses noted that the Science Council of Canada was widening the scope of its studies. They noted that the council lacked social science representation yet was suggesting "goals" that involved the social sciences.

For example, the Social Science Research Council commented:

> A very different situation which requires serious attention is the structural organization of a dynamic and efficient science policy for Canada.
>
> One of the basic components of such a policy from the point of view of the SSRCC is that advice on the social sciences should be given by those familiar with those disciplines. We view with some alarm the possible influence of the Science Council of Canada in areas of the social sciences and even the humanities.
>
> In publishing Report No. 4, *Towards a National Science Policy for Canada,* the Science Council of Canada has provided a statement which is revealing. The goals set out are quite arguable. But what this Research Council views with considerable concern is the very involvement of the social sciences in all these goals. Yet within the membership of the Science Council itself there is only a very marginal representation of those same disciplines.
>
> Difficulties with the interpretation of the role of the Science Council of Canada were experienced when that Council established a project inquiring into the *Support of Research in the Universities.*[81]

The Humanities Research Council had a similar comment:

> This Research Council has viewed with some concern the apparent influence of the Science Council of Canada which seems, in its recent Report No. 4, *Towards a National Science Policy for Canada* to establish goals which involve work of greater importance to the social sciences than to the natural sciences, where they are qualified to give advice. The Council is anxious to modify the objective of the Science Council which would see it developing affinities with the social sciences and "possibly even some aspects of the humanities." Which aspects of the humanities the members of the Science

> Council would want to become involved in, is not made clear. Though we may overestimate the influence of that body, an incident of direct experience is noted here.[82]

The joint brief of the French-speaking Quebec universities stressed the fact that the universities should not be isolated from each other and "as a result of the major contribution made by the state and by the business community to scientific progress, it is of primary importance that the universities seek to co-ordinate their research policies." The brief added that the university could not be isolated from other sectors either, or from the needs of society.

> We wish to emphasize the need for close co-operation between the parties involved in the conducting of research: governments, industry, labour unions and other groups. Such co-operation seems to us essential to the avoidance of useless duplication of effort and expense, and the ensuring of harmonious development in the various fields of research ... with constant thought being given to the research needs revealed by society.[83]

In discussing this with us, Dr. L'Abbé claimed that the major sectors must co-operate, not only in a research policy, but "even with regard to the particular goals of the university."

The brief from the French-language universities not only reminded us of the fact that our next generation of science policy would have to take the social sciences into account but also clearly demonstrated that an overall science policy for Canada would have to take into account the pluralism of Canadian society. The three universities put the matter this way:

> The cultural plurality of Canadian society, to say nothing of our national duality, implies that any overall science policy should refrain from opposing or even re-directing, individual policies that may be espoused by any of the cultural communities that together constitute the Canadian people. On the contrary, a science policy for Canada must be based on this objective reality, and must comprise the sum of the directions in which each of these communities wishes to progress.[84]

### VIEWS FROM THE PROVINCIAL RESEARCH ORGANIZATIONS

While Canadian universities were concentrating on their various missions, as they saw them, provincial research organizations, at the other end of the R&D spectrum, emphasized the use of knowledge and the introduction of new technology in industry. Representatives of six provincial research organizations appeared before the Committee. Four of these had submitted written briefs earlier and elaborated on them.[85]

Not all provincial agencies have the same degree of affiliation with their provincial governments, and some provinces have no research agencies at all. Thus, no representatives from Quebec, Manitoba, Newfoundland, or Prince Edward Island were present at this hearing; Dr. G. Bursill, executive director and deputy chairman of the New Brunswick Research and Productivity Council stated, however, that "our council operates for Prince Edward Island in a fairly informal way."

The provincial groups were unanimous in feeling that the federal government had ignored them and had failed to avail itself sufficiently of their particular capabilities in the past. Several statements attest to that feeling. Dr. T. P. Pepper, assistant director of the Saskatchewan Research Council said:

> We wish in particular to express our appreciation to this Committee for explicitly recognizing the existence of provincial research organizations. To our knowledge, this is the most overt recognition we have received to date from the various agencies studying Canadian science.[86]

And Dr. E. J. Wiggins, director of the Research Council of Alberta, added:

> The provincial research organizations have been over-looked to a considerable extent in most studies of a national science policy to date, although I am sure this is quite inadvertent.... We are still somewhat sensitive about the fact that the Science Council Report No. 4 manages to discuss Canadian science policy without once mentioning the provincial research organizations.[87]

As an aside, we note with pleasure that this situation changed after our hearings. A special study prepared for the Science Council of Canada by Mr. A. H. Wilson entitled *Research Councils in the Provinces; a Canadian Resource,* with a foreword containing specific recommendations by the Science Council, is due to be published early in 1971.

Dr. Wiggins explained why provincial research organizations were established:

> The geographic dispersion of the Canadian population has caused the provinces to feel that their scientific and technological needs could not always be adequately met by the central government; and... they have undoubtedly felt that an independent effort would give them an advantage in developing their local economy and in broadening their industrial base.[88]

This consideration seems to be reflected in the terms of reference of the various groups, in the composition of their governing boards and their staffs, and in their sources of funding.

At the time of our hearings, the research organizations had a combined income of about $10 million, much of which was derived from industrial contracts. The organizations employed a total of 750 people, half of whom were scientists and engineers. The boards of directors of all six research organizations comprised 97 members, 44 of whom were industry representatives.

Much of the evidence presented by these research groups suggested that the original motives for their foundation still held and that, as they had developed the competence and expertise to meet regional needs, their capabilities should be encouraged by a national science policy.

The agencies offered various measures of their success in meeting or creating a demand for their services. The brief of the Ontario Research Foundation (ORF) for instance, declared:

> During the decade 1958-68 about 3,500 firms spent in excess of $9 million on research and development at the Foundation, and the annual industrial volume increased from $475,000 to $1.3 million....
>
> A study made by the Canadian Manufacturer's Association reflects the effectiveness of ORF's industrial research efforts. Of 381 Canadian companies reporting research activities, more than half availed themselves of outside help... for assistance in specialized research programmes. The most frequently mentioned sources of such assistance were:

| | |
|---|---|
| Ontario Research Foundation | 62 |
| National Research Council | 38 |
| Dept. of Mines & Tech. Surveys | 18 |
| B.C. Research Council | 18 |
| Pulp & Paper Research Inst. | 16 |
| ... | |
| Naval Research Establishment | 2 |

> While the data presented are a measure of the effectiveness of ORF, it is more significantly, when viewed in total, a measure of the importance of contract research in industrial development.[89]

Dr. P. C. Trussell of the B.C. Research Council described the council's "sink-or-swim" type of development:

> We have learned over the years how to earn our way in the industrial R&D field.... This has been done by using both our research experience and our innovative wits.[90]

As a consequence, B.C. Research is now the council best able to support itself, earning 75 per cent of its income through contract research fees.

The Saskatchewan Research Council commented on its relations with a federal government agency:

> Annually renewed expenditures [under ARDA]... provide a bona fide demonstration of the efficacy with which a provincial organization can carry out research in its own territory.[91]

The Research Council of Alberta pointed out that NRC's information service was operated regionally by the provincial groups:

> The Technical Information Service and Industrial Engineering Service... are operated by the provincial groups with technical and financial support from [NRC]. This arrangement has been in effect in Alberta for the past 16 years, and has proven very satisfactory. While the program is national in scope, its operations are tailored to the particular needs of each province, and its services reach individual users *in the most effective way*.[92]

Dr. Wiggins of Alberta explained how the provincial research groups had developed capabilities in a particular area of science and technology:

> We do feel that they have some special contributions to make in this regard, particularly with the current emphasis on applied science and innovation.... I would particularly like to mention their strong technological orientation as contrasted, perhaps, with the more basic scientific interest of many of the other Canadian research groups, their flexible, interdisciplinary style of organization, their close contacts with private industry and their familiarity with the important problems and characteristics of each region of Canada.[93]

The Saskatchewan Research Council added:

> Under [our] terms of reference, matters under study... are perforce mission-oriented. Analogously, other provincial research agencies undertake highly applied research. This emphasis has fostered the development of flexible organization structure that facilitates the efficient performance of mission-oriented programs.[94]

The Ontario Research Foundation described industry's attitude toward its work:

> Another strong indicator of industry's continuing high regard for the Foundation is the fact that Canadian industry has recently subscribed almost one million dollars toward the cost of the ORF's new building at Sheridan Park.... It is significant that these contributions are entirely voluntary and may be regarded as a direct acknowledgement of ORF's value to the industrial community at large.[95]

A number of the groups explained why they felt they were better equipped than others to perform certain types of work. The Saskatchewan Research Council, for example, declared:

> Since provincial research councils are flexible and mission-oriented, they are . . . able to undertake advantageously inter-disciplinary studies on behalf of government and industrial clients . . . . [they] are perhaps more suitable than is industry to undertake investigations involving increased "opportunity" for whole sectors of the economy or segments of the population. Such work may be by-passed by industry because the dollar returns to a single operator or a consortium in a limited economic sector may not be sufficient to warrant such studies.[96]

The Research Council of Alberta contrasted the provincial groups with academic establishments:

> In comparison with the universities, the provincial research organizations have fewer operational or administrative difficulties in meeting the specific research and development needs of industry or government, since their total mission is research. There is no conflict with teaching or publication pressures, and the work that can be undertaken is not limited by the interests of staff members and graduate students.[97]

The Alberta council felt that provincial groups had advantages over federal departments when it came to the stimulation of regional industry:

> The provincial organizations have greater freedom than most federal agencies to undertake research contracts for private industry or to engage in joint projects with individual companies. These relationships facilitate the provision of technical assistance where it is most needed and help to encourage the commercial exploitation of new technology.[98]

Anticipating fears that a "contract research" facility might discourage industrial in-house R&D, the council commented:

> Experience has shown that the provision of these services in no way discourages private industry from establishing its own research facilities as soon as conditions permit; in fact, a successful research project performed by an outside agency is often the best possible way to convince management of the value of a research department to the company.[99]

Specific suggestions and recommendations made by the provincial research organizations are listed below. They are presented in the form given them by the Research Council of Alberta except when differences in emphasis were evident or when another council suggested something not mentioned by Alberta.

All of the councils supported the first recommendation:

> The provincial research councils and foundations should be recognized as a distinctive element in Canada's scientific and technological effort, with a role that is complementary to that of federal, industrial or university research organizations.[100]

These were the second and third general recommendations:

> There should be acceptance by the federal government of the value of regional policies toward science and technology matching these policies to the geographic and economic characteristics of the region. In each of these regions, full advantage should be taken of all existing research and development facilities—industrial, educational, federal, provincial, and independent.[101]

and

> There should be a continuing effort to decentralize the scientific and technological activities of the federal government whenever it is practical to do so, to improve regional contacts. This decentralization may be accomplished by the establishment of additional regional laboratories by the federal government itself, and also by contracting out federal research programs to other agencies. The latter course has the advantage of encouraging local enterprise and of injecting new ideas and approaches into government operations.[102]

Most of the agencies felt that federal "recognition" and a move toward decentralization should bring about some tangible changes in federal programs. For example, they considered that they should qualify, as do universities and industrial firms, for federal contracts and granting schemes designed to stimulate research and development.[103]

Why should they qualify for federal grants? The answers varied. For instance, Dr. J. E. Blanchard, president of the Nova Scotia Research Council, said:

> All our work is directed towards the betterment of the economy of Nova Scotia. Unfortunately, this does not always result. In fact, at the moment our largest industrial contract will probably result in an industry not in Nova Scotia but outside Nova Scotia .... I do not agree that the work we are doing should not qualify us for some participation.[104]

Dr. W. R. Stadelman, president of the Ontario Research Foundation, commented:

> We have done work for B.A. on the improved oil burner for refinery use. The new refinery being built at Point Tupper in Nova Scotia will be equipped with this .... The tanker, the *Peerless,* which they operate on the high seas and Great Lakes is also equipped with this. Is that international? We work with C.I.L. having to do with the removal of sulphur dioxide. British Columbia

> had sulphur dioxide being spewed out, so has New Brunswick; certainly Ontario and Quebec have. We do work for Cassiar Asbestos whose head office is in Toronto, but I believe their mine is in the northern part of British Columbia .... Whom are we benefitting? We are benefitting the mine, we hope, because we will sell more and more asbestos. It is a non-Ontario situation.[105]

The Saskatchewan Research Council referred again to its experience with ARDA:

> In our view, the success of this arrangement demonstrates the desirability of Federal-Provincial dialogue concerning the continuation and expansion of the shared-cost principle in various scientific fields.[106]

On the other hand, both the Ontario Research Foundation and the B.C. Research Council put more emphasis on contract research. Dr. Stadelman said:

> I think the giving out of more contracts to all types of institutions and asking for competitive bids would be one [way of helping]. In our particular case, I think an undertaking to help us develop a skill in an area over a term of three years, with the understanding that after that time it would be dropped, because at that point industry should be able to carry on by itself, without support.[107]

And B.C. Research, as has been mentioned previously, doubted the value of "gifts":

> We would not look forward to money being made available as an R&D slush fund .... [This] would be the worst thing that could happen to us psychologically—whether we were on the receiving end or not.[108]

The fourth recommendation followed from much of what had already been said, and was supported not only by all the provincial research councils, but by various universities, industries, and private associations:

> Full advantage should be taken of the capabilities and growth potential of existing research organizations before new research groups are established with federal support. When it is found necessary to establish new research groups, this should be done in collaboration with existing research organizations as far as possible, to avoid unnecessary duplication of facilities. As an example, the provincial research organizations could advantageously be involved in the planning of any new industrial research institutes at provincial universities.[109]

The fifth recommendation, unanimously supported by the provincial groups, stemmed from the past shortcomings of federal-provincial relations:

> The present avenues of co-operation between federal and provincial research agencies should be strengthened and rationalized, and new avenues explored.

> Any legislative or administrative barriers to technical co-operation and financial assistance should be eliminated as far as possible; the type of relationship which is now in effect with the National Research Council in the operation of the Technical Information Service should be extended to other fields. Provision should also be made for federal assistance to the provincial research organizations in establishing facilities for new types of industrial technology.[110]

The last recommendation made by the Research Council of Alberta dealt with a matter not covered by the other councils:

> Mechanisms should be established that will permit staff exchanges or transfers between federal and provincial research organizations without loss of pension benefits or other rights, so that the special capabilities of staff members may be utilized where they are most needed at any particular time. Short-term exchanges should be encouraged to broaden the experience of staff members and to improve mutual understanding between federal and provincial groups.[111]

The Saskatchewan Research Council offered a related but different suggestion:

> Provincial research institutions constitute a pool of scientific manpower thoroughly familiar with mission-oriented research, particularly in resources management areas, and should be recognized as sources of potentially desirable candidates for international development assignments.[112]

In summation, most research councils implicitly welcomed a nationally "planned" shift of emphasis from basic science to more direct support of mission-oriented and applied research, development work, and stimulation of the total innovation process. They urged national consideration of regional needs through improved federal-provincial consultation. Above all they hoped that their capabilities would be enlisted in the struggle for improvements in Canadian life.

From the evidence before this Committee, it appears that provincial agencies take a pragmatic view and their actions are clearly focussed on the applications of science and technology. This point was made very clear in the presentation by Hydro-Québec. Dr. Boulet, the director of research, described the proposed Hydro-Québec Institute of Research and stated: "Its main effort will be directed to the transmission and distribution of electricity. . . . These laboratories will be available to all Canadian manufacturers for individual or group research to enable Canadian industry to develop and test all types of electrical equipment.[113]

Dr. Boulet, like many other witnesses, drew attention to the need for more mobility in the R&D community and to the need for a better balance between fundamental research and development. Noting the importance of mobility for R&D staff, he suggested that "you take an engineer in industry and send him to the university to teach a course and discuss with the people there, and you take a professor at the university and send him into industry to see what are the practical things. By doing that I think you will get back to the contact between these people."[114]

Dr. Boulet was concerned about the balance of Canada's R&D activities:

> I say that we are spending right now so much money in fundamental research in Canada, and so little in applied research and development, that we produce good fundamental research and nobody is using it, and I think it is about time that we go ahead and start some development that will give jobs for people and produce something for the nation . . . . If you go to Sweden you will find they do very little fundamental research.[115]

This view was one of the common themes of the industrial briefs. Dr. Maurice l'Abbé, vice-rector (research) at the University of Montreal, was one university spokesman who saw the need for more applied work. He told the Committee:

> We all agree in Canada that the viewpoint is applied science today. This is much more costly, of course, but it is also much more productive . . . . I think one has to very much point out that the need is for applied research and in applied research we are weak owing to very peculiar situations.[116]

## CONCLUSION

A major theme developed by universities was that they needed more support for basic science and fundamental research. This point was in line with the conventional wisdom, which also insisted on the need to produce more pure scientists. Other important issues were also raised. For instance, the need for more research in the social sciences was stressed but some concern was expressed about the growing student enrolment in these disciplines in the light of national requirements.

It was emphasized that applied research and engineering disciplines in universities should receive greater assistance. In this connection, it was strongly recommended that federal government laboratories should be more decentralized than they are now and that centres of excellence in universities or close to university campuses should be developed with clearly defined responsibilities. This request came from Quebec's French-speaking universities in particular but was also submitted by representatives from the Atlantic provinces and other parts of Canada.

Provincial research foundations claimed that they had an important role to play in assisting industry to develop and use new technology. However, their action had been limited in the past partly because they had been ignored by federal agencies. They favoured much greater federal-provincial co-operation in the future in the field of science and technology.

## FOOTNOTES AND REFERENCES

Hereafter the Proceedings of the Senate Special Committee on Science Policy are referred to by number only, followed by Appendix number between brackets, and page number.

1. No. 66 p. 7976.
2. No. 50 p. 6279.
3. No. 71 p. 8365.
4. No. 67 (159) p. 8085.
5. No. 45 (65) p. 5829.
6. No. 47, p. 5929.
7. No. 48 (86) p. 6143.
8. Ibid p. 6144.
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13. No. 47 (70) p. 5956.
14. No. 48 (89) p. 6168.
15. No. 45 (66) p. 5840.
16. No. 47 (78) p. 6043.
17. No. 45 (61) p. 5778.
18. No. 48 (90) p. 6191-6192.
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27. No. 48 (89) p. 6180.
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60. No. 48 (86) p. 6152.
61. No. 80 (220) p. 185-186.
62. No. 51 (100) p. 6398.
63. Ibid.
64. Ibid.
65. No. 48 (88) p. 6165.
66. No. 57 (120) p. 7017.
67. Ibid p. 7018.
68. No. 58 (125) p. 7099.
69. Ibid p. 7104.
70. No. 60 (133) p. 7284-7285.
71. No. 58 p. 7055.
72. Ibid p. 7058.
73. No. 57 (121) p. 7037-38.
74. No. 57 (120) p. 7019.
75. No. 57 (120) p. 7019-7020.
76. No. 58 (123) p. 7085.
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89. No. 50 (96) p. 6317.
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# 9

# INDUSTRY AND GOVERNMENT:

# FURTHER OBSERVATIONS FROM THE EVIDENCE

Many Canadian industrial organizations, including individual firms, presented their views to the Committee about various science policy issues as they saw them. This chapter gives an outline of their representations on the main topics of interest to the Committee. It adopts more or less the framework that was used for Chapter 7, dealing successively with problems related to scientific and technical information, the performance of R&D by industry, co-operation between government agencies and the private sector, the supply of scientific manpower, co-ordination between sectors of performance, and central mechanisms within the government to ensure the balance of the national R&D effort. While we quote mainly from briefs presented by industry, we also draw occasionally from the evidence submitted by other organizations.

## A SCIENTIFIC AND TECHNICAL INFORMATION SYSTEM

On the basis of evidence to this Committee it appears that a scientific and technical information system (STI system) is not only an important facet of science policy but may be considered a vital part of the "nervous system" of a science-policy-making body. This view was implicit in the recommendation of the Aluminum Company of Canada Limited. Alcan suggested a Department of Science and Technology as an overall "co-ordinating authority", within which there would be "a national information pool which would collect, file, and disseminate all existing data as well as all data currently being generated by government agencies, university research centres and



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other non-proprietory sources throughout the country, and all other readily available data from foreign sources, and that a computerized system be used to permit effective and economical response to any valid request originating from the Canadian scientific community or from any other legitimate party."[1]

The Committee was frequently told that a computer-based information system—such as that suggested by Alcan—was not possible; however, Dr. John M. Carroll, associate professor of computer science at the University of Western Ontario, told the Committee that a computer-based "inventory of what is going on in Canada"[2] to assist government policy-making "is definitely within the state of the computer art today. I have the utmost confidence that such a system could be developed."[3]

### 1. *Information system within Canada*

First of all we must consider the flow of information within Canada. The vital role envisaged for this system can be inferred from the brief of Dalhousie University, which stated: "It is agreed that the development of communication systems is perhaps the single most important element of a useful science policy."[4] Like Alcan, Dalhousie University's brief suggests an associated central mechanism: "There is a necessity for a single, central authority to which both the planning and the co-ordinating groups should report."[5]

Witnesses left no doubt that Canada's internal STI and communication systems needed improvements. The brief of Acadia University stated that "there appears to be a relative lack of interaction and communication between scientists in university and those in industry."[6] The gaps in the existing scientific and technical information system, therefore, are aggravated by the lack of communication between scientists in different sectors. Dalhousie University's brief states, too, that "the effective flow of information from the scientific community to the general public is presently insufficient."[7]

The Machinery and Equipment Manufacturers' Association of Canada pointed to an inadequate supply of usable information and suggested how this problem and the aggravating problem of the lack of communication between scientists and industry might be solved by government action in the STI field. Their brief stated:

> A wealth of scientific information is being generated each year by a wide range of scientific and technical bodies. It is likely that a high proportion of this information does not reach the machinery manufacturers at all, and certainly not in a form which can be understood and used by them. There may be a very considerable gap between the two groups—the scientists and industry—and it would clearly be to the advantage of both if communications between them were better. This would appear to be an area in which govern-

ment might take the initiative in co-ordinating and collating scientific and research information on the one hand, and ensuring its useful distribution to potential areas of application in machinery manufacturing and other industries. . . . industry might use this channel to acquaint the scientists more thoroughly with its needs and priorities.[8]

The brief of Laval University and the Universities of Montreal and Sherbrooke stressed the need for more co-operation in the research conducted in different sectors and stated: "It will be important . . . to establish a system for the exchange of information regarding their findings." The brief went on to say that communication within the scientific community was of crucial importance.[9] Carleton University's Faculty of Engineering made the same point: "There is a need for publication and dissemination of Canadian applied research results, both at the popular and at the scientific levels."[10] And Gulf Oil Canada Limited recommended that government "research information services" should "be greatly expanded to make scientific information readily available to working scientists."[11]

As mentioned previously, 98 per cent of the world's science and technology is done outside Canada. Well developed information systems are growing up around these activities, and there is obviously a danger that Canadians might be tempted to rely on such systems without developing an internal information system. This problem is touched on in the brief of the Department of Geological Sciences, University of Saskatchewan, Regina Campus:

A deficiency in the structure of science in Canada is the poor means of communication of information whose significance may be short-lived. In this respect, Canadian science tends to be an appendage of U.S. science which has available to it, a variety of means of rapid dispersal of scientific ephemera . . . . It is . . . considerably easier for Canadian scientists to know the needs and pressures of science in the United States than the same things in their own country. Canadian institutions, to some extent, communicate to each other and to the world via American media . . . . It does seem that a national science policy for Canada should include a better and more rapid means of information dispersal than exists at present.[12]

When the subject is of vital importance to Canada or cannot be disengaged from unique Canadian conditions (for example, certain urban situations), the problem can be serious. As Mr. Eric Beecroft, past chairman of the Canadian Council on Urban and Regional Research, pointed out, it is important to recognize the political decision-making aspect of such problems:

Canadians, therefore, should exchange information among themselves and not be at the mercy of networks which are north-south or which are primarily

> international in character. We are constantly feeding information and data from Canadian cities and municipalities into very elaborate electronic data gathering equipment in New York and Chicago then buying it back again with an enormous amount of information which we sometimes do not need, and which we have to interpret in very, very different ways . . . .[13]

Timeliness is important in information exchange between scientists, as Dalhousie University pointed out: "Canada cannot afford time lags of months or years in communicating among scientists the results of research or details of programs in progress. . . ."[14] The time relationship between basic scientific research and technology is not the most serious, for according to Dr. G. A. Harrower, dean of the faculty of arts and sciences of Queen's University, "the social justification for science lies in the application" but "it requires something like a 25 year lead time."[15] However, it is important to minimize the time lag in the use of new technology in industry and Messrs. J. Mardon and J. Root recommended in their brief that "a series of government sponsored, adequately stipended and prestigious lectures should be inaugurated to make clear the present state of technology and cause our industrial managers and technologists to ask themselves, 'Are we doing this now?' "[16]

Several large Canadian companies appeared alert to the importance of information. For example, the Steel Company of Canada Ltd. included these among its recommendations:

(1) The government should provide centralized clearing houses for scientific information.

(2) The facilities of the National Science Library should be expanded to provide broader service.

(3) The facilities and retrieval system of the Canadian Patent Office should be improved especially to facilitate the examination of Canadian patent art.

(4) The Technical Information Service should be improved along the lines of the United Kingdom Technical Information and Library Services Reports Centre of the Ministry of Technology and of the U.S. National Referral Centre for Science and Technology, Library of Congress.

(5) Government employees responsible for disseminating technical information should be given opportunities to study appropriate segments of Canadian industry.[17]

### 2. *Technology and information from outside Canada*

Basic scientific information is distributed more freely and effectively than information about technology, yet Canadian industry must have ready access to new technology. Clearly, any Canadian STI system must meet this requirement. The point was made by several industrial representatives. For example the brief of the Canadian Chemical Producers' Association suggested that "to benefit from the developments in foreign technology as rapidly as possible, high priority should also be given to the expansion and improvement of the scientific literature services provided by NRC . . .", and went on to suggest an "expansion of translation services to facilitate the assimilation of the foreign literature."[18] Syncrude Canada Limited recommended that "the Government should establish a central technical information centre with the objective of promoting the effective use of current technology throughout Canadian industry,"[19] and MacMillan-Bloedel Limited called for "a 'National Technology Bank' to assist in obtaining needed technology from anywhere in the world which can be exploited and commercialized by Canadian industry."[20] Mr. R. G. Johnson, president of the Canadian Institute of Steel Construction, stated: "International exchange of technology is essential. In many fields there is more economic value in applying the best foreign work to our situation than in doing original work of limited application."[21] Dr. Bertrand B. Hillary, chairman of the research and development committee of the Canadian Chemical Producers' Association, declared that "any company in Canada that is going to be internationally competitive must import technology because it can only generate a small fraction of the total research that it needs—or technology, to use a broader term—and we feel we must import."[22]

A slightly different emphasis came from the Abitibi Paper Company Limited. In response to the question, "Are the results of foreign science and technology available to Canadian industry in a timely and suitable manner?" the Company answered: "There are few legal restrictions. However, dissemination of information is at its infancy in Canada, and bold imaginative steps, say under the auspices of the National Science Library, would be a fit subject for government subsidization."[23]

Syncrude Canada Limited stated: "With limited resources, Canadian government and industry cannot expect to be in the forefront of research in all desirable fields of development. Yet at the same time, the Canadian economy cannot afford to operate with less than the most current technology. Science policy might be aimed at fostering the necessary co-ordination to optimize the balance between search and research. Information retrieval is possibly one of the most fruitful fields for research in Canada. . . . Much study is needed on the most effective ways to assemble, present, and disseminate the flood of new technology. If this does not reach the technician in the form he wants, it simply is not information."[24] The brief of Northern Electric Company Limited recommended "that precise definitive research action be taken in Canada to develop a science which will permit improved planning and designing of communication environments."[25] The Company was surprised that the Science Council's Report No. 4 made no special mention of communications, for "Canada's unique environment, both social and physical" required special communication systems.[26]

Canadian Industries Limited felt that the mere increase in R&D in Canada would not satisfy the demand for technology, and that a purposeless promotion of R&D could do more harm than good: "For this country to adopt a parochial attitude of self-reliance in science would be extremely short-sighted. . . . Much technology must of necessity be imported; even the more technologically advanced nations, such as the United States and Germany, must engage in considerable trading of technology."[27] The idea of "trading" technology was also mentioned by Dr. B. B. Hillary: "We must be able to export technology. This means the sale of our research and getting a return for it. It gives us the opportunity to exchange research for other research we need; it is a 'swap' sort of deal."[28] In order to trade technology some Canadian companies must create some of their own negotiable technology, as Northern Electric pointed out: "While Canada must not try to compete in all fields, it must be prepared to compete with other nations in many areas. No nation can be a successful exporter of manufactured products if it imports all its technology."[29]

Nevertheless, as Mr. F. P. Mitchell, president of Orenda Limited, said, it is possible to "run out of technology." By the mid-1960s Orenda had exhausted its accumulated technology (related to industrial gas turbine engines): "Technology was advancing very rapidly and we were just not keeping pace." Mr. Mitchell continued:

> This is still the case, but we have rectified the situation somewhat by aligning ourselves with a big United States company, and this has given us access to technology, which we really had to have in order to advance development. We have had very little Government funding during this particular period of time . . . . We are competing against giants who have continued in fully-funded government programs. We do not have that assistance.[30]

Mr. Mitchell described Orenda's foreign ownership and went on to say:

> But from my point of view, there has been no disadvantage to this type of ownership; it has been an advantage. The source of technology has been vital to us from the U.S. company . . . . The U.K. company aids us in our international sales programs, which we need.[31]

The increasing role of technology in industrial innovation has led to an increased international trade in technology. This is particularly evident in the case of Japan; for as Dr. Saburo Okita, president of the Japan Economic

Research Centre, told the committee: "Last year we spent $240 million U.S. for importing technology, and we exported $27 million U.S. of technology to foreign countries."[32] In Japan, the successful management of the whole innovation process has created a demand for new technology and in consequence a demand for more R&D in Japan.

More than one company pointed out that foreign ownership offered a unique means of importing technology. For example Mr. John D. Freitag, president of Litton Systems (Canada) Limited, said: "It is our opinion that foreign technology is only available to Canadian industries in a timely and suitable manner through the subsidiaries of foreign firms. This establishes a base from which a lesser amount of Canadian resources can be applied to achieve product goals that would otherwise be unattainable."[33] These benefits of foreign ownership were also pointed out by Imperial Oil Limited:

> We consider that Canadian affiliates of international petroleum companies have a very great advantage, as compared with wholly owned Canadian companies, in that they have access to an extremely large amount of proprietary technology . . . . In general, it is our opinion that a degree of foreign ownership assists rather than hampers economically successful innovation in Canadian industry. It provides the broad, low-cost technological foundation essential for further Canadian research and innovation.[34]

Chemcell Limited, however, suggested that subsidiaries could get more help from their parent firms than they often did. In order to build up Canadian industry the company concluded, among other things, that greater efforts should be made "to encourage the flow of technology from foreign parent firms into Canadian enterprises."[35]

It is worth considering whether and when Canadian industry will switch emphasis and establish its own subsidiaries in foreign countries. For example, will AECL spin off subsidiary firms to obtain its share of the huge worldwide market for nuclear power plants? Swedish overseas subsidiaries doubled in number during the 1960s to more than 1,800; from 1964 through 1969 Sweden invested $1 billion overseas. Helge Berg, an economist of the Federation of Swedish Industries, has commented: "I think you'll find that the major reason for establishing plants abroad these days is to be in touch with large markets where there are fast technological developments."[36]

## INDUSTRY AND SOME FACTORS ACCOUNTING FOR ITS WEAKNESS

### 1. *Problems of the original science-based industries*

The chemical industry and the electrical machinery industry were the first two products of the second industrial revolution, in which science was wedded to technology. These two industries have been at the heart of development in the leading developed nations. The chemical industry, for example, has played a dynamic role in Japan's spectacular economic growth. In Canada, according to our witnesses, these industries are in very poor health.

Mr. L. Hynes, president of Canadian Industries Limited, told the Committee: "Our return on investment over the past 20 years . . . has not been anything like good enough. We have, unfortunately maybe, talked people into putting money into the company but they should have put it somewhere else. For the future it is even worse."[37] Mr. Hynes stated that there was no incentive for the chemical industry to make any new investment. It was pointed out by some committee members that some countries were highly successful in exporting chemical-based products; could R&D help the Canadian industry by developing new technology that might lead to exports? This question was answered by Dr. Herman F. Hoerig, vice-president for research and development at DuPont of Canada, Limited, who said that the problems of the Canadian chemical industry had nothing to do with a lack of technological know-how or scientific expertise: "The problem is not one of a lack of competent scientific personnel, nor is it a lack of communication and exchange of technology world-wide. The level of intelligence in this area is equal to that which exists elsewhere."[38] Dr. Hoerig went on to point out that Canada at present is a net *importer* of chemical products and went on to remark: "Now, the question is: Can the Canadian chemical industry become a net exporter of goods? I think the answer to that, to be pragmatical and realistic, is that it is not on the cards."[39] He quoted a forecast that Canada's net deficit in imports of chemical products would reach almost $1 billion in five years' time.

Representatives of the chemical industry suggested that world tariff barriers were a main reason for this problem. As Dr. Hoerig said, "This pessimism is due to the fact that the tariff barriers on chemicals in the rest of the world are such that the manufacture of these goods in Canada does not make it possible for the industry to gain access to these other large markets in competition with other large-scale producers. It is just about that simple."[40]

Mr. F. S. Capon, vice-president of DuPont of Canada Limited, mentioned "the problem of scale." He explained: "In our industry, for example, we believe we do the best job in the world in making nylon. . . . With full efficiency and with all the technology available in nylon, we have unit costs that indicate that our costs per pound of nylon are considerably higher than the costs in any other country because we cannot run one type of nylon day in and day out on one machine. . . ."[41] Mr. Capon went on to point out that anti-combines laws prevent one solution to the scale problem, which would be to operate a single large nylon plant for all Canada.[42]

Mr. William J. Cheesman, president of Canadian Westinghouse Company Limited, suggested that there were troubles in the electrical manufacturing industry—and indeed in the whole secondary manufacturing industry. Mr. Cheesman told the Committee: "In our business, particularly with heavy electrical apparatus, the utility class of apparatus, this has been a very difficult period or is a very difficult period for that sector of the electrical industry. The earnings are hardly sufficient to keep the industry alive, let alone generate the kind of research and development funds which we wish and in fact see needs for. However, there is room for argument and room for difference of opinion as to whether those opportunities really exist for Canadian manufacturers."[43] Later he said: "The return on investment available in the electrical manufacturing industry in Canada today is just not attractive to risk takers. Some 29 per cent of the stock in our company is available to the general public, but there is not a great deal of interest in it by Canadians. . . . The return on investment available in our industry and in much of the secondary manufacturing industry in Canada is not sufficient to attract the people with risk money."[44]

Mr. Cheesman declared that tariff regulations were a major cause of the troubles of the electrical industry. He said: "We have seen severe incursions into the Canadian market in the last few years by off shore manufacturers into those product market areas. It would seem that any amount of research and development that we have been able to do as an industry is hardly enough to keep us alive and surviving. We are faced with a non-free trade situation where the countries that are exporting these apparatus products into Canada have a closed market at home."[45]

Thus the evidence suggests that the problems of developing successful innovations in two of the mature science-based industries transcend the direct problems of R&D, although these industries agree that they need to conduct more R&D, that they need government assistance to do so, and recommend that more of government's in-house research be placed in industry.

### 2. *Some myths about research*

We have seen in earlier chapters that Canadian conventional wisdom over the past half-century has laid great stress on economic growth through "research"; seldom has attention been placed on the other facets of innovation. Basic long-range research was put forward as the necessary seed bed from which a flourishing industrial development would arise. For decades leading spokesmen claimed that research was the activity that needed to be increased in order to advance Canadian development and economic growth. The federal government backed this view, built laboratories, and increased support to universities in order to increase the number of trained researchers in the country.

The almost exclusive preoccupation with "research" in the past was an understandable reaction to the meagreness of Canada's effort, especially in comparison with other nations. The unfortunate side effect was the view that research was a modern-day talisman that would enable scientists to solve all problems with ease—except for the necessary but difficult and expensive activities of research. As Mr. Capon of DuPont of Canada put it, "Canadians have tended to assume that all research is desirable and justified."[46]

Dr. Lionel A. Cox, director of research of MacMillan-Bloedel Limited, suggested one reason for this over-emphasis on research: "There is a tendency in Canada to have 'scientific national pride' and a 'not invented here' factor, which makes research people duplicate scientific and technological work that has already been done in other parts of the world."[47] His brief also stated: "At the present time, the government stresses too heavily the importance of R&D in improving our economic growth in Canada. . . ." Other witnesses pointed out that any attempt at national self-sufficiency in R&D was bound to fail. For example, Mr. J. Cogan, senior vice-president of Imperial Oil Limited, pointed out that "in Canada we can develop only a small proportion of the total technology upon which our business operations are based. . . . There should be no restriction to taking maximum advantage of the most efficient and particularly low cost technology available from any other source."[48]

Industry's feelings about research were described by Mr. Capon:

> The true incentive for research is the opportunity for profitable growth to result from research effort . . . . We believe that a full-scale scientific effort will develop automatically from an expansion of the opportunity for technologically-based industry to succeed in Canada.[49]

This "opportunity for technologically-based industry", witnesses pointed out, does not arise solely from R&D but is vitally dependent on the economic environment. Mr. Cogan put it this way:

> The needs and opportunities for industrial research and development are strongly responsive to the economic environment and obviously the industrial base which the environment forces. In other words, the industrial load really sets the basis for the demand for technological needs, although it is a chicken-and-egg proposition beyond doubt.[50]

Recognition of opportunities involves, of course, perception of human needs; but according to Mr. Cogan more is involved: "The recognition of the opportunities and their successful commercialization is strongly influenced naturally by the effectiveness of the communications at the various interfaces and stages of innovation and between the parties to the innovation."[51] Research is just one of the many vital parts of this process. As Mr. Hynes put it, "A high level of research and development work in itself will not produce the desired economic benefits to the nation."[52]

A misunderstanding of the nature of curiosity-oriented research, or research whose goal is discovery, is also an ever-present danger. Mr. V. O. Marquez, president of Northern Electric Company Limited, warned the Committee that "the problem with discovery, which is the area of activity that takes place in the university, is that you are seeking knowledge," but "its translation into usable goods or services may not take place for a hundred years. There is very little connection."[53] One danger is that, if those authorizing the funding of discovery-oriented research hold the talisman view of research, they will become disenchanted with the output of that research, because rarely will it be immediately applicable for pragmatic purposes.

Mr. Marquez also stated that "in Canada there is an imbalance. This is perhaps not to say that there is too much effort and money being spent on discovery so much as it is to say that there is too little being devoted to innovation."[54] Such an imbalance, if it exists, could easily result if the research funding is based on the talisman theory, because fundamental research is normally much less expensive than the activities associated with innovation and there would be a temptation to believe that innovation could be supported at bargain basement prices.

Witnesses also pointed to another myth about research, that money or legislation alone spells scientific success. As Mr. Hugh S. Sutherland, vice-president of Shawinigan Chemicals Limited, told the Committee, "Scientific progress cannot be assured by legislation."[55] The point was underlined by Dr. C. J. Mackenzie: "The worst thing to do is to provide more money than can be effectively used. There are only two kinds of research—good and bad. Good research requires good scientists."[56] Mr. Cogan put this to the Committee in different words: "The quality of work through the entire innovation process is, I feel, of greater importance than the quantity. I might say that research is expensive, very expensive, and poor research, I think, is fantastically expensive."[57] Another declaration that money alone is not sufficient came from the British Columbia Research Council: "B.C. Research would be prepared and most anxious to tie in with an integrated plan for R&D in Canada. But we would not look forward to money being made available as an R&D slush fund. We have learned over the years how to earn our way in the industrial R&D field (75% self-supporting) . . . To have R&D slush funds set up would be the worst thing that could happen to us psychologically—whether we were on the receiving end or not."[58]

The evidence, therefore, suggests to us that there are a number of dangerous myths about research. There is the myth that money or legislation alone can assure scientific advance. There is the myth of national self-sufficiency in research. The most dangerous myth appears to be the talisman theory of research, or what Lord Blackett is reported to have called the "magic wand" theory. The talisman theory can, we believe, seriously endanger and even kill the rare and valuable flower of fundamental scientific research by causing its funding to be based on false hopes and its growth to be judged by the wrong criteria. It verges on hypocrisy to base the funding of a creative scientist in the field of astrophysics, for example, on the claim that his work might help the development of power stations based on nuclear fusion. All may not agree, but we prefer James D. Watson's account of the unravelling of DNA,[59] which clearly shows that the motive was his great ambition to win the Nobel Prize, rather than the hope of discovering something that might eventually lead to improvements in agriculture or medical treatment.

The talisman theory can also distort our approach to industrial innovation by suggesting that research, or R&D, are necessary and sufficient conditions for innovation, that they are all that is necessary to produce laboratory discoveries, and that an entrepreneur can then transfer these discoveries to the marketplace. The evidence points elsewhere: it shows that R&D is necessary for innovation but that government science policy for the support of industrial R&D and government in-house research in support of industry must be integrated with other policies that affect the innovation process.

### 3. *Bridging the gap between industry and government*

In the historical chapters we noted that, for decades, government scientific leaders have rationalized the expansion of government in-house research laboratories and programs by saying that industry did not have the competence to conduct research. One witness who strongly commented on this facet of traditional wisdom was Mr. William J. Cheesman, president and chief executive officer of Canadian Westinghouse Company Limited. Mr. Cheesman noted that as a result of this traditional view, government research programs stay within government laboratories much longer than they do in the United Kingdom or the United States. Government laboratories seem to be reluctant to hand over the tasks to industry. Mr. Cheesman cited two cases he was familiar with:

> The argument that is put forward for keeping those projects in the government laboratories is that only the government laboratories have the class, kind and quality of manpower to undertake these projects. The fallacy as we see it is that, of course, industry will never have the class, kind and quality of manpower required to undertake such projects until we have the projects to perform.[60]

Mr. Cheesman said that the defence electronics industry was fortunate in escaping from this situation in the early 1950s "when by edict the government research laboratories were called upon to transfer some of their basic and applied research projects to industry."[61] This helped give birth to Canada's avionics industry—but only, he suggested, against the advice of government bureaucrats:

> A survey was done by a team back about 1950, which came back here to Ottawa with the report that the Canadian electrical and electronics industry did not have a research and development capability sufficient to handle the projects which were then under way in government laboratories . . . . By edict these projects were put out into industry. Industry recruited the scientists and engineers and built up the electronic industry . . . .[62]

Mr. Cheesman continued:

> We have a more recent example of one government laboratory that saw a large increase in its workload and was exhorted by many to contract this work to industry. Again the traditional observation was made that industry does not have the engineers and scientists who can perform the work. However, it is interesting to observe that the same government laboratory within two years was able to find the people to grow from 200 to approximately 800 within its own walls.[63]

When asked the name of the laboratory Mr. Cheesman answered: "It was the power projects organization of Atomic Energy of Canada."[64] Mr. Cheesman went on to state that it was advantageous to have the R&D in industry, where there is contact with the other facets of the innovative process; production, marketing, and the execution of the full product cycle.

The Canadian Chemical Producers' Association also commented on the fact that a large portion of federal government funding for research is used in the federal government's own laboratories. The association's brief stated:

> The situation in Canada where government research activities are largely divorced from industry should be compared with other major industrial coun-

tries where a large proportion of government sponsored research is carried out by industry.... Private industry involvement maximizes the opportunity for turning the results of government-oriented research to national commercial advantage—the conduct of research on the scene of business operations provides the likeliest environment for the recognition and exploitation of commercially valuable "fall-out", whether from basic or applied research.[65]

Some major Canadian companies commented on the usefulness of the research conducted in government laboratories. For instance, Northern Electric's brief devoted a section to NRC:

> The National Research Council was established ... to assist or promote scientific and industrial research in Canada. In recent years, NRC staff members and representatives of industry have been disturbed at the reluctance of industry in Canada to interest itself in NRC's patents and new products. No doubt, industry in Canada suffers from a low entrepreneurial coefficient, but one of the contributing factors is that industry plays a relatively unimportant role in establishing NRC's projects. NRC's designs have consistently high technical merit, but this alone is not enough to warrant commercial support.
>
> There should be much closer liaison between NRC and industry at the planning stages of program formulation and it should continue through the earlier creative stages to the point where the project must be transferred to industry for production and commercial exploration.... We believe NRC should maintain continuous dialogue with a standing organization of industry representatives from the technical and managerial levels. This organization would be industry appointed only...[66]

Several industrial briefs commented on the problems created when government laboratories conducted research that was intended for industrial use eventually. The Electronic Industries Association's brief was one:

> With regard to Government Research Laboratories, the Electronics Industry finds from time to time that applied research being carried out by them could have been pursued in Industry and preceded by meaningful market surveys... Things have changed and very knowledgeable people, many with international reputations, are available in industry. There is, therefore, less need than formerly for Federal Government requirements to be met by their own laboratories.[67]

The Canadian Electrical Manufacturers Association argued that "in general, Government R&D programs should be restricted to fundamental or basic research with development work minimized and limited to specific areas of activity."[68] Among their suggested guidelines for government in-house research is this: "Government laboratory programs should be authorized if they do not compete with work being performed in universities or industry."[69]

The brief also notes that "it has been said by some that Canadian industry does not have the capability to undertake major technical developments in a number of areas. It is our belief that industry can marshall the capability, if given the opportunity."[70]

One of the chief points in the joint submission of the Canadian Pulp and Paper Association and the Pulp and Paper Research Institute of Canada was this:

> We suggest, further, that federal government research activities, and indeed research philosophy, receive the most careful study with a view to determining whether they reflect an adequate concern with the potential economic benefits of research to the Canadian economy.[71]

Gulf Oil Canada Limited suggested that the federal government's first priority in the field of science and technology was not to conduct research but "to disseminate new and existing knowledge into channels which may augment the national economy".[72]

Dr. Lionel A. Cox, director of research at MacMillan Bloedel Limited, said that the bulk of applied research conducted in government laboratories was "in the areas where there is an opportunity to gain larger markets through exports." He continued: "This type of research eventually has to be transferred to the export industries concerned, if the technology is going to be used for the economic good of Canada. Do the government laboratories have the mechanism for transferring this technology to industry effectively and efficiently?"[73] This is an important question, because the stated purpose in setting up most government laboratories over the years was that they would conduct the research that would eventually cause industry to flourish. This has been one of the main thrusts of our conventional wisdom during the past half century.

Dr. Cox also noted that "at present, the government's intramural research, which is performed directly by government agencies and departments, is highly orientated to basic research . . . In the area of development work, it has been suggested that the government laboratories, such as the National Research Council, might be encouraged to carry out more development work and less basic and applied research. Government laboratories should not carry out development work themselves, since this is expensive in many cases, and cannot be done effectively without close co-operation with the manufacturing and marketing people in the industry in which the product or process will eventually be exploited and applied. Therefore, it is recommended that: Advanced development work be done by industry and sponsored by the government under a "contract research system".[74]

Dr. G. Shane, director of research for Shell Canada Limited, told the Committee:

> I would like to say that we feel that a greater effort should be made to encourage and support research in industry as contrasted to government in-house programs. The problem that we find with in-house programs . . . is that it is very difficult for us in industry to get the results and implications of these programs in time to be of any use to us. We feel that research done in our own labs is much easier to exploit. The research programs are directed in a way that is commercially necessary . . . . In addition, we feel that there is a lack of liaison between industry and government labs . . . so as to enable us to get a quick return from research done there.[75]

Dr. Shane suggested that government could assist industry to build up staff and experience by contracting out research.

Many witnesses pointed out that institutions not dependent on their own earnings or some other control method could drift from their objectives and in time become monuments to past problems. Dr. Cox was one who touched upon this topic:

> Mission-oriented government laboratories can be useful. Unfortunately, once they have fulfilled their task, it is sometimes difficult to switch them off their programs, even if these programs have outlived their usefulness . . . . Seldom, if ever, is the number of scientists and engineers in a government laboratory reduced as is the case in industrial research laboratories, which are profit oriented.[76]

Co-ordination between researchers in different organizations means that they are working on separate tasks that converge upon a common goal. Some witnesses suggested that there was a gap between government in-house research (and university research, too) and the technological needs of industry. The Mining Association of Canada put it this way:

> We have not been without a major scientific effort during the past three decades and, as is also well known, the larger part of the total effort has been carried out in federal departmental agencies and in the National Research Council Laboratories . . . . We suggest that a gap has for too long existed between the prosecution of relatively "basic", as well as so-called "applied" research—as carried out in government agencies and often in universities—and, at the other end, technology in plant . . . . While we would not presume herein to suggest and develop all of the reasons for the existence of this gap, we are of the opinion that a lack of sufficient common interest and effective communication between government research agencies and the industrial sector has resulted in a less than desirable efficiency in the utilization of the results of research.[77]

The Mining Association made an observation about the discontinuity between non-industry laboratories and industrial use: "Within this gap there has been an intended area which, in a general way, encompasses the phases of applications research and engineering design and adaptation—necessary steps towards a workable technology."[78] There is a striking parallel between this comment and the observation made to the Committee by Canadian Patent and Development Limited, a government agency with a vital role to play in connecting the worlds of government research and industrial application.

Some witnesses commented on the spin-off from government in-house research. The Aluminum Company of Canada Limited said:

> The federal agencies appear to be highly oriented toward pure science. There is little spin-off from NRC research that can be used in the aluminum industry in particular. This may not apply to Canadian industry as a whole, but the question of whether NRC and other government agencies engaged in research relate their programs to the needs of industry in general may well be asked.[79]

This statement by Alcan surprised the Committee, because earlier NRC had presented a brief that described their continuing research on materials fatigue as one of their significant programs. Their description stated that "the fatigue failure of engineering materials is now the most wide-spread and intractable problem of engineering design . . . A multi-pronged attack on the fatigue problem has existed in the National Research Council for more than 20 years."[80]

In the discussion that followed presentation of the NRC brief a Committee member asked: "How much of this research work on metal fatiguing is being done in industry in Canada? This seems to be one area where many industries should be doing a continuing job on this subject."[81] The scientist directing NRC's fatigue research answered: "The answer is very simple, sir: It is, effectively, zero."

The Committee asked Mr. G. M. Mason, technical director of Alcan, for his opinion on this matter. Mr. Mason answered: "I can only say that I am astonished, because we have done a fair amount of work on aluminum properties. . . . I think it is more a question that we have not got together than that we are not using NRC."[82] The Chairman then asked Mr. A. D. Fisher, vice-president of the planning, engineering and research division of the Steel Company of Canada, whether his firm was conducting research on metal fatigue. Mr. Fisher answered:

> I think I would agree with Mr. Mason, that NRC are not aware of what is going on, and I do not know exactly how they would be aware unless it were

> through some kind of publication, because we do not work with them intimately in this area. Certainly we in the steel industry have put forth a major effort to make steel more acceptable for us and to overcome some of the problems to do with metal fatigue. . . . We have put a lot of effort into this, on the metallurgical and other aspects, to overcome some of the problems of metal fatigue. I believe that a lot of basic work has been done by industry generally on this problem.[83]

Happily, there have also been many instances of satisfactory collaboration between government laboratories and industry. For example, Dr. Ronald S. Stuart, director of research of Merck Frosst Laboratories, told the Committee that "we have made real efforts to collaborate and co-operate with the National Research Council."[84] Dr. Schaus, director of research and quality control, Canadian Breweries Limited, said that "when we get assistance from the National Research Council on a special problem where we do not have the necessary specialized equipment, we have had nothing but first-class co-operation and first-class results."[85] Dr. Stuart mentioned a collaborative project in isotopic chemistry with NRC: "This is an idea that they had, and we and they have developed it together. It has been a very successful collaboration. Unfortunately, there are not enough examples of that type of thing. I might say that we have looked at certain things with the Department of Agriculture; so far we have found nothing that we have been able to make into something useful."[86]

Dr. Stuart went on to tell the Committee: "I think part of the reason may be that government's scientists and university scientists, and perhaps we in industry as well, are not in sufficient contact. . . . I think we must get to know at the planning stage each other's needs . . ."[87] Later Dr. Stuart suggested that it was difficult for government researchers to appreciate the full range of problems associated with industrial research: "We have attempted to use results of the Department of Agriculture's research, and on that particular problem . . . we got all sorts of information we needed, but it was clearly evident that if they had some industrial thinking at the front end then the results might have been different and more useful. . . . If they had had industrial help, then I think they would have come up with a more useful result or at least they would have had a much greater chance . . ."[88]

The evidence before the Committee includes many cases in which government in-house research led to major and important industrial innovations; in some cases to new companies, even to new agricultural crops and new industries.[89] However, the evidence from the productive sector suggested that the work of government in-house laboratories has not been as helpful as it was originally hoped and intended when these laboratories were built. Some witnesses have seriously doubted whether R&D initiated by government researchers and conducted in government laboratories had a reasonable chance of success, especially in view of the fact that R&D alone is only one link in the innovation chain and must be intimately connected with all the other links. Other witnesses suggested that industrial research in government laboratories would be more likely to be used by industry if program selection and co-ordination were improved. Most witnesses from the industrial sector agreed that there was a serious gap between the government laboratories and industry, the declared potential user of these laboratories' output. So it is interesting to note that from the very beginning of the campaign to build government laboratories and do research of potential use to industry, no one ever put forward a *detailed* mechanism for translating laboratory research into industrial innovations. It seems to have been simply an article of faith that a felicitous transfer would occur. The Committee believes that this must now be questioned.

Most briefs presented by industries and industrial associations recommended stronger, more comprehensive, and less restrictive federal government incentives to stimulate innovation in industry. The Committee was struck by the fact that this suggestion also received broad support from "wise men", individuals, non-industrial associations, and the academic sector. It was one of the most widely approved recommendations made throughout our hearings.

All the briefs from companies and industrial associations contained detailed criticism of existing incentive programs. It was nonetheless apparent that these programs have been helpful to industry. For example, the Steel Company of Canada declared:

> Our overriding comment on government incentive programmes is that such programmes provide the most effective means for the encouragement of research and development in Canada within the limits of available funds. Without such encouragement, for example, it is doubtful if this Company would have built its Research Centre or have carried through some of its more costly and effective research programmes.[90]

But Stelco was typical of industry in also offering criticism and suggesting improvements:

> Our experience also leads us to the opinion that the government incentive programme has been unnecessarily complicated by the creation of a number of plans to meet a variety of situations, their administration by a number of different departments and agencies, and their frequent revision or discontinuation.... We would, therefore, recommend that, so far as possible, govern-

ment incentive programmes be consolidated and administered through a single agency, or at least have a common application and submission procedure.[91]

The Committee is pleased to note that improvements have already occurred in incentive programs: improved information about the programs, extension of some programs, and correction of some of the problems in the PAIT program. This has helped to strengthen the bridge between governmental intentions and industrial innovation.

### 4. *The problem of manpower*

In previous chapters it was noted that from the beginning NRC regarded basic research as the seed-bed for industrial development. Great strides have been made in producing more Ph.D.s; the annual output has been increased from about 200 in 1959 to the point where it is reasonable to project a figure of around 2,000 a year in 1973.[92]

The Royal Society of Canada stated in its brief that the majority of Ph.D. graduates in the sciences and engineering "must seek industrial employment, in their own country or elsewhere. Canadian industries should offer more attractive employment inducements to Ph.D. graduates in science and engineering, and take advantage now of the unprecedented opportunity to permit competent staff of great potential accomplishment."[93] In a similar vein, the brief from Carleton University's Faculty of Engineering noted Dr. Schneider's expectation of a surplus of Ph.D.s and stated:

> These conclusions depend upon the continuation of present hiring policies and management decisions regarding the use of these highly trained persons. It is to be hoped that the greater depth of understanding that is usually linked with this advanced degree will be recognized soon by management. Employment of Engineering Ph.D. graduates by industry should result eventually in better leadership as some of these people assume executive positions.[94]

The National Committee of Deans of Engineering and Applied Science declared: "Some way must be found to increase the incentives for stimulating Canadian industrial research and development. One method might be to subsidize in some way the employment of Ph.D. engineers for a number of years. This would have the added effect of upgrading the educational level of future management."[95]

A witness from industry, Mr. V. O. Marquez, president of Northern Electric, agreed that the Ph.D. graduates "that we produce have to find work in this country in one or the other of two basic places, either back in the universities, where they help train more Ph.D.s, or in industry." As for industry, Mr. Marquez commented: "If we are not developing the innovative end of the scientific spectrum, which is the one which takes place in industry, at at least a parallel or balancing rate to support the rate at which discovery is growing, then, of course, we are going to have Ph.D.s who are going to have to look for employment outside of Canada."[96]

Some witnesses questioned whether the training and attitudes of Ph.D. graduates fitted or motivated them for work in industry. Messrs. J. Mardon and J. Root stated in their brief: "Our education system is deficient in that . . . we are educating our scientists and technologists for an unreal rather than a real world. This is most clearly evident in the 'Ph.D. cycle'."[97]

The lack of contact between universities and the "real world" was stressed by Dr. Lionel Boulet, director of research at Hydro-Québec, who said that after the war "university professors decided to go into communications, electronics, satellites, and all of those things" and this led to a lack of interest in the electric power field. "We were giving to our students mostly a course for physicists—theory, and no application and no problem," Dr. Boulet added. He went on:

> We developed such a mentality that a professor from McGill University could tell me the other day, "You know, we are graduating our fifth generation of doctorates in electrical engineering this year. This generation was produced by the fourth one we had, and the fourth by the third, and the third by the second, and the second by the first, and not a single one of them ever went into industry to have training, so they do not know the industrial problems" . . . . If you go to Europe, it is the reverse: a man becomes a professor in a university only after he has reached a high point in his career and he is known, and the appointment is made on a competitive basis, so he has 15 or 20 years of experience.[98]

The same idea was expressed recently by the newspaper columnist Richard Needham, who wrote:

> Some day soon, one of the Canadian universities will set up a course on the care and feeding of camels. And will the people who graduate in it go to the Middle East? Don't be silly; they'll just go to other Canadian universities and set up courses there on the care and feeding of camels. Graduates from these courses will go to teach the subject in high schools and community colleges. Eventually, Canada will have 10,000 accredited camelologists, none of whom has ever seen a camel.[99]

The Research Board of the University of Manitoba deplored the same tendency in the education of nuclear physicists:

> Although the point is always made in seeking support for nuclear physics (for example) that this subject provides an excellent setting in which to acquire a solid knowledge of the concepts and techniques of physics, the general

> usefulness of their training is seldom emphasized to the graduate students themselves. Instead they are apt to gain the impression that they are especially trained for a noble calling of nuclear physics and to settle for less would be unworthy of them. The rest of the scientific world might find this attitude tolerable if unlimited positions existed for nuclear physicists—but this is no longer the case.[100]

The brief went on to explain: "Although nuclear physics has been chosen as the example, these comments apply equally to many other fields of specialization."

Dr. Pierre Gendron, president of the Pulp and Paper Research Institute of Canada, pointed out that the manpower problem stemmed in part from Canada's implicit science policy:

> As to whether we have a science policy in Canada, I sincerely believe that we have not got one. Since 1945 or the end of the war, there was, however, one shape of a policy which added a tremendous effect in Canada and was evolved by the National Research Council which was to build up fundamental research in the universities. That was a policy decision. The increase in grants that were made by the National Research Council over that period was definitely to produce more scientists so that they could be used by industry later on. Unfortunately, I think this policy has not worked as well as it was intended to, because what has happened is that we do produce a great number of qualified scientists in Canada, but mostly they go back to the universities to build up a university machine. In my opinion, this has tended to give the universities the attitude of an ivory tower where the application of research has been cut out. If there had been more interchange between industry and the universities at an earlier stage of this program I think probably the situation would be somewhat better than at this stage.[101]

Mr. Sutherland of Shawinigan Chemicals told the Committee that when a Ph.D. did join a private firm "very often [he] becomes unhappy in industry because he finds shortly that he is moved to some project for which he perhaps was not trained at the university, and he looks around and sees that the National Research Council are doing this kind of thing that he likes to do, and so he tends to move there or perhaps go back to university."[102]

We cite one more witness on the "Ph.D. cycle". Mr. Maurice Kenyon Taylor, director of R&D for Ferranti-Packard Limited, representing the Electronic Industries Association of Canada, underlined the remarks in the association's brief:

> Students who are at the top of the classes in the sciences have a temptation to remain in the comfortable academic environment and carry out research there. The result of this is an expansion of the post graduate research facilities and an ever increasing demand for more and better research workers and money for their support.[103]

Engineering was singled out for comment by some witnesses. The National Committee of Deans of Engineering and Applied Science opened their recommendations by stating:

> The existence of a significant cadre of engineering research workers in Canadian universities makes it now imperative that engineering be recognized as a distinct entity, and not as a branch of the sciences . . . Engineering motivation is quite different; it deals with synthesis of information and techniques at least as much as with phenomenological analysis; and it must involve itself with economics, sociology and ecology, if it is to make its proper contribution. That this state of mind has not really been attained is clearly revealed in the presentation of data by the National Research Council to this committee . . . All the statistics dealt with 'science and engineering' as if this combination were homogeneous and amenable to the same policy considerations.[104]

The brief went on to note that in 1966 the Deans' committee had recommended the formation of an Engineering Research Council as an adjunct to the National Research Council, (Messrs. J. Mardon and J. Root recommended the formation of a National Engineering Academy.)[105]

There were specific references to shortages of engineers in several briefs. Canadian Westinghouse recommended "attention to the supply of production oriented engineers in Canada",[106] the president of Westinghouse commented that "our problem is in getting young scientists and engineers who are interested in solving the nuts and bolts problems of manufacturing industry today."[107]

Dr. G. G. L. Henderson, vice-president of exploration at Chevron Standard Limited, told the Committee that "there is a shortage of geologists and geophysicists just the same as in the earth sciences. We have difficulty in recruiting our requirements and have been forced to go abroad to Europe." He also noted: "We have found that there are very few Ph.D.s interested in going into industry, although there has been a slight improvement in that trend."[108] Dr. Henderson did not believe that there would be a surplus of Ph.D.s in the earth sciences in the foreseeable future. He noted, in fact, that those he could hire tended to drift away from his firm: "The earth sciences seem to have a heavy mortality. We seem to be stocking the government . . . . I can assure you that we have personally been responsible for staffing some of the departments of government. I am quite sensitive on that point."[109]

Despite the surplus of Ph.D.s, witnesses still found some shortages. Mr. Cogan of Imperial Oil told the Committee: "We have no difficulty currently in securing high quality competent Ph.D.s for our requirements. . . . There is probably some surplus."[110] The brief from Imperial Oil Limited noted: "At the present time, we find there is a good supply of competent chemists



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and chemical engineers. There is some shortage of geophysicists, geologists and mechanical engineers."[111] Dr. G. Shant, director of research for Shell Canada Limited, and Dr. D. C. Downing, director of research for Shawinigan Chemicals Limited, both told the Committee that they could hire Ph.D.s fairly readily and that there appeared to be a surplus.

Dr. Stuart of Merck Frosst Laboratories told the Committee that many Ph.D.s in organic chemistry coming out of the universities might have difficulty finding employment. He indicated, however, that his company had great trouble finding Ph.D.s with enough training. He described his search for two Ph.D. organic chemists and said: "Of all the people we saw there were not many . . . that were really well qualified"; they lacked training and were "too specifically orientated."[112] Dr. Stuart added that "the universities are commencing to realize that they are turning out people who are not necessarily people the country needs, speaking from the point of view of training. They are well-trained people, but it is not the training we need to do the work we have. The only pharmacologist applications we get are from foreign people. After looking for two years, we finally got an Egyptian."[113]

Dominion Foundries and Steel Limited declared: "While Canadian universities graduate scientists and engineers skilled in their respective disciplines, they lack a broad knowledge which would result from a well-rounded education."[114] Abitibi Paper Company Limited reported: "At present there is a super-abundance [of scientific manpower in Canada], though this may be a temporary situation. Many Ph.D.s are looking for positions and quality is good . . . Immigration has flooded the country with inadequately-trained foreign graduates who suffer also from lack of adaptability to Canadian methods. The supply of technicians trained in post-secondary institutes is good, and growing perhaps into a surfeit."[115]

Shortages of skilled manpower could also have a serious effect on regional development. Mr. B. J. Starkey, vice-president of engineering for E.M.I. Electronics, told the Committee: "In the Atlantic provinces, Nova Scotia in particular, it is very difficult to attract engineers . . . to the industry there . . . Even the local school graduates as a rule do not want to stay in the Atlantic provinces . . . [It] is much easier to recruit people in Australia, the U.K. or even in the States. We have got engineers from all over the world, but very few Canadian engineers. They simply do not want to stay there."[116]

We could go on almost endlessly citing problems associated with scientific and engineering manpower, echoing those we have discussed and reaching into the social sciences, mental health, medical research, and urban affairs. Many witnesses, too, stressed the importance of developing courses in management, but the examples we have given suffice to show that Canadian industrialists are seriously concerned about the nature of Canada's university training.

## SUGGESTIONS FOR MORE EFFECTIVE CO-ORDINATION

The Committee received a number of comments about the co-ordination of science policy and of government measures affecting R&D activity. Most witnesses seemed to recognize that there were limits to measures that could be taken to redress their specific problems. Often this undercurrent became explicit and witnesses warned that a new policy to redress one specific situation might well aggravate another. For example Canadian Industries Limited said: "It behooves legislators to be alert concerning the degree to which government actions in pursuit of other policies (e.g. in the field of patents, tariffs, anti-combines, taxation, etc.) may unwittingly thwart the aims of science policy."[117] In the same vein the brief of Uniroyal Research Laboratories stated: "A tariff policy must be developed which is compatible with our national policy and our science policy."[118]

Other witnesses used different examples to illustrate the connection between science policy and other government policies. Many said this vital integration would not be possible without a conscious and coherent overall science policy, and the most common recommendation was the establishment of a co-ordinating mechanism. Recognizing that the government's portfolio of policies involves several departments and ministers, some witnesses recommended that this co-ordinating function should be the active responsibility of a single department or minister.

### 1. *The need for a central co-ordinating body*

The need for co-ordination was stated by Dr. W. R. Horn, research co-ordinator of the Mining Association of Canada:

> We believe, Mr. Chairman, that a policy-directing agency, responsible for the statement and control of national priority objectives will be strongly required.... The co-ordination of research objectives must surely be held as one of the most important features of any future science policy and practice in this country. Again, whether this is a job for an advisory body or for a minister with authority for the distribution of research funds, we are not prepared to competently suggest, though we would comment that we are not aware of any method for the effective and continuing co-ordination of research, other than one involving control over the distribution of the funds for its prosecution.[119]

The brief of Dalhousie University referred to the need for a planning group and a co-ordinating group, both of which "would be required to determine effective ways for the execution of agreed plans, and would have to evaluate the relative positions of universities, governments and industry,"[120] and declared that there would then be the "necessity for a single central authority to which both the planning and co-ordinating groups should report."[121]

Some witnesses pointed out the need for strong central co-ordinating bodies in particular fields of research. The Canadian Mental Health Association's brief states, for example, that the government should consider establishing "a federal research planning, funding and evaluation centre" and "should provide an information centre and clearing house for scientific data for Canada in the mental health sciences."[122]

Another such situation was considered by Mr. John F. Postma in a brief prepared for Notre Dame University of Nelson B.C. Even basic academic research, he stated, "cannot be independently and autonomously engaged in to an unlimited degree . . . Even this work needs to be co-ordinated." Mr. Postma stressed "the glaring lack, especially on a national scale, of effective master-planning and of appropriate structures for co-ordination between universities, the various levels of government, business and the professions, with regard to post-secondary education generally and with regard to research in particular." He continued: "One would hope it to be possible to fashion an effective planning and co-ordinating body"[123] from such agencies as the Treasury Board, NRC, the Science Council, other government agencies, industrial research associations at the national level, the A.U.C.C., and so forth. He continued: "Such a planning and co-ordinating body should be capable of setting general patterns and guidelines for the development and operation of the appropriate, equally pluralistic structures at the provincial level. In any case, we hope that Canada's basic approach to these problems will amount to more than ineffectual tinkering."[124]

Dr. Pierre Gendron, president of the Pulp and Paper Research Institute of Canada discussed with us the need for greater co-ordination between government, industry, and the universities. He drew attention to the fact that the institute was a unique example of one means of establishing co-operation in a specific field.[125] Another institutional means of effecting co-operation between government and a specific business sector was recommended by Mr. J. C. R. Punchard, assistant vice-president of Northern Electric Company. He described the Canadian Radio Technical Planning Board and suggested that this was "a model organization which could form the kind of organization to provide an interface between government and all industry on matters pertaining to research and development."[126]

Another special co-ordinating body was recommended by the Chemical Institute of Canada: "That the government create a National Science Foundation which would co-ordinate its support on all matters which would touch on the maintenance of supply and upgrading of competence of technically-trained people."[127]

The University of Toronto saw a need for a co-ordinating body. It recommended that "the distribution of government funds for support of research and also the way in which the funds are utilized by government departments, agencies and councils should be the subject of advice and criticism by a duly constituted government body."[128]

The faculty of engineering of Carleton University stated in its brief: "An effective science policy requires a body having adequate responsibility to do the planning and enforce its decisions. We believe that the Government of Canada should assume the responsibility for Science Policy, as it does for Foreign Policy and Defence Policy. Various advisory bodies can be consulted, or instituted if necessary, but the final policy decisions must rest with the Government."[129]

York University's faculty of science declared: "Serious consideration should be given to unifying and co-ordinating the government's present activities in science and technology under a responsible authority whose major responsibility would be to keep a watching brief on all aspects of Canadian science and technological activity and to administer funds for it, and to advise the government on such matters. We recognize the problems in implementing such a proposal but the need for improved co-ordination is urgent."[130]

We would like to note the remarks of that experienced man of science, Dr. C. J. Mackenzie. He told the Committee: "There are, as we know, departments dealing with day-to-day policy on such matters as defence research, space research, oceanography, pollution, etc. In all of these fields, I suggest there should be some overall government policy, or at least guidelines, before departments and agencies are allowed to embark on ad hoc expenditures which may often determine, but not follow government policies. The future policy of the government very often is determined by the activities and expenditures of government departments, without any reference to government overall policy. This may not have been so wrong in the past and there was little complaint in the early days, but it should not be acceptable today."[131]

The impact of science and technology on society will, according to some witnesses, require changes in the science policy making process. For example, the social sciences may well have to play a greater role in policy making. The Social Science Research Council of Canada put it this way: "Before major policy decisions are made, there must exist an advisory machinery through which the most authoritative advice from social scientists can be expressed and taken into account."[132]

Several witnesses claimed that existing co-ordinating committees or bodies were ineffective; some went so far as to suggest that they were ineffective by nature. Mr. A. Andras, director of the Canadian Labour Congress's legislation branch, stated: "while we have a great many advisory committees in government . . . they do not meet frequently, they are not properly staffed."[133]

Notre Dame University's brief spoke of "the chaos even within those research areas that are presently considered to be of legitimate and direct federal interest. We suffer from too many 'co-ordinating' bodies operating with an indefensible degree of independence from one another."[134]

Dr. Max Tishler of Merck Frosst Laboratories told us that improved communication and intercourse between the government, university, and industrial sectors could not be improved by committees. He said: "How do you do that? Not by committees. . . . I think those committees can be lawfully deadly because, from my point of view, committees are dominated by certain people and they can go in the wrong direction. The strongest person, the most vocal person, is the one who wins."[135]

Mr. Maxwell Weir Mackenzie, a man greatly experienced in federal government decision-making, told the Committee: "During my time in Ottawa as deputy minister, priorities were determined by the forcefulness or otherwise of the individual minister concerned. A forceful minister got his departmental projects through and a less forceful one, who might have had a better project, often failed."[136] This suggests that matters requiring the co-ordination of science policy with other government policies need the attention of a minister with authority who is solely responsible for such matters.

One co-ordinating mechanism favoured in the federal government is the advisory committee. These committees usually include expert members from government, universities, industry, and other organizations in the private sector. Many witnesses, particularly witnesses from government agencies, told us that these committees were the means by which co-ordination was effected. We have counted almost 200 such committees with approximately 2,500 members. One striking fact is that scarcely more than 10 per cent of these members are from the industrial sector—a weak representation, it seems, if the committees are associated with research intended to assist industry. Although these numbers may now have changed, we found, for example, that of approximately 90 members of the committees attached to the policy and planning branch of the Department of Energy, Mines and Resources, only one came from industry. Of the 50 or so members connected with the mines branch there were slightly more than a dozen members from industry. Of the 170-odd members of the Defence Research Board's committees, only about half a dozen came from industry. NRC has an elaborate series of associate committees and these were an important innovation in the early days when there was hardly any other means for Canadian scientists to get together. Today there are about 600 members of NRC committees of whom about 100 are from industry. The very low industrial representation on NRC's committees appears, on the face of it, to be a strange situation if an appreciable amount of NRC's activity is directed at eventual industrial application; particularly when one reads in the 1969 *Canada Year Book* that "the application of science to Canadian industry has always been one of the major concerns of the National Research Council. Since 1917, representatives of industry, government, and the universities have co-operated, through NRC Associate Committees, in solving pressing industrial and economic problems. There is a constant flow of personnel and information between NRC laboratories and those of industry, and roughly 70 per cent of the Council's own effort involves applied research intended for industrial use."[137]

There may very well be good reasons for the low representation of the productive sector in these inter-sectoral, government sponsored committees. Nevertheless it is not obvious that these purely advisory committees could effectively co-ordinate R&D throughout the various sectors involved.

But there were witnesses, none the less, who recommended against a strong central co-ordinating unit, a department, or a minister. For example the brief of the Royal Society of Canada stated: "The growth of a large, bureaucratic science policy apparatus within the government is undesirable. The Science Council of Canada is the soundest source of expert advice to the government on scientific issues . . . Through its Chairman, the Council's views on matters of national science policy should be sought by and made known to the responsible Ministers."[138]

Similarly, the Canadian Biochemical Society declared: "In our judgment, the creation of a central, science-policy making authority is not now in the best interests of Canadian biochemistry . . . [139] In recent years, much effort has been devoted to finding new means by which Federal government policy should be determined. Yet we who are most concerned, the research scientists and their chosen representatives in national scientific societies, have been little consulted."[140]

We have noted that the French-language universities favored co-ordination between the various sectors involved with R&D. Dr. L'Abbé informed the Committee that his own university, Montreal, had told the Macdonald Commission that it supported the setting up of "a national committee which would not be federal only but rather a joint federal-provincial committee. Such a committee would thus include both the federal government and the provinces in its representations, because, in view of certain aspects of research, each province should actually establish a policy in this area. The federal government should also establish one, since there should be a policy for Canada as a whole, for the Canadian nation. I feel, then, that the various governments must work together . . . This would make it possible to solve jointly the problems of disparity . . . It would make possible concerted action on important scientific developments which are now very expensive for a country and which must be carried out with a great deal of selection. These policies must be very specific . . . but they must at the same time be universal and involve everyone."[141] Dr. Larkin Kerwin of Laval agreed: "The committee suggested by Vice-Rector L'Abbé would be an excellent idea because it would answer a need which is not satisfied at the moment."[142]

### 2. *A minister or department for science policy*

The Electronic Industries Association included in its brief a section entitled 'Absence of Science Policy Direction', which declared: "Hitherto there has really been no real science policy."[143] The association warned that the determination of science policy "is a continuing dynamic process . . . We do not think a policy can be laid down for all time, except in the most general terms; viz., that there must exist such a policy."[144] Although a science policy mechanism should be "an essential control and recognized as such to ensure our future well-being," nevertheless, "we . . . draw the attention of the Committee to the fact that at the present time there are no bodies who have the power to control or even to indicate the direction of science with the possible exception of financial controls through the Treasury Board, and this amounts to a question of how much is asked and how much is available for granting."[145] The association indicated where it felt the problem lay:

> We would like to draw the attention of your Committee to this gap at the top because we believe that the importance of instituting a means for formulating and controlling National Science Policy transcends both party politics and the push-button mind. We believe that if your Committee will suggest a solution on how the gap can be filled it will have performed a service which will endure for many generations for the benefit of all Canadians.[146]

Any consideration of "a gap at the top" inevitably leads to discussion of decision-making at cabinet level and whether or not there should be a minister to close the gap.

The Pharmacological Society of Canada did not think that a minister was necessary. Its brief stated: "Since science is an all-pervading activity, it is believed that it would be unrealistic to establish a federal Department of Scientific Affairs. Neither should there be a Minister of Science Affairs without a Department. Other mechanisms must be found to centralize scientific affairs. One such mechanism could be the maintenance of the Special Committee on Science Policy, which could become a standing Committee of the Senate, and act as a permanent public forum for the expression of the views of all concerned."[147]

Mr. A. D. Fisher, vice-president of the planning, engineering and research division of the Steel Company of Canada, expressed a similar concern: "We are not in any way arguing against the need for a national science policy. . . What we are arguing against is the kind of centralized effort that we felt was being suggested, where effort in research and development would be concentrated through some kind of government agency, and to a degree withdrawn from the private sector."[148] Later he stated: "I am not against the suggestion that we should give industry incentives to do more. I am, however, concerned about setting up a government agency under a minister who may really mitigate against our effort, who may begin to dictate what we should be doing, or where in his view our contribution might be more effective . . . We feel we should be left to determine in a major way our own destiny in this regard."[149]

Mr. Fisher's view was not unique in the industrial sector. For example, the Canadian Manufacturers' Association's brief stated: "It is believed that the creation of a Federal Department of Science or Scientific Affairs is unnecessary and in many respects undesirable. It is therefore recommended that such a department should not be established." The Manufacturers' Association is also opposed to a Minister without operational responsibilities: "The alternative possibility of naming a minister responsible for science who would have no departmental responsibilities is not considered practicable. It is therefore recommended that such an appointment should not be made."[150]

Mr. Everett Biggs, president of the Agricultural Institute of Canada, told the Committee: "It is possible that a minister responsible for science policy could be workable. My stronger reservation is the idea of forming a new government department which increases the public cost and just increases, again, [the need for] inter-departmental coordination, because the tentacles come out in turn to form a new department. I speak after 20 years in government administration."[151] There were many witnesses who, like Mr. Biggs, appreciated the difficulty of obtaining inter-departmental coordination,[152] and, thinking that without such co-ordination an overall science policy would be impossible, went on to recommend a minister or a department as the workable solution.

It is important to take note of the possible ambiguities and/or semantic problems associated with the terms "Minister of Science", "Minister of Science and Technology", and so forth. The situation is confused because we have never had a federal minister with such a title, and in other countries the ministers with such titles and/or their associated departments have very different responsibilities. In our discussions we found it necessary to determine, when a witness stated that he was for or against a "Minister of Science", just what responsibilities he associated with this minister. In some countries, a ministry has taken over direct policy and operating control of the R&D activities of several departments; in others the minister is not responsible for governmental R&D but for science policy and for ensuring that it is integrated with other government policies. None of our witnesses favoured a minister whose responsibilities would include operational control. There were witnesses who favoured a Minister for Science Policy but, there again, there was an important distinction that came out in discussion with Dr. Larkin Kerwin.

Dr. Kerwin indicated that he did not like the idea of a Minister of Science who would be responsible for a large department conducting and centralizing science, and yet he did not favour "no minister" either. He suggested that a "middle term" between the two would be a committee of ministers. He used the example of France to illustrate the point:

> From what I have studied, this middle term has been found by France. In France, science is the responsibility of a group of ministers, and this group, forming the Science Committee, is chaired by the prime-minister himself, and in general, the work is done by the . . . Delegate General. But, then, the total budget for French science is submitted to the House by a group of ministers and thus it does not compete with the other departments and it is sponsored by the prime minister himself. . . .[153]

Dr. L'Abbé expressed the concern felt by all witnesses at the suggestion of a minister with a large and direct operating responsibility:

> After all, like many others, considering the multiplication today of the organizations which are engaged in science policy or in carrying out research work, it seems clear that something of the sort [a minister] becomes essential. Must it take the shape of a Department of Science and Technology, an agency which has therefore not only a consultative role, but also an executive one? Personally, it seems to me that this is a thing toward which one should tend, but maybe not directly, otherwise we always have committees or advisory

councils, which make recommendations, but, in the end, the decision makers are somewhat dissociated from the motivations which permitted the formulation of the recommendation .... The consultative and the executive become too dissociated.[154]

Dr. S. B. Frost, dean of the University of McGill's faculty of graduate studies, was also opposed to a minister with large operating responsibilities, but as for a minister mainly responsible for keeping an overview of science policy, he stated: "To have a minister responsible for the general oversight, I think, would be an excellent thing. . . ."[155]

Mr. Andras of the Canadian Labour Congress said he thought that it would make "good sense" to have a cabinet minister for science policy and that "the tenor of our brief would be that this would be a good idea."[156] Dr. J. J. Green of Litton Systems (Canada) Ltd., a man of long time science policy experience both within and outside of government, suggested a minister without departmental responsibility, a minister who would be responsible for bringing to cabinet the proposals of the scientific community and who would assess programs and recommend pilot projects. Dr. Green stated that this should be the minister's full time responsibility.

The question of a minister came up during discussion with some of the associations and learned societies. Prof. Douglas Verney, president of the Canadian Political Science Association, stated that, on the basis of the discussion in which he had been engaged, he thought that "a greater effort is required and some form of organization, such as a minister, might well be considered."[157] Other colleagues agreed; for example. Prof. W. J. Waines, appearing with representatives of the Humanities Research Council of Canada, said he thought that there should be "a very strong minister" who would be responsible for science policy and its inter-relation with other government policies.[158] Prof. Waite, chairman of the Humanities Research Council, suggested that "a minister, or ministry of research" might simplify matters.

During discussion of some of the industrial briefs, Mr. L. Hynes, president of Canadian Industries Limited, said that he had been worrying about a department of science since joining the Science Council. He said his views had firmed up: "Having visited the Atomic Energy labs, the University of Manitoba, and the fisheries lab out in British Columbia, I find that we seem to have people locked into very watertight compartments in our scientific endeavours."[159] He later said: "The efficiency with which the taxpayer's dollar is spent in the area of technology, I think, is a great question. . . . I am beginning to wonder whether it would not be a case for a minister of technology. . . .[160] He would not take over the scientific work of everybody, but would be like the Auditor General on the spending of money. He would be the critic on behalf of the people, saying whether they are getting their money's worth in science-orientated departments."[161] Mr. Hynes also stated: "We should have this person as a very senior cabinet minister, I think, because he should participate very closely in the program of planning the nation's objectives."[162]

Dr. H. F. Hoerig, the vice-president in charge of research and development for DuPont of Canada Ltd., said he supported Mr. Hynes's views: "It seems to me that one of the needs for a science coordinator is to bring about in government a recognition that some of the old principles that we have adhered to for so many years are no longer viable and really do not have anything to do with the 20th century. In other words, we have to be willing to scrap some concepts that have been very good for this country over a period of many years. . . . If we have an outlook in this country that we are going to think in terms of rear-view driving in connection with the industries we have today and not set up our structures in terms of the requirements of tomorrow, we are just going to find that this dilemma is not going to be solved."[163] The problem, Dr. Hoerig pointed out, "is that this country is undergoing, and is in the midst of, a very serious transition which is brought about by technological change."[164]

The research advisory board of the University of Guelph declared: "A ministry should be established in the federal government with responsibilities for research in the areas of the natural sciences, the social sciences and the humanities,"[165] thus taking science in the broad continental manner. The brief of the department of computer science of the University of Western Ontario, after describing some objectives of a national science policy, suggested that they should be implemented by a "cabinet-level Department of Science and Technology."

The Biological Council of Canada recommended in its brief "that the Privy Council Committee for Scientific and Industrial Research become the political entity for formulating science policy and that its chairman be a minister without other departmental responsibilities."[166] The Canadian Heart Foundation recommended that "the Chairman of the Privy Council Committee on Scientific and Industrial Research should be other than the President of the Treasury Board."[167] (The foundation also recommended that the Senate establish a Standing Committee on Scientific Affairs and that the chairman of the committee be the chairman of the Privy Council committee.) The University of British Columbia recommended that "the decision-making body reporting to the cabinet" should be the Privy Council Committee on Scientific and Industrial Research, and "to this group there should be added a Minister for Science who would be the Chairman and who would be the spokesman for science policy in the Cabinet."[168]

It should be noted that these three organizations are in effect recommending a cabinet committee comprised of ministers of departments involved in science and technology, together with other ministers, such as the Minister of Finance and the Minister of Industry, Trade and Commerce, and that the chairman of this committee be a minister responsible for science policy matters. The references to the Privy Council Committee on Scientific and Industrial Research arise from the fact that this has been the traditional title of a cabinet committee for many years.

The brief of the Aluminum Company of Canada suggested the need for a coordinating authority, and suggested that it "might take the form of a Department of Science and Technology, but what is of paramount importance in this age of increasing complexity is to make sure that it be provided with the authority to take all necessary means and steps to maximize the over-all return accruing from governmental agencies."[169] The brief of Canadian Industries Limited stressed that a science minister would need authority:

> We are concerned with developing and maintaining a concerted approach to the implementation of science policy on the part of large and powerful government departments ostensibly concerned with other important matters outside the area of science but who have it in their power unwittingly to frustrate science policy. It seems doubtful that this co-ordination task can be accomplished by a minister of science or science policy unless he is attached in some way to an obvious power centre. . . .[170]

Parliamentary responsibility was not forgotten. The Chartered Institute of Secretaries of Joint Stock Companies and other Public Bodies in Canada recommended "that consideration be given to establishing at an appropriate time a Ministry of Science to advise and report to Parliament on scientific activity in Canada."[171]

## CONCLUSION

The evidence presented by industry and other private organizations on the topics covered in this chapter is fundamentally similar to the views submitted by representatives of the federal government sector. It shows that there is no adequate scientific and technological information in Canada on what goes on at home and abroad. It reveals that relatively too much R&D is being performed by government laboratories and that the Canadian government could do much more to encourage R&D and innovation in industry. The lack of effective co-operation between performers of R&D and the shortage of scientific manpower in several areas have also been noted. In this connection, private industry was critical of the performance of universities as training centres for future scientists and engineers.

Finally, as did representatives of the federal government sector, industries and other private organizations expressed concern about the lack of co-ordination within the Canadian government with respect to science, technology and innovation. The need for more effective central mechanisms was pointed out and various suggestions were made for filling "the gap at the top".

The striking similarities of the views presented by the federal government sector and private organizations clearly show that the national debate on science policy which has been going on in Canada, particularly since the Committee began its public inquiry, has produced a consensus at least on vital issues. This new wisdom, which advocates objectives and strategies quite different from those of the conventional wisdom of the past, offers opportunities for the future of science, technology, and innovation in Canada that should not be lost.

## FOOTNOTES AND REFERENCES

**Hereafter the Proceedings of the Senate Special Committee on Science Policy are referred to by Number only, followed by Appendix number between brackets, and page number.**

1. No. 71 (173) p. 8417-8418.
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3. J. M. Carroll, op. cit. p. 5943-5944.
4. No. 45 (64) p. 5824.
5. op. cit.
6. No. 45 (65) p. 5829-30.
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9. No. 46 (67) p. 5880-5884.
10. No. 47 (81) p. 6071.
11. No. 65 (151) p. 7935.
12. No. 48 (87) p. 6157-6158.
13. No. 62, June 12, 1969, p. 7395.
14. No. 45 (64) p. 5824.
15. No. 47 May 28, 1969, p. 5923.
16. No. 75 (184) p. 8816.
17. No. 71 (172) p. 8383-84.
18. No. 63 (139) p. 7534.
19. No. 67 (150) p. 8070.
20. No. 69 (166) p. 8255.
21. No. 59 p. 7151 (also see brief).
22. No. 63 p. 7490.
23. No. 69 (167) p. 8271.
24. No. 67 (157) June 18, 1969, p. 8067.
25. No. 68 (161) June 19, 1969, p. 8139.
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49. No. 65, June 17, 1969, p. 7879.
50. No. 67, June 18, 1969, p. 8038.
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56. Phase I, p. 34.
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128. No. 47 (73) p. 6010.
129. No. 47 (81) p. 6071.
130. No. 47 (70) p. 5952-53.
131. No. 2, Mar. 12, 1968, Phase 1, p. 31-32.
132. No. 57 (120) p. 7026-7027.
133. No. 61 p. 7337.
134. No. 48 (82) p. 6099.
135. No. 66, June 18, p. 7978-7979.

136. No. 1, Oct. 9, p. 3.
137. Canada Year Book, 1969, Dominion Bureau of Statistics; p. 389-399. The excerpt is from a section "The National Research Council of Canada".
138. No. 54 (112) p. 6704.
139. No. 52 (103) p. 6468.
140. No. 52 (103) p. 6479.
141. No. 46 p. 5861-5862.
142. Ibid p. 5862.
143. No. 63 (143) p. 7673.
144. Ibid.
145. Ibid. p. 7674.
146. No. 63 (143) p. 7673-7675.
147. No. 78 (189) p. 9197.
148. No. 71, June 24, 1969, p. 8349.
149. No. 71, June 24, 1969, p. 8350.
150. No. 79 (204) p. 183.
151. No. 61, June 16, 1969, p. 7338.
152. Canadian Association of Geographers brief states, for example, "a national science policy must involve cross-departmental collaboration of a sort very hard to maintain, because departments have a vested interest in their particular bit of the whole."
153. No. 46 p. 5876.
154. Ibid p. 5875.
155. Ibid p. 5816.
156. No. 61, June 12, 1969, p. 7338.
157. No. 58, June 10, 1969, p. 7075.
158. No. 58, June 10, 1969, p. 7076.
159. No. 65, June 17, 1969, p. 7898.
160. No. 65, June 17, 1969, p. 7899.
161. No. 65, June 17, 1969, p. 7899.
162. No. 65, June 17, 1969, p. 7899.
163. No. 65, June 17, 1969, p. 7899-7900.
164. No. 65, June 17, 1969, p. 7899. Dr. Hoerig cited a possible future change in which it might be cheaper to make paper from oil rather than cellulose from the forests.
165. No. 47 (78) p. 6050.
166. No. 52 (101) p. 6432.
167. No. 79 (195) p. 10.
168. No. 48 (83) p. 6120.
169. No. 71 (173) p. 8417.
170. No. 65 (149) p. 7923-7924.
171. No. 80 (218) p. 152.

# 10

## THE NEED FOR AN OVERALL SCIENCE POLICY

The bulk of the evidence presented to the Committee, including what came from the federal government sector, stressed the need for an overall science policy. For instance, Mr. Jean Boucher, then the director of the Canada Council, stated that a national science policy "must provide a rationale for the apportionment of government funds between ministries and research councils on the one hand, and on the other, between development budgets, research contract budgets and research grant budgets."[1] It was indicated to us by many groups and individuals that without such an overall policy, it would be almost impossible to develop an effective, coherent, and co-ordinated national R&D effort. The Committee's critical review of Canada's past performance and current special position in the international race also substantiates that conclusion.

It would be unfair, however, to assert that this prevailing view is shared by everybody. There are still people who claim that politicians should not mix with science and that science should be left to the scientists. There are others who argue that scientific activities should be viewed merely within the context of particular missions of government departments and agencies. They contend that the government should have a set of specific science policies as integral parts of defence, economic growth, and public welfare policies but they reject the concept of a general science policy—of an overall approach to problems related to science and technology—as meaningless and useless.

These are minority views. Yet the concept of an overall science policy is so fundamental to the approach to be developed in Volume II that the fact that it is still being challenged deserves more than a brief mention. This concluding chapter of the Committee's critical review of Canadian science policy is therefore devoted to an examination of these two minority views. In it we endeavour to show that they are incomplete and incapable of leading to a balanced national R&D effort.

## THE REPUBLIC OF SCIENCE

Some scientists are still proposing that they should be left completely free to determine their activities and their projects. They want more public support, and to that limited extent they accept the idea of a policy for science, but they reject the attempt to mobilize science as a tool for policy.

In his article on "The Republic of Science" published in the first issue of *Minerva,* Michael Polanyi has developed the most articulate arguments in favour of leaving science free to operate as a self-regulating system. He argues that science should be left to whatever co-ordination scientists may choose to impose on their activities. His central thesis is summarized in this comment:

> So long as each scientist keeps making the best contribution of which he is capable, and on which no one can improve, we may affirm that the pursuit of science by independent self-co-ordinated initiatives assure the most efficient possible organization of scientific progress. And we may add, again, that any authority which would undertake to direct the work of the scientist centrally would bring the progress of science virtually to a standstill. . . . I appreciate the generous sentiments which actuate the aspiration of guiding the progress of science into socially beneficent channels, but I hold its aim to be impossible and nonsensical. . . . Any attempt at guiding scientific research towards a purpose other than its own is an attempt to deflect it from the advancement of science.[2]

In its purest and most elaborate form, this approach suggests that the scientist should be free to select his research projects and should receive the funds to carry them out, provided that they have been found by his peers to have scientific merit. In other words, this doctrine holds that the scientific community—or, in the economist's language, the suppliers of research—should determine the level and distribution of scientific activities, thus applying to science a classical law of markets, that supply creates its own demand.[3]

In Canada, the Republic of Science is as old as the first attempt to build a science policy. Its ideal had obviously been reached when Dr. E. W. R. Steacie, then president of the National Research Council, could say (as he did in 1958): "We are, in fact, one of the few countries which has recognized the fundamental fact that the control of a scientific organization must be in the hands of scientists," and could add that the National Research Council had "enjoyed far-sighted treatment from the governments of the day which has left it free from many of the normal aspects of government control and interference."[4] Dr. Steacie could have added that this freedom that was allowed in NRC also applied to scientists in other government establishments and to the administration of government support programs for academic research and training.

The concept of the Republic of Science is still popular today among the pure scientists in universities and government laboratories, as can be seen in an extract from a recent speech by Dr. A. E. Douglas, director of the applied physics division of NRC:

> [Science] will not necessarily advance in directions suited to Canadian needs. The choice is not whether or not Canada can mould science to suit her particular economic and social needs; this is impossible; the only choice is whether or not Canadian scientists, both pure and applied, will be working in the forefront of the new developments such that Canadian industry and society can take advantage of new discoveries. The proposal of the Science Council that we should shape our laboratories to meet predetermined social and economic objectives is one which will effectively bar many Canadian scientists from the most profitable areas of science. It is the fear that our instructions and our budget will be designed to force us into these backwaters of science which has done much to undermine morale.[5]

It is when the concept of the Republic of Science is proposed as a general strategy for the organization of the national R&D effort that it becomes completely unacceptable. As such, it rejects government intervention in this whole field, except to finance it. This doctrine has the same origin as economic liberalism. Indeed, industrial *laissez-faire* asserts, to paraphrase Polanyi's statement, that "the pursuit of profit by independent self-co-ordinated initiatives assures the most efficient possible organization of economic progress." It is now widely recognized that society cannot rely exclusively on the "independent self-co-ordinated initiatives" of private producers to maximize economic and social progress. Yet the limitations and deficiencies of the Republic of Science are even more serious than those attributed to economic laissez-faire.

For one thing, the basic assumption underlying that doctrine is more unrealistic than the hypothesis of pure competition on which the model of economic liberalism rests. In the real world of today the number of researchers is vast and continues to grow and it is not true to say, as Polanyi assumes, that "each scientist keeps making the best contribution of which he is capable and on which no one can improve." Indeed, this condition is very seldom met and when it is, most people would agree that the scientist should be left completely free, within certain financial limits, to determine his own activities. Excellence is so rare that it must remain free.

For another, one of the important requirements of economic liberalism is that private producers should use their own funds in the pursuit of their objectives. In our democratic society, there cannot be any objection to scientific laissez-faire if the scientist is prepared to use his own funds, unless his research activities go against the law of the land. This, however, is not what the modern proponents of the Republic of Science want. They are asking at the same time for more public money and less public control. Society, and government as the guardian of the public interest, obviously cannot accept a request that in too many cases would amount to a social security measure or job-creating program for scientists.

Finally, Polanyi exaggerates, to say the least, when he claims that "the aspiration of guiding the progress of science into socially beneficent channels" is "impossible and nonsensical". So does Dr. Douglas when he says that "the proposal of the Science Council that we should shape our laboratories to meet predetermined social and economic objectives is one which will. . .force us into the backwaters of science. . . ."

Such statements cannot be reconciled with the major scientific and technological developments that have occurred since World War II in industrialized countries, especially in the United States. Most of the American science effort during the last 25 years has been guided by social and economic objectives, if defence and landing on the moon are included among those objectives. The fact that non-scientific purposes have been the main determinants of research in the United States has not brought "the progress of science virtually to a standstill" and has not forced American researchers "into the backwaters of science".

The Republic of Science, like economic liberalism, may have been a desirable institution in the 19th century, but it cannot be accepted as "the most efficient possible organization of scientific progress" for the benefit of society in the conditions likely to prevail during the rest of the 20th century. This does not mean that centres of excellence in pure and basic science should not be developed and maintained in advanced countries or that scientists and engineers financed through public funds or working for industry should not be allowed to do curiosity-oriented research of their own choice. It does mean that laissez-faire cannot be justified as a general principle for the organization of scientific progress when the tremendous cost of research has to be met mainly by public funds and when the good and bad effects of science and technology on society are becoming so far-reaching. In other words, in such conditions scientists, as suppliers of research services, cannot be the sole determinants of the level and the distribution of science activities.

Thus scientists and politicians can no longer ignore each other. There are, of course, areas of possible conflict between the two. The scientist, who is used to living isolated from the rest of society, wants to keep his freedom. The politician, as the guardian of the public interest, seeks to save money and to increase his control over research in order to maximize its social benefits. Don K. Price has summarized this attitude:

> Politicians want to cut down on the appropriations for research, to have more of the money spent on practical technology and less on academic theory and to break down the degree of autonomy which the leaders of the scientific community gained a generation ago in the procedure by which research grants are distributed.[6]

But politicians and scientists cannot continue to work at cross purposes as they have done for too long in Canada. The politician and the public administrator will have to respect the scientist and his freedom, to seek his advice and welcome his criticism. The scientist will have to accept the fact that most research activities have become political in the best sense of that word and must be guided by national goals and subjected to systematic review in the light of those objectives. Not only should the scientist accept this new situation, he should also be prepared to take an active part in the formulation and the endless re-definition of the goals and content of science activities.

In other words, the politician and the scientist must learn to become partners. They must not only live together but work together and help each other to serve society better. It can be a most rewarding challenge for the scientist with his new responsibilities to integrate himself into society. The researcher will of course have to remain a true scientist but he will also become a servant of the public with important social functions to fulfil. This politician will have to remain the guardian of the public interest but he will also become more aware that scientific progress needs a climate of freedom. This is the kind of mutual respect and comprehension that must develop between the politician and the scientist, if the goals of society and science are to be met.

William D. Carey expresses the same basic idea in different terms when he writes:

> If [public policy toward science] is to be strong, it must first be relevant and it must be shown to have relevance. If research and development are necessary

> prerequisites of acceptable national security, or of better health care, or of efficient transportation, or of safer airways, or of getting the mail delivered, or of the control of crime and violence, or of the enrichment of education and learning, and if these are the central concerns of our society, then science and its advocates must learn to shape research and development accordingly and give it relevance in these terms.[7]

This plea for relevance is an ideal very different from the pursuit of utilitarian objectives that some scientists fear in what they regard as the threat of government control. It touches on the purpose of our lives. It is a plea for humanism. As Sir Eric Richardson, director of education of London's Regent Street Polytechnic, said:

> Science without humanity is void, Humanity without science is blind.

## THE REPUBLIC OF MANAGEMENT

There is a second school of thought that denies the need for an overall science policy. Indeed it claims that such a policy is meaningless and useless. It can be described as the Republic of Management. It contends that R&D activities are useful to solve economic and social problems but that they should be determined at the micro level, in the light of the particular missions of the various government departments and agencies, under the benevolent supervision of the Treasury Board.

What is needed, according to the advocates of the Republic of Management, is a series of specific science policies in such fields as health, agriculture, and transportation, not an overall science policy. And these specific policies should be formulated and implemented by those directly responsible for the missions. This presents yet another mechanism of "independent self-co-ordinated initiatives," as in the Republic of Science, except that the power to decide and to initiate has been transferred from supply of research services to demand from the myriad of scientists to the myriad of specialized public administrators.

There is another important difference. In the Republic of Science, science activities are treated as an independent, integrated, and self-sustaining system organized from within. In the Republic of Management, they are considered as a set of isolated and separated sub-systems regulated from outside by the requirements of economic, social, or cultural missions. Dr. Richard R. Nelson, formerly of the Rand Corporation, is one of the better known representatives of that school of thought. When he appeared before the Senate Committee, he denied that there was such a thing as economic policy and then said:

> In exactly the same sense, I wonder if it is meaningful to think of something called an overall science policy. There is a tremendous variety of objectives and instruments that come under that umbrella. You have objectives relating to defence, to economic growth, to science per se, to education. There is a vast variety of instruments: spending, taxes, patent protection, regulatory policy. Many of these objectives are relatively independent of each other. Many of the instruments can be used relatively independently. What you mean by a science policy, as contrasted with other policies, is very unclear.... Put in another way, for most decisions involving science it is neither necessary nor helpful to have an overall science policy.... Defining such an entity leads one to compare cancer research with a new accelerator, rather than cancer research with hospitals. The latter seems much more fruitful for sensible policy making.[8]

Dr. Claude Isbister, then deputy minister of the Department of Energy, Mines and Resources, expressed similar views before the Committee:

> With respect to the public sector, it is important to note that when government appoints a department or agency to do something, it must also approve its right (indeed its obligation) to do the research necessary for it to achieve its mission. The department or agency has the responsibility of allocating its funds in various ways, among them being support for research. To deny a department or agency its power to control its funds is to deny the department or agency its ability to discharge its function.
>
> The decisions of the department or agency as to the allocation of funds in support of research will depend on the department's or agency's estimate of the possibilities for productive research in its area of responsibility, and on the availability of appropriately trained scientists and engineers. Clearly the department or agency is, or should be, in the best position to make these estimates, and so to make the best of the available resources.[9]

Dr. W. G. Schneider, the president of NRC, expressed much the same idea in a recent speech:

> Now that science and technology have become central forces in our society, we are witnessing a wide concern and a major pre-occupation with so-called science policy. Actually, the term itself is a misconception, and the current quest for a unique or global science policy reflects a basic lack of understanding of science itself. On the one hand we are talking about the application of scientific knowledge and the techniques of science toward achieving predetermined economic or social objectives. In this sense science is but a means to an end, and in some instances not necessarily the most important or the sole means. Thus the policies associated with the deployment of scientific resources cannot be divorced from policies related to the original

economic or social goals. Since the latter cannot be defined in terms of a single global policy, it is illusory to think that the applications of science can be so defined.[10]

It is evident that research can make an important contribution to the definition and solution of specific problems facing the government, such as national defence, health and welfare, national and regional economic development, and the rational exploitation of resources. It is equally true that public managers at the top of various government agencies are well placed to define what they expect from research and what they need to know to serve the public interest. They simply cannot leave the scientist completely free to choose his own area of inquiry and hope that through some mysterious process he will come up with the answers they need. Public administrators, as supporters and users of applied research and development work, must have their say in the selection of programs and projects.

The Republic of Management is particularly well qualified to determine the R&D services that it requires to develop its own policies. This is true, for instance, of the medical research done in the Department of National Health and Welfare in connection with the administration of the Food and Drugs Act, or the economic research done in the Department of Agriculture for the Agricultural Stabilization Board. Research of this kind is considered to be an ingredient of the agency's political function. It is certainly true that individual agencies are particularly well suited to organize and operate these research services, although the proliferation of royal commissions and task forces set up in recent years to improve departmental policies shows that they could have been more effective in this rather limited and practical area of R&D.

The Committee believes, however, that the Republic of Management has more serious limitations in the broader area of research and development supported or conducted by a federal agency to assist or complement what is being done by industry, universities, and provincial governments. This type of R&D is illustrated by the science activities of the Department of Agriculture, which are designed not as a preliminary step in the formulation of agricultural policies but for direct application by Canadian farmers. This kind of R&D activity can be regarded as a parallel but at the same time competing means of achieving the department's broad mission, which is the growth and prosperity of Canadian agriculture.

Apart from their own research services, most federal agencies have a research mission designed to support or complement R&D activities conducted by provincial governments, universities, and industry. At present these research missions constitute the bulk of federal government science activities. Several government agencies have no legislative and regulatory function or only a small one because constitutional authority in their fields belongs primarily to the provinces. Their primary role lies with their research mission. The National Research Council, the Department of Energy, Mines and Resources, and the Forestry Branch of the Department of Fisheries and Forestry are in that category.

The Committee is convinced that serious imbalances and weaknesses have developed in Canada over the years in this broad area of research missions where R&D activities are carried out for others. These deficiencies have appeared mainly because of the limitations of the Republic of Management and, more precisely, because the government has relied exclusively on a series of limited and isolated science policies, without having an overall view of what was going on and a global strategy for what had to be done.

## INHERENT LIMITATIONS OF ISOLATED SCIENCE POLICIES

There is a striking analogy between government science activities and government financial activities. Both kinds of operations are carried out in one form or another by all departments and agencies. They both involve the transfer of something—money or information—from the federal government sector to others. In carrying out their specific mission, all government agencies must plan their expenditures, prepare a budget, and thus develop their own financial policy. In the same way, they must all make decisions about their science activities and thus formulate their own science policy.

But governments do not rely exclusively on the particular financial policies developed by their specialized agencies. If they did, they would have no overall financial policy or they would get one by accident. It is easy to imagine the kind of financial situation that would result in the absence of an overall financial policy. Yet this is precisely the approach that has been used by the Canadian government in dealing with its science activities. The results of this exclusive reliance on specific and isolated policies have not been too happy.

The Committee has found, through its historical studies, its international comparisons, and its evidence, that the broad directions of Canada's R&D effort were determined largely by the Republic of Science and the Republic of Management. At least six inherent limitations of that joint system can be identified.

1. *Government agencies with important policy and regulatory missions generally tend to neglect their research missions, and agencies with small policy missions tend to overemphasize their research functions, at least in relative terms.*

Public managers are quite naturally inclined to put the emphasis on their policy mission if it is of any significance and to devote most of their attention and money to it rather than to their research mission, which is always risky and in any case not likely to yield practical results for several years. This natural psychological preference helps to explain why such federal agencies as the Department of National Health and Welfare, the Department of Finance, the Department of Transport, the Department of Indian and Northern Affairs, the Department of Justice, Central Mortgage and Housing Corporation, and the CBC, which all have important federal policy missions, have not developed their research operations. On the other hand, federal agencies responsible for academic research, atomic energy, and renewable and non-renewable resources generally have no important policy mission. Their natural tendency is to become research organizations and, like all other organizations, their basic objective is to expand and to grow.

Agencies in the first group tend to neglect their research mission, those in the second group to overemphasize that function. The result is a marked imbalance in the federal government's total science effort. Science activities are underdeveloped in sectors where the federal government has an important policy mission and over-expanded in sectors where it has little or none. Thus specific science policies as defined by individual government agencies tend to be seriously distorted in the wrong direction, and the whole system has an inherent bias against the topics of most direct interest to the federal government.

2. *In a system relying exclusively on specific and isolated policies the inevitable compartmentalization of the federal administration is itself another cause of gaps.*

It is obviously impossible to assign each problem requiring the attention of government exclusively to one agency. There will always be government-wide questions for which no single agency—or no agency at all—is responsible. Important problems of the post-industrial society, such as pollution, poverty, and urban congestion are in that category. Although the solution of these problems and the science activities connected with it may have a high priority for society and the government as a whole, they may be of only marginal importance to individual agencies. Thus gaps tend to develop as government-wide research problems are neglected.

It may also happen that a research program has a high priority for a particular agency and a low one for the government as a whole. For instance, it might have been quite important for the Department of National Defence to develop the Arrow, for the Department of Energy, Mines and Resources to have a telescope in British Columbia, or for AECL to build an intense neutron generator, but it was found that the programs did not have the same high priorities for the government as a whole. But there are certainly less spectacular projects of this kind that go ahead unnoticed. To that extent, certain research sectors are over-expanded. It is clear that government's overall research priorities do not always coincide with those of individual agencies.

This limitation was emphasized by a number of witnesses who appeared before the Committee. But it is not specific to the Canadian scene. This point was also underlined in the 1967 annual report of the Federal Council for Science and Technology in the United States:

> For example, an emerging social or economic problem that does not fit within the mission of an existing organization is likely to receive inadequate attention, if so much reliance is placed upon the existing bureaucratic apparatus. Similarly, new opportunities offered by science and technology are not likely to be aggressively exploited if no single Federal agency has a clear and exclusive responsibility. Finally, questions relating to the appropriate total investment in science and technology, and to the effects of the total Federal investment on such important sectors as academic science cannot be adequately considered agency by agency.[11]

3. *Research organizations, when they are autonomous, are like other agencies in seeking to accomplish their missions completely by themselves.*

This natural inclination toward self-sufficiency leads to a relative over-expansion of the government research sector compared with other sectors of performance. When government agencies have to decide whether their research programs will be carried out in their own establishments or assigned to industry, for instance, they are normally inclined to prefer their own laboratories. They view their support of extra-mural science activities as marginal and residual, although in fact such support, through contractual arrangements, could produce more beneficial results in terms of application and could at the same time reduce the need for government incentives and grants for industrial research. There is an inherent conflict of interest here for government research agencies which, in the absence of a general science policy, is not often likely to be resolved in the public interest. So it is clear that exclusive reliance on science policies formulated in isolation by individual agencies in no way guarantees a proper distribution of government science activities between the three main sectors of performance.

4. *The agencies' natural inclination to self-sufficiency also leads to undesirable duplication, both internationally and domestically.*

The extent of the duplication of research activities between nations is impossible to measure even approximately, though it can be said that imitation and unconscious duplication are widespread. In his article on "Measuring the Size of Science," Derek J. de Solla Price states that "science is a highly redundant process" and that "about a quarter of all discoveries are rediscoveries."[12] Research agencies often determine their science activities without taking proper account of what is going on in their field in other countries. They lack adequate systems of scientific and technical information —and if they were to develop their own services, this in itself would involve extensive, expensive, and undesirable duplication within the government administration. So government research agencies working in isolation can hardly be expected to apply the principle of the division of labour internationally. And yet it is much less risky and much more economical to import the results of research done abroad than to do research in-house.

Domestically the government agencies often duplicate each other's work in their attempts to be self-sufficient. It happens with the amassing of scientific and technical information, and it happens with the funding of academic research and training, when mission-oriented agencies develop their own support programs independently of the policies followed by the research councils. It would indeed be surprising to get a rational and balanced approach out of more than 20 unco-ordinated programs.

Dr. Nelson is quite right when he says that many research objectives and instruments "are relatively independent of each other". But it is equally true that many are relatively interdependent. Dr. Harvey Brooks points this out clearly:

> It is much less possible today than it was thirty years ago to associate specific areas of knowledge with specific federal missions. Individual agencies can no longer afford to be intellectually self-sufficient, either in the sense of dependence on other agencies or in the sense of dependence on non-government science and technology. Although today is popularly thought of, with some justification, as an age of increasing specialization, it is, paradoxically, also a day of disappearing barriers between scientific disciplines....
> Agency missions depend on so many parts of science that no agency can

afford to develop internally all the competence it needs to discharge its responsibilities effectively. . . . It is inevitable that the interdependence of all areas of science and technology should generate a demand for planning of the federal technical enterprise as a whole.[13]

This growing interdependence cannot be effectively handled by isolated science policies unless agencies agree to consult with each other and to co-ordinate their activities. But co-ordination is hardly compatible with self-sufficiency and although there is a lot of talk about it, it is seldom practised —again, because of a conflict of interest. Co-ordination is in the public interest, but self-sufficiency is to the advantage of individual agencies and when it prevails, interdependence is ignored and undesirable duplication becomes inevitable. This assessment is also confirmed by the evidence presented to the Committee.

5. *Government research agencies are more likely to be defensive than self-critical; why should they differ from other institutions?*

But the absence of self-criticism is not conducive to good management and it cannot easily be righted by Polanyi's "independent self-co-ordinated initiatives." That is why, for instance, these organizations tend to lose sight of their initial missions as the years go by. As Harvey Brooks writes: "What starts as a hothouse plant often grows into a rampaging weed."[14] A. M. Weinberg, the director of the Oak Ridge National Laboratory, offers an astute observation:

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.[15]

Another aspect of this internal management problem is the reluctance of agencies to cut programs that have failed or lost their priority. This weakness has been underlined by the Science Council:

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.[16]

Reliance on individual agencies to determine government science activities can thus lead to an undue emphasis on basic and applied research at the expense of development work and to the continuation of R&D programs that have lost their significance. It is clear that the distribution of the Canadian government's science activities suffers in this way.

6. *Another weakness of isolated science policies is that they can unconsciously be in conflict, particularly in the sector of public support for industrial research.*

The government may provide direct incentives to promote this type of research through the Department of Industry, Trade and Commerce, for example, and at the same time discourage it with the patent and monopoly policies of the Department of Corporate and Consumer Affairs. The Department of Energy, Mines and Resources may allow the use of NTA in detergents as a substitute for phosphates in order to fight water pollution, but the Department of National Health and Welfare may find that NTA is a menace to human health while phosphates are not. The Department of Agriculture may spend large sums to maintain the market for natural milk while the Department of Fisheries and Forestry is carrying out a research program to produce artificial milk. Such inconsistencies may be inevitable but they should at least be conscious and explicitly recognized, and that cannot happen easily under a system of isolated policies.

## THE ROLE OF AN OVERALL SCIENCE POLICY

It should be obvious by now that a government cannot rely exclusively on a system of micropolicies to determine its science activities any more than it can to organize its fiscal action. This system has inherent weaknesses and potential deficiencies and alone cannot guarantee an optimum level and distribution of government science activities. These limitations are now generally recognized in the Western world. Dr. Christopher Freeman, the director of the Science Policy Unit at the University of Sussex and one of the best British experts on the subject, writes:

> Nor can science policy be reduced to the level of a residual of all other policies—economic policy, military policy, health policy and so forth. It requires independent consideration in its own right, because the available resources are limited and the parts of the whole system are interdependent.[17]

In his critical assessment of the American situation, which in this respect at least is very similar to Canadian conditions, William D. Carey, the former assistant director of the Bureau of the Budget in charge of science and technology, has this to say:

> If our policies and strategies for science and technology are hard to fathom, perhaps it is because we are not well organized. Research and development are decentralized through the Federal Government, managed as a network held together loosely by the White House science office. There is no prime mover; the decision-making patterns are pluralistic. As an institutional process, science and technology are not responsive to standards of balance, purpose or priorities. The component elements serve as mission-related conduits for funding research, development, training and academic science; they do not function as a system, because there was not a system to begin with.[18]

A growing number of western countries, particularly in the 1960's have decided to develop an overall policy to complement, inspire, and control policies related to particular government missions. The Canadian government followed this trend by setting up the Science Secretariat in 1964 and the Science Council in 1966. But, as recently as 1969, Mr. Charles Drury, president of Treasury Board and chairman of the Privy Council Committee on Scientific and Industrial Research, recognized "the need for establishing an overall national science policy."[19]

It must be emphasized again that the role of an overall science policy, like that of a macro-economic policy, is not to replace specific policies but to support them with a basic framework, broad terms of reference, and criteria to assess their efficiency. At the inaugural meeting of the Science Council the Prime Minister defined the area of general science policy as covering "decisions that determine the balance of our national scientific effort; the role of that effort in relation to our country's aspirations; its adequacy as to research on the one hand and applied use on the other."[20]

A general science policy includes a number of vital tasks:

- To maintain an integrated network for scientific and technological information on what is going on at home and abroad;
- To make sure that the national scientific establishment as a whole is adequate in the context of the international scientific and technological race;
- To provide a balanced supply of scientific manpower related to national requirements;
- To ensure proper balance—between scientific disciplines; between pure research, mission-oriented research, and development work; between the public sector, industry, and universities as performers of research;



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- To prevent over-expansion in certain R&D sectors and to fill significant gaps in others, namely, in the objectives and problems of a post-industrial society;
- To ensure co-ordination in the many no-man's lands of collective needs, where multi-disciplinary and inter-agency programs are essential;
- To keep an overall picture of the output as well as the input of the national science effort so as to make sure that excellence is achieved, that missions are respected, and that the results of research reach the users.

It has become a major responsibility of government in this age of the scientific revolution to ensure that society gets the maximum benefits from science and technology at a minimum cost. To do this the government needs not only science policies by sectors, such as health, transportation, energy, and agriculture, but also the macroscopic approach that only a coherent overall science policy can provide. These two approaches must complement each other.

If general science policy is to accomplish its crucial role effectively, it must also develop a system of control, to make sure that the strategy will be respected in the detailed decision-making process, and review mechanisms, to make sure that priorities, strategies, and programs are adjusted to the rapid change that is so characteristic of the whole sector of science and technology. Perhaps more than any other sector of policy, science policy requires the careful application of systems analysis.

It is especially urgent for Canada to adopt a systematic overall science policy. We still have to solve the problems left by our failure to meet the initial objectives of our national R&D effort, and at the same time we have to meet new objectives and new needs arising from the challenges and opportunities of the affluent society and the permanent technological revolution.

The "first generation of science policy" in the western world was centred around the objectives of national defence and industrial innovation to promote economic growth. To a large extent, the Canadian R&D effort has failed to sustain market-oriented technological innovation. We now know the reasons for this failure. We need an overall science policy and a global strategy to correct the situation. Indeed, perhaps more than ever before we need to create the proper technological environment for the development of the productive sector. We must generate new employment opportunities to cope with a growing labour force and acute regional economic problems.

But as we try to readjust our R&D effort to serve this national purpose more effectively, we must also develop a "second generation science policy." It will be centred around the good life rather than the "goods life", to use Lewis Mumford's expression. We cannot spend the next decade totally preoccupied with the development of basic science and market-oriented technology. We must also organize our national science effort so that it can make its full contribution to the solution of the social problems that will otherwise soon cripple our society.

Canada's R&D effort suffers from serious gaps. We do very little research in education, which is emerging now as the "single largest industry in all developed nations". The same is true of such other major collective problems as urbanization, pollution, the negative impact of technology, health care, social security, leisure, and human maladjustment to a rapidly and constantly changing technological and social environment. A "second generation science policy" must meet all these problems.

## CONCLUSION

To attain the economic objectives of the first generation science policy, we put the emphasis on science and government laboratories, in the hope that they would foster new industrial technology. This strategy failed. When it came to social objectives, we made another strategic mistake. We believed that we could succeed merely by devoting huge sums of money to them.

Every year we are building more schools, more universities; we are providing easier access to education. And yet we have more student unrest and more parental concern that our children are not getting an adequate preparation for real life.

We are spending large sums to improve housing conditions, but our cities are becoming more and more crowded and inhuman. We are spending over three billion dollars every year on social security, but the poor are becoming relatively poorer and more and more restless as they live, through television or otherwise, closer to affluence. We are building more hospitals and providing for free hospitalization and better medical care, but a greater number of people die of incurable diseases, and the mysterious diseases of the mind are spreading.

Our obvious failure to cope with our collective problems forces us to recognize that we do not even understand the true nature and the real dimensions of most of these difficulties. In other words, we are just beginning to realize that we have seriously neglected to support research and development activities in these crucial sectors. No wonder they still remain so puzzling and so frustrating to us.

Yet, as we awaken to the urgent need for more research and development for social and collective purposes, we should not repeat the mistake of the past and think that this tragic gap in knowledge and understanding will be filled simply by devoting more money to science activities. We need more research, but not only that; we need good research and we need innovation. We must develop a coherent overall science policy so that we can not only meet our economic objectives more effectively but also more realistically face our mounting social problems.

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# ANNEXES

## ANNEX A

### DEFINITIONS

Some useful definitions for the various steps in the R and D process were put forward by the Zuckerman Committee[1] in 1961 and again in 1963 by the Committee of Enquiry into the Organization of Civil Science chaired by Sir Burke Trend.[2] The definitions are as follows:[3]

"We have taken "research and development" to mean, in general terms, all those activities which are directed towards the acquisition of scientific facts and techniques, or towards their application, to the design of new or improved materials, or equipment, or to the devising of new processes, often involving, in the later stages, the construction of prototype equipment or pilot plant.

We have found it helpful to differentiate between five categories of activity normally included under the port-manteau term, research and development. These are pure basic research, objective basic research, applied (project) research, applied (operational) research, and development. Our definitions of these terms are set out in the following paragraphs. We would, however, emphasize two points. First, there is and can be no clear-cut line of demarcation between one form of research and another; basic research and development are, so to speak, bands at opposite ends of a continuous spectrum. Second, most organisations engaged in research will be concerned to some extent with the whole range of research and development. •

(i) *Pure Basic Research*

Pure basic research is research carried out solely in order to increase scientific knowledge: that is, knowledge of the nature of the material world. Such research is commonly called either "fundamental" or "pure" or "basic". These words, particularly "fundamental", are often connected with the idea of work of high intellectual quality. A fair amount of "pure" scientific research may, however, be of a routine or of a preliminary nature. For example: (i) "filling in", where a main break-through has already been made; (ii) exploratory work in fields where a good deal of semi-empirical experimentation is needed before the real problems can be identified; (iii) descriptive observational work, notably in biology and geology. A line of "pure basic" research is selected by the individual worker to satisfy his own tastes and intellectual curiosity.

Examples of pure basic research are:

A study of the properties of high energy cosmic ray particles. The correlation of the chemical and structural changes that take place in muscle during its contraction and relaxation.

(ii) *Objective Basic Research*

Between "pure" and "applied" research there lies an intermediate category of scientific work to which we have given the name "objective basic". This denotes

[1] Committee chaired by Sir Solly Zuckerman in the United Kingdom, the Committee was formed in May 1958 and reported in July 1961. "Report of the Committee on the Management and Control of Research and Development," Office of the Minister of Science, HMSO, London 1961, 129 p.

[2] HMSO, London, 1963, Cmnd. 2171.

[3] "Report of the Committee on the Management and Control of Research and Development," *op. cit.*, pp. 6-8.

basic research in fields of recognised potential technological importance. It is well known that the pursuit of defined technological objectives, for example the development of a supersonic aircraft, sometimes exposes an area in which existing scientific knowledge is seriously insufficient. It then becomes necessary to try to organise an increase in this knowledge before a further technological advance can be made. Research of this type may be as intellectually exacting as what we have called "pure basic" research. The difference between "pure basic" and "objective basic" research derives mainly from the fact that the latter is stimulated primarily by technological needs. It therefore calls for a planned approach even when the satisfaction of these needs is remote. This characteristic of "relevance" to a definable technological objective is a practical criterion which differentiates "objective" basic research from "pure" basic research.

Examples of objective basic research are:

The study of the fundamentals of plasma physics, which may provide data likely to be of value to work on thermo-nuclear fusion directed to the harnessing of new sources of energy. A study of the growth of virus in living cells, which may provide information of value in combating virus infections of man.

(iii) & (iv) *Applied (Project or Operational) Research*

As indicated above, applied research has as its object the attaining of a practical goal, which can be fairly precisely defined, such as a new process or piece of equipment. We believe that this type of work is best described as *project research* to distinguish it from applied research directed to improving the use of an existing process or piece of equipment. The latter may be called *operational research.*

Examples of applied research are:

*Project.* To provide design data for a nuclear-powered submarine. To determine the cause of the specific failure of a particular crop and to derive a remedy to prevent its recurrence.

*Operational.* To improve the working performance of an existing type of graphite-moderated carbon dioxide-cooled nuclear reactor. To provide the data for improving the design and layout of farm buildings by a study of their purpose and day-to-day use.

(v) *Development*

Development bridges the gap between research and production. It may be defined as the work necessary to take, for example, a new process or piece of equipment to the production stage. It will often include the erection and operation of pilot plants or the construction of prototypes.

Examples of development are:

The work required to determine the best production techniques for the manufacture of solid fuel elements for a nuclear reactor, research having determined the necessary composition of the fuel elements and the material for the containers. The work required to determine the appropriate process for manufacturing penicillin on a large scale, research having established its antibiotic properties, and small-scale trials its clinical usefulness."

# ANNEX B

## GUIDE FOR SUBMISSION OF BRIEFS

*Introduction*

Part I of this guide is for the assistance of all organizations or individuals intending to submit briefs. Part II describes information required from agencies of the Federal Government.

## PART I

*General Guidance*

I. 1. *Contents of Submissions*

Briefs should deal with the subject matters which fall within the scope of inquiry of the Committee, as contained in the attached Order of Reference (Appendix A). This Order of Reference, and any other relevant material which may be made available by the Committee, should be carefully read before briefs are prepared.

To make submissions to the Committee as useful as possible and to facilitate the Committee in obtaining a full understanding of the views put forward and recommendations made, the following points should be borne in mind when preparing the briefs:

(a) Factual information should be included tending to substantiate the conclusions put forward, the views expressed and the claims made.

(b) Recommendations should be made as specific as possible, putting forward concrete proposals indicating whether and what action should be taken, what form the action should take, and how the proposal could be implemented in practice.

(c) The brief should be prefaced by a summary of the main conclusions and recommendations.

(d) Brevity is recommended in the main body of the submission. Those preparing briefs may, if desired, submit relevant evidence in appendix form.

(e) In the case of associations and organizations, the briefs should include information on the personnel, objectives and nature of the group.

I. 2. *Format of Submissions*

Briefs should be double spaced with consecutive paragraphs numbered, on foolscap (8″ x 14½). The name and address of the association, organization or person submitting the brief should be clearly indicated. Where organizations and individuals wish to appear at the hearings, the names and addresses of those who will represent the organizations or of the individuals should be stated.

The curriculum vitae of all those intending to participate in the presentation of the brief and the subsequent discussions must be attached to the brief.

I. 3. *Number of Copies of Submissions*

The Committee requires fifty (50) copies of each brief. It is suggested that copies in French be provided. Organizations and others submitting briefs may wish to have available additional copies which they can pass on to the press and other interested parties. Although each organization is responsible for the distribution of its brief, the Secretary will distribute it to the members of the Parliamentary Press Gallery upon receipt of an additional 95 English-language and 35 French-language copies. It is imperative that the requisite number of copies of the brief reach the Secretary's office at least two weeks before a scheduled hearing.

I. 4. *Presentation of Submissions*

The full texts of the submissions, ordinarily will be taken as read. At the hearings, participants will be asked to summarize the information contained in their submissions as well as their conclusions and recommendations. They are free to elaborate orally and present arguments. Persons appearing before the Committee may be questioned directly by members of the Committee on the material submitted in their briefs and the recommendations put forward, but they will not be subject to examination or cross-examination by other persons.

I. 5. *Exhibits at Hearings*

Participants are permitted to introduce at the hearings supplementary information and material in written form. These will be known as exhibits.

I. 6. *Transcripts of Proceedings of Hearings*

The proceedings at the hearings held by the Committee will be recorded and printed. Copies may be purchased from the Queen's Printer. Reports of the Committee's proceedings are supplied at reduced rates when ordered immediately following the Committee sitting. A limited number may be obtained without charge on application to the Secretary.

I. 7. *Confidential Character of Submissions*

Submissions made to the Committee will remain confidential until released, the release date being the day on which the organization's representative appears as a witness. In the case of briefs supplied but not presented at the hearings, the release date will be at the discretion of the Chairman.

## PART II

*Specific guidance for agencies of the Federal Government*

### II. 1. *Introduction*

All departments, boards, crown corporations and other organizations (hereafter referred to as agencies) under the jurisdiction of the Federal Government are asked to submit briefs if they expend funds for scientific activities. Appendix B defines "scientific activities" and other terms.

### II. 2. *Content of Submissions*

Briefs should contain any information, comments or counsel considered relevant to the inquiry of the Committee in view of the Committee's Order of Reference (attached as Appendix A). As well, the Committee requests information regarding the following:

2. 1. *Organization*—Supply text or diagrams regarding the following:

(a) Organizational block diagram of agency showing main units such as divisions and sections. Indicate those units conducting or funding scientific activities.

(b) Block diagram, when appropriate or necessary, indicating Parliamentary reporting channel (s), formal connections to other Federal agencies, advisory committees, etc.

(c) Block diagram indicating the organization of units (e.g. divisions, sections, task forces, etc.) responsible for scientific activities.

(d) Description of formal agreements regarding scientific activities between agency (or one of its units) with organizations outside of Canada including foreign governments or their agencies.

(e) Information concerning overseas offices of agency dealing with scientific affairs.

2. 2. *Organizational functions*

(a) What are the agency's statutory functions and powers regarding scientific activities.

(b) What organizational policies have evolved (e.g. regarding the implementation of (a)) that could be considered to define your agency's "policy regarding science" or "science policy".

(c) Taking (a) and (b) into account, briefly describe the organization's functions and responsibilities in relation to:

(i) other Federal agencies

(ii) industry

(iii) educational institutions

(iv) international representation and the monitoring of scientific activities outside of Canada

(v) other

and describe the process whereby these are achieved or honoured, citing cases-in-point if appropriate or necessary.

(d) Describe the process whereby your operational effectiveness, duties and goals are reviewed and revised.

(e) Describe any outside studies commissioned (during the last five years) to suggest improvements of agency's operating procedures.

(f) Comment on the relationship between the agency's responsibilities and powers, and its activities and programmes.

(g) What have been, what are currently, and what do you foresee as being the major hindrances to the effective performance of your functions, the honouring of your responsibilities and powers.

(h) What major changes in organization functions are forecast as probable or desirable during the next five years.

2. 3. *Personnel Policies*

(a) What steps are taken to identify and hire those members of university graduating classes who will be the most effective researchers for your organization.

(b) Have any unique criteria been developed (or any research initiated to develop criteria) to help identify those who will be creative and effective researchers.

(c) What steps are taken to identify those members of the staff with high potentiality as research administrators.

(d) What distinctions are made between administrators of research and researchers as such; for example, regarding promotion, salaries, etc.

(e) What is the policy regarding intramural and extramural education for staff members conducting or administering research.

2. 4. *Distribution of activities*

Some agencies expend funds on scientific activities in many regions of Canada. These are requested to give information and advice regarding the following:

(a) The regional pattern of agency's spending (intramural and extramural) on scientific activities (e.g. by province).

(b) The regions, if any, particularly suited for certain scientific activities.

(c) Activities carried out, on an annual basis during the last five years, to assist in the investigation of regional problems of phenomena.

(d) The role of your agency in contributing to regional development.

(e) In your experience, the cost and benefits of regional distribution of your scientific activities and the necessary conditions for this distribution to contribute to regional development.

2. 5. *Personnel associated with scientific activities*

Note that the following information is required for each of the units conducting scientific activities mentioned in Section 2.1. (c).

(a) Current personnel establishment and people on strength by category of personnel. (Indicate the number of guest workers, staff-on-loan, post-doctorate fellows, etc.)

(b) Number of above professional staff devoting most of their time to administrative duties.

(c) Tabulated information regarding professional staff associated with scientific activities (divided into three categories according to degree level—i.e. bachelor, master, doctorate).

(i) Country of birth.

(ii) Country in which secondary education taken.

(iii) Country in which university degree taken (bachelor, master, doctorate).

(iv) Number of working years since graduation and number of years employed in present organization.

(v) Average age.

(vi) Percentage able to operate effectively in Canada's two official languages.

(d) Total number of professional staff in each degree category for each of the years 1962 to 1968 inclusive and estimates for each of the years 1969 to 1973.

(e) Percentage of turnover of professional staff in the three degree categories for each of the years 1962 to 1967.

(f) Percentage of current professional personnel who, since graduation, (i) have been employed by industry at one time, (ii) have been on the staff of universities, (iii) provincial departments or agencies, or (iv) other Federal agencies.

(g) Number of staff in each degree category on education leave.

(h) Number of university students given summer employment in the field of scientific activities for the years 1962 to 1967.

2. 6. *Expenditures associated with scientific activities*

Where appropriate, please use definitions given in Appendix B.

(a) Total funds spent by agency on scientific activities broken down into the following categories:

*Functions:* (1) intramural R&D, (2) data collection, (3) scientific information, (4) testing and standardization, (5) support of R&D in industry, (6) support of R&D in universities, (7) support of higher education in engineering and science. Give Primary function (if applicable).

*Scientific discipline:* (1) engineering and technology, (2) natural sciences: (a) agricultural sciences, (b) astronomy, (c) atmospheric sciences, (d) biological sciences, (e) chemistry, (f) mathematics, (g) medical sciences, (h) oceanography, (i) physics, (j) solid earth sciences, (3) social sciences: (a) anthropology, (b) demography, (c) economics, (d) political science, (e) psychology, (f) sociology. Give primary, secondary and tertiary discipline (if applicable).

*Areas of application:* (1) nuclear energy, (2) space travel and communications, (3) war and defence, (4) agriculture (inc. fisheries and forestry), (5) construction, (6) transportation, (7) telecommunications, (8) health, (9) industry, (10) underdeveloped areas, (11) economic and fiscal policy (national and international), (12) regional development, (13) social welfare and social policy, (14) educational techniques and policies, (15) administration, (16) other (please identify). Give primary and secondary areas if applicable.

Above to be tabulated for each of the fiscal years 1962-1963 to 1966-1967, estimates for 1968-1969, and projections for the five fiscal years beginning 1969-1970.

(b) Operating and capital funds expended by the units described in (2. 1 c.) (e.g. divisions, sections, etc.) for the fiscal years 1962-1963 to 1966-1967 inclusive, estimates for 1967-1968, and five year forecasts for fiscal years 1969-1970 to 1973-1974.

(c) Funds expended to further professional university education of staff for each of the fiscal years from '62-'63 to '68-'69 inclusive (e.g. costs of educational leave to take higher degree, payments to cover costs of taking courses at local universities).

2. 7. *Research Policies*

In the following, the term "project" is used very broadly to describe a distinguishable discrete research activity; this could range from scientific research orientated to extend the range of understanding of one item within a particular discipline to an interdisciplinary research and development task. The term "programme" is used to denote a planned goal-directed scientific activity requiring more than one "project" for its accomplishment. In other words, it is through a series of related "projects" that a "programme" is conducted.

(a) *Units concerned with intramural research activities*

1. Describe process whereby various types of programmes and projects are selected, initiated and monitored (e.g. what role do other Federal agencies or units play in this process).

2. How are priorities established between programmes and projects and in what terms are priorities expressed and implemented.

3. Are network methods such as Critical Path Network or Programme Evaluation and Review Technique (CPN or PERT) used to plan and monitor programmes and projects; briefly list current examples of such use.

4. What uses have been made during the last five years (and are being made currently) of contracting out projects in support of intramural programmes. In what sectors have these contracts been let (cite cases-in-point).

5. What are the policies regarding the funding of extramural research programmes in the universities and industry. How are they related to the policies governing intramural programmes and to other Federal agencies.

6. In a changing technical environment it become necessary at times to shift research resources from one programme (possibly even terminating it) to a new programme. By what process is this done and describe any current difficulties.

7. How are intramural and contracted extramural research results *transferred* to those having potential need of them (e.g. industry, other government agencies or universities).

(b) *Units exclusively concerned with extramural research activities*

Some units' sole activity in the field of the Committee's concern is the funding of extramural scientific activities.

1. Describe process whereby various types of programmes and projects are accepted for funding and describe what relation these factors have on the acceptance process:

(i) Previous record of achievement of unit or individual requesting funds

(ii) Nature of proposed project

(iii) Policies of granting agency

2. How are priorities established between programmes or projects.

3. How are projects monitored and the results evaluated.

4. How are priorities implemented in the allocation of resources to programmes or projects.

5. Are network methods such as CPN or PERT used to plan and monitor programmes or projects; briefly list current examples of such use.

6. In a changing technical environment it becomes necessary at times to shift research resources from one programme (possibly even terminating it) to a new programme. By what process is this done and describe any current difficulties.

7. How are extramural research results *transferred* to those having potential need of them.

8. What percentage of funds *available* to the agency for the support of extramural scientific activities were actually expended during each of the fiscal years '62-'63 to '66-'67.

9. What percentage of the total funds *requested* from the agency were in fact *granted* in each of the fiscal years '62-'63 to '66-'67.

2. 8. *Research Output*

The previous items have been concerned with "inputs" to research activities and the state and manner of organization of the research process. The following items refer to the research "output" and it is understood that such measures have limitations. Please give brief details regarding the following for each of the years 1962 to 1967 inclusive:

1. Patents arising from research activities. Number of licences granted and value of resulting production in Canada and elsewhere.
2. Books or journal articles arising from research activities.
3. Reports issued from agency and units.
4. Conferences or other means used to transfer information regarding the results of a project or programme to extramural groups.
5. That means for the transfer of scientific and technological data obtained from countries outside Canada, to extramural groups.
6. Individuals who had the opportunity to train themselves in specialized fields whilst employed with you and subsequently left and made important contributions to their field.
7. Research teams that have arisen in this period and who have unique and valued abilities in important fields.
8. Unique or valuable research tools, facilities, or processes added or developed during the above period.
9. Details concerning the impact of your scientific activities and research output on the advancement of scientific knowledge and Canadian economic development.
10. Any other measures or indications of research output.

2. 9. *Projects*

1. For each unit responsible for scientific activities, (intramural or extramural), list the titles or other brief descriptions of projects which were conducted

during each of the years from 1962 to 1967 inclusive. Indicate projects that are part of an overall programme and briefly describe the programme.

2. Present case histories of what you consider as the most significant completed projects of the last five years. These should be selected as examples of what are considered to be the results of the agency when operating in its role with maximum effectiveness; in other words, examples of what the agency considers among its "best work". The projects selected, when possible, should be presented under the broad categories of "basic research", "applied research", and "development", and it is suggested that no more than *five* are to be singled out in any one category.

2. 10. *Organizations not currently engaged in scientific activities*

The Special Committee on Science Policy was constituted to consider and report upon those agencies of the Federal Government directly engaged in scientific activities. The Committee was also charged with recommending a science policy for Canada and is of the opinion that any government policy related to science must take some account of the effects of science on all governmental functions including those of agencies or units not engaged in scientific activities. The Committee, therefore, invites all agencies under the jurisdiction of the Federal Government to include in their briefs comments as to the effects of scientific activities on their own operations and in particular, to comment on the following items:

1. Forecasts of the effects of changes in *technology* on the agency's operations, functions and responsibilities during the next 5 to 10 years.

2. Studies of possible improvements in the agency's effectiveness due to new scientific or technical developments.

3. The type of scientific or technical advice sought during the last five years; the source of this advice.

4. Future plans determined by, or deternated to take account of, recent scientific and technical developments.



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# ANNEX C

## INDEX OF THE PROCEEDINGS OF SPECIAL COMMITTEE ON SCIENCE POLICY SHOWING AGENCIES AND ORGANIZATIONS

*Second Session of the twenty-seventh Parliament 1967-68*

*Phase 1*

| | |
|---|---|
| March 12, 1968 | —The Canada Council |
| | —*Dr. C. J. Mackenzie* |
| March 13, 1968 | —The Science Council of Canada |
| | —*Professor V. W. Bladen* |
| March 19, 1968 | —*Lord S. Blackett* |
| March 20, 1968 | —*Professor Arthur Porter* |
| March 21, 1968 | —The Science Secretary of the Privy Council |
| | —The Medical Research Council |
| April 17, 1968 | —*Dr. Christopher Wright* |
| | —*Dr. Hans Selye* |
| April 18, 1968 | —*Dr. James R. Killian Jr.* |
| | —*The Hon. C. M. Drury* |
| | —The Science Council of Canada |
| | —The Science Secretariat of the Privy Council |
| April 24, 1968 | —*Dr. Richard R. Nelson* |
| April 25, 1968 | —*Dr. Alexander King* |

*First Session of the twenty-eighth Parliament 1968*

| No. | | |
|---|---|---|
| 1 | October 9, 1968 | —*Mr. Maxwell Weir Mackenzie,* Chairman, Royal Commission on Security; Member of the Economic Council of Canada |
| 2 | | —*Dr. Jacques Spaey,* Secretary General (National Science Policy Council) of Belgium & Chairman (Interdepartmental Scientific Policy Committee) |
| 3 | October 24, 1968 | —National Research Council |
| 4 | | —Department of National Defence |
| 5 | October 30, 31/68 | —Atomic Energy of Canada Ltd. |
| 6 | October 31, 1968 | —Eldorado Nuclear Limited |
| 7 | | —Canadian Patents & Development Ltd. |
| 8 | November 6, 7/68 | —Science Council of Canada |
| 9 | November 20, 1968 | —Atomic Energy Control Board |
| 10 | November 21, 1968 | —Dept. of Agriculture |
| 11 | November 26, 1968 | —Science Council of Canada |
| 12 | November 27, 1968 | —Organization for Economic Co-Operation & Development (OECD) |
| 13 | | —Dept. of National Health & Welfare |
| 14 | November 28, 1968 | —Dept. of Veterans Affairs |

| No. | | |
|---|---|---|
| 15 | December 11, 1968 | —Dept. of Fisheries & Forestry |
| 16 | | —Dept. of Energy, Mines & Resources |
| 17 | December 12, 1968 | —Dept. of Fisheries & Forestry |
| 18 | December 18, 1968 | —Dept. of Transport |
| 19 | | —Canadian National Railways |
| 20 | December 19, 1968 | —Canadian Transport Commission |
| 21 | January 29, 1968 | —National Research Council |
| 22 | January 30, 1968 | —Science Secretariat (Privy Council Office) |
| 23 | | —The Bank of Canada |
| 24 | February 5, 1969 | —Dominion Bureau of Statistics |
| 25 | | —Economic Council of Canada |
| 26 | February 6, 1969 | —Treasury Board |
| 27 | | —Dept. of Labour |
| 28 | February 12, 1969 | —Dept. of Manpower and Immigration |
| 29 | | —Public Service Commission |
| 30 | February 13, 1969 | —Medical Research Council |
| 31 | February 26, 1969 | —Dept. of Indian Affairs & Northern Development |
| 32 | February 27, 1969 | —The Canadian International Development Agency |
| 33 | | —Central Mortgage and Housing Corp. |
| 34 | March 5, 1969 | —Dept. of Finance |
| 35 | | —*Mr. Maurice Goldsmith,* Director, Science of Science Foundation, London, England |
| 36 | March 6, 1969 | —Treasury Board |
| 37 | | —Post Office Department |
| 38 | March 12, 1969 | —Dept. of External Affairs |
| 39 | March 29, 1969 | —*Sir Geoffrey Vickers,* V.C.<br>—*Professor Eric Trist*<br>—*Assoc. Professor Francis G. Bregha*<br>—*Mr. James Ham* |
| 40 | April 23, 1969 | —Dept. of Regional Economic Expansion |
| 41 | April 24, 1969 | —Canada Council |
| 42 | April 30, 1969 | —Dept. of Industry, Trade & Commerce |
| 43 | May 21, 1969 | —Committee of Presidents of Universities of Ontario<br>—The Centre for Urban & Community Studies, University of Toronto<br>—Vice-President & Graduate Dean, University of Toronto<br>—Physics Dept. University of British Columbia |
| 44 | May 27, 1969 | —Association of Universities & Colleges of Canada |
| 45 | | —Acadia University, Wolfville, N.S.<br>—Dalhousie University, Halifax, N.S.<br>—Mount St. Vincent University, Halifax<br>—St. Mary's University, Halifax<br>—St. Francis Xavier University, Antigonish<br>—Nova Scotia Technical College, Halifax<br>—University of New Brunswick, Fredericton<br>—University of Moncton, Moncton |



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| No. | | |
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| | | —Prince of Wales College, Charlottetown, P.E.I. |
| | | —Memorial University of Newfoundland |
| 46 | May 28, 1969 | —University of Montreal |
| | | —McGill University, Montreal |
| | | —Bishops' University, Lennoxville |
| | | —Loyola College, Montreal |
| | | —Sir George William University, Montreal |
| | | —Laval University, Quebec |
| 47 | May 28, 1969 | —Brock University, St. Catharines, Ont. |
| | | —University of Ottawa, Ontario |
| | | —York University, Downsview, Toronto |
| | | —Lakehead University, Port Arthur |
| | | —University of Waterloo, Ontario |
| | | —University of Toronto, Ontario |
| | | —St. Paul's University, Ottawa |
| | | —Queens University, Kingston |
| | | —Dept. of Religion, McMaster University |
| | | —Laurentian University |
| | | —Research Advisory Board, University of Guelph |
| | | —Faculty of Arts, Carleton University, Ottawa |
| | | —Dept. of Computer Science, University of Western Ontario |
| | | —Faculty of Engineering, Carleton Univ. |
| 48 | May 29, 1969 | —Notre Dame University, Nelson, B.C. |
| | | —University of British Columbia |
| | | —Research Board, University of Lethbridge |
| | | —University of Alberta |
| | | —Dept. of Geological Sciences, University of Saskatchewan, Regina Campus |
| | | —University of Saskatchewan |
| | | —University of Calgary |
| | | —Junior High School, Grade VIII Students, Winnipeg |
| | | —University of Saskatchewan, Saskatoon |
| 49 | | —Canadian Association of Graduate School |
| 50 | June 3, 1969 | —Research Council of Alberta |
| | | —Saskatchewan Research Council |
| | | —New Brunswick Research & Productivity Council |
| | | —Nova Scotia Research Council |
| | | —British Columbia Research Council |
| | | —Ontario Research Foundation |
| 51 | June 3, 1969 | —Human Resources Research Council of Alberta |
| | | —The Canadian Council for Research in Education |
| 52 | June 4, 1969 | —Biological Council of Canada |
| | | —Canadian Society of Microbiologists |
| | | —Canadian Biochemical Society |
| 53 | | —The Royal College of Physicians and Surgeons of Canada |
| | | —The Assoc. of Canadian Medical Colleges |
| | | —The Canadian Society for Immunology |

| No. | | |
|---|---|---|
| | | —Canadian Society for Clinical Investigation |
| | | —The Canadian Physiological Society |
| | | —The National Cancer Institute of Canada |
| | | —The Council of the Canadian Association of Anatomists |
| | | —The Assoc. of Chairmen of Canadian Departments of Pathology (Medical Schools of Canada) |
| 54 | June 5, 1969 | —The Royal Society of Canada |
| 55 | | —The Chemical Institute of Canada |
| 56 | June 6, 1969 | —National Committee of Deans of Engineering and Applied Science |
| | | —Association of Consulting Engineers of Canada |
| | | —Association of Professional Engineers of the Province of Manitoba |
| | | —Engineering Institute of Canada |
| 57 | June 10, 1969 | —Social Science Research Council of Canada |
| | | —Canadian Economics Association |
| | | —Canadian Association of Geographers |
| | | —Canadian Sociology & Anthropology Association |
| 58 | | —Canadian Political Science Association |
| | | —Canadian Historical Association |
| | | —Humanities Research Council of Canada |
| | | —Classical Association of Canada |
| | | —Association of Canadian University Teachers of English |
| | | —Canadian Council of Teachers of English |
| | | —Social Science Research Council of Canada |
| 59 | June 11, 1969 | —Canadian Construction Association |
| | | —Canadian Institute of Steel Construction |
| 60 | | —Canadian Psychiatric Association |
| | | —Canadian Medical Health Association |
| 61 | June 12, 1969 | —Department of Industry & Commerce, Province of Manitoba |
| | | —Canadian Labour Congress |
| | | —Agricultural Institute of Canada |
| 62 | | —The Arctic Institute of North America |
| | | —Mining Association of Canada |
| | | —The Canadian Council on Urban & Regional Research |
| 63 | June 13, 1969 | —The Canadian Chemical Producers' Association |
| | | —Canadian Pulp & Paper Association |
| | | —Pulp & Paper Research Institute of Canada |
| | | —Machinery & Equipment Manufacturers' Association of Canada |
| | | —Pharmaceutical Manufacturers' Association of Canada |
| | | —Canadian Electrical Manufacturers' Association |
| | | —Electronics Industries Association |
| 64 | June 17, 1969 | —Canadian Standards Association |
| | | —Patent & Trademark Institute of Canada |
| | | —National Design Council |

| No. | | |
|---|---|---|
| 65 | | —Dupont of Canada Ltd. |
| | | —Canadian Industries Ltd. |
| | | —Dunlop Research Centre |
| | | —Shawinigan Chemicals Division |
| | | —O. H. Johns Glass Company Ltd. |
| | | —Uniroyal Limited, Research Laboratories |
| 66 | June 18, 1969 | —Merck Frosst Laboratories |
| | | —Canadian Breweries Limited |
| 67 | | —Chevron Standard Ltd. |
| | | —Syncrude Canada Ltd. |
| | | —Shell Canada Ltd. |
| | | —Imperial Oil Ltd. |
| | | —Shawinigan Chemicals Division |
| | | —Gulf Oil Canada Ltd. |
| 68 | June 19, 1969 | —Northern Electric Co. Ltd. |
| | | —E.M.I. Electronics Canada Ltd. |
| | | —Canadian Westinghouse Co. Ltd. |
| 69 | | —Chemcell Ltd. |
| | | —MacMillan' Bloedel Limited |
| | | —Abitibi Paper Co. Ltd. |
| 70 | June 20, 1969 | —The De Havilland Aircraft of Canada Ltd. |
| | | —Orenda Ltd. |
| | | —Computing Devices of Canada Ltd. |
| | | —Litton Systems (Canada) Ltd. |
| | | —Aid Industries Association of Canada |
| 71 | June 24, 1969 | —Dominion Foundries & Steel |
| | | —Steel Company of Canada td. |
| | | —Falconbridge Nickel Mines Ltd. |
| | | —Aluminum Co. of Canada Ltd. |
| 72 | | —The Bobtex Corporation Ltd. |
| | | —Air Industries Assoc. of Canada |
| | | —United Aircraft of Canada Ltd. |
| | | —Aviation Electric Ltd. |
| | | —Canadair Ltd. |
| 73 | June 25, 1969 | —Quebec-Hydro Electric Commission |
| 74 | | —Bell Canada |
| | | —John Labatt Limited |
| 75 | June 26, 1969 | —University of Saskatchewan, Saskatoon |
| | | —School of International Affairs, Carleton University, Ottawa |
| | | —Virginia Polytechnic Institute, College of Engineering, Blacksubrg, Virginia |
| | | —Department of Management Science, University of Waterloo |
| | | —Pulp & Paper Group, Major Forest Products & R.O.R. Associates |
| 76 | | —Royal Architectural Institute of Canada |

| No. | | |
|---|---|---|
| | | —Canadair Ltd. |
| | | —Northern Electric Research & Development Laboratories |
| | | —Department of Industry, Trade & Commerce |
| | | —Toronto Public Libraries |
| | | —Laval University, Centre de Documentation |
| | | —Acres Intertel Ltd. |
| 77 | June 27, 1969 | —The Sheridan Park Association |
| 78 | Briefs | —The National Librarian |
| | | —The Pharmacological Society of Canada |
| | | —The Association of Deans of Pharmacy of Canada |
| | | —SNC Enterprises Ltd. Montreal |
| | | —Ontario Department of Trade & Development |
| | | —Canadian Public Health Association |
| | | —The Canadian Nurses' Association |
| 79 | Briefs | —The Canadian Heart Foundation |
| | | —The Canadian Assoc. of Chiefs of Police Inc. |
| | | —The Brewers Association of Canada |
| | | —The Voice of Women |
| | | —The Canadian Easter Island Expedition Society |
| | | —The Canadian Council of Furniture Manufacturers |
| | | —The Consumers' Assoc. of Canada |
| | | —The Canadian Institute of Mining & Metallurgy |
| | | —The Canadian Home Economics Association |
| | | —The Canadian Manufacturers' Association |
| 80 | Briefs | —Canadian Conference of University Schools on Nursing |
| | | —The Canadian Dietitic Association |
| | | —C.A.P.E.R., Toronto, Ontario |
| | | —Professional Institute of the Public Service of Canada |
| | | —Royal Astronomical Society of Canada |
| | | —The Canadian Association for Education in the Social Service |
| | | —The Chartered Institute of Secretaries of Joint Stock companies & Other Public Bodies in Canada |
| | | —The Members of the Prosthetics/Orthotic Research & Development Unit, Sanatorium Board of Manitoba, Winnipeg |
| | | —The Canadian Psychologica I Assoc. |
| | | —The Canadian Meteorological Society |

*Second Session of the twenty-eighth Parliament 1969-70*

| No. | | |
|---|---|---|
| 1 | | —Joint session with the Committee on Science & Astronautics of the House of Representatives of the United States of America |
| 2 | Briefs | —Canadian Library Association |
| | | —Notre Dame University of Nelson, British Columbia |

*No.*

—Science Faculty, Saint Mary's University, Nova Scotia
—The Nutrition Society of Canada
—The United Nations Association, Halifax Branch, Nova Scotia
—The Council for Laboratory Animals, Vancouver, British Columbia
—The North American Lily Society, Inc.
—The Rapeseed Association of Canada
—The Canadian Society of Plant Physiologists
—The Committee of Chalk River Nuclear Laboratories Professional Employees
—The Canadian Construction Association
—The Department of External Affairs
—The Canadian Society of Laboratory Technologists
—The Association of Canadian Medical Colleges
—The Association of Canadian Map Libraries
—The Canadian Advertising Research Foundation
—Export Credits Insurance Corporation
—The International Synthetics Foundation
—The Canadian Medical Association
—The University of Alberta
—The Canadian Institute of Onomastic Sciences
—L'Association canadienne-française pour l'avancement des sciences

3 Brief —The Canadian Peace Congress

## ANNEX D

### LIST OF WITNESSES AND INDIVIDUALS WHO HAVE SUBMITTED BRIEFS OR GIVEN TESTIMONY (REFERRED BY PROCEEDINGS' NUMBER) AND OF INDIVIDUALS WITH WHOM THE COMMITTEE MET DURING VISITS TO EUROPE AND THE UNITED STATES*

ABELSON, Dr. Philip—Editor of U.S. Journal *"SCIENCE"*, Visit to U.S.

AEBI, Dr. P.—Director of the Vorort. Swiss Union for Commerce and Industry. Visit to Europe.

ADAMSON, Mr. R. T.—Executive Director and Chief Economist. Central Mortgage and Housing Corp. Proceedings No. 33.

AIGRAIN, Mr. Jacques—General Delegate of Scientific and Technological Research. France. Visit to Europe.

ALER, Mr. B—Ministry of Industry of Sweden. Visit to Europe.

ANDRAS, Dr. A.—Director Legislation Branch. Canadian Labour Congress Proceedings, No. 61.

ANDREW, Mr. G. C.—Executive Director, Association of Universities and Colleges of Canada, Proceedings No. 44.

ANNIS, Air Marshall C. L.—General Manager, Canadian Patents and Development Limited. Proceedings No. 7.

ANSTEY, Dr. T. H.—President-Elect, Agricultural Institute of Canada. Proceedings No. 61.

ARCHER, Mr. Maurice—Vice-President, Research and Development, Canadian National Railways. Proceedings No. 19.

ARMSTRONG, Mr. Alan—Executive Officer, The Canadian Council on Urban and Regional Research. Proceedings No. 62.

AVERY, Mr. B. A.—Director of Engineering, Orenda Limited. Proceedings No. 70.

BACHYNSKI, Dr. Morrell—President, Canadian Association of Physicists. Proceedings No. 55.

BADGLEY, Prof. Robin F.—Professor and Director, Behavioural Sciences, Faculty of Medicine, University of Toronto, Proceedings No. 39.

BAKKER, Dr. G.de—Netherlands Agriculture. Visit to Europe.

BALCER, Mr. Leon—President, Electronics Industries Association. Proceedings No. 63.

BALLARD, Dr. B. G.—President, Canadian Patent and Development Limited, Proceedings No. 7.

BANNIER, Dr. J. H.—Director, Netherlands Organization for the Advancement of Pure Research (ZWO). Visit to Europe.

BARBER, Dr. L. I.—Vice-President, University of Saskatchewan. Proceedings No. 49.

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*Note: Affiliations and titles listed are those held by individuals at the time of meetings.

BARDWELL, Mr. K. O.—Mines Branch, Dept. of Energy, Mines & Resources, Proceedings No. 80.

BEECROFT, Mr. Eric—Past Chairman, The Canadian Council on Urban and Regional Research. Proceedings No. 62.

BELAIRE, Mr. Fred—Secretary, Economic Council of Canada. Proceedings No. 25.

BELL, Mr. D. D.—Staff Engineer, Eldorado Nuclear Limited. Proceedings No. 6, October 1968.

BELL, Dr. R. E.—Vice-Dean, Arts & Science, McGill University. Proceedings No. 46 & 49.

BELLEAU, Dr. Bernard—Senior Consultant, Bristol Laboratories and member, Pharmaceutical Manufacturers' Association of Canada. Proceedings No. 63.

BERRILL, Mr. K.—Chairman, University Grants Committee. U.K. Visit to Europe.

BEVERIDGE, Dr. J. M. R.—President (Academic) Acadia University, Wolfville, N.S. Proceedings No. 45.

BIGGS, Mr. Everett—President, Agricultural Institute of Canada. Proceedings No. 61.

BLACKETT, Lord—Advisor, British Minister of Technology, President, Royal Society, London, U.K. Proceedings No. 5, March 1968. Visit to Europe.

BLADEN, Professor V. W.—Department of Political Economy, University of Toronto. Proceedings No. 4, March 1968.

BLANCHARD, Dr. J. E.—President, Nova Scotia Research Council. Proceedings No. 50.

BOBKOWICZ, Dr. A. J.—Vice-President, The Bobtex Corporation Limited. Proceedings No. 72.

BOBKOWICZ, Dr. Emilian—President, The Bobtex Corporation Limited. Proceedings No. 72.

BOGGS, Mr. W. B.—President and Chief Executive Officer, The De Havilland Aircraft of Canada Ltd. Proceedings No. 70.

BONNEAU, Prof. Louis-Philippe—Member. The National Research Council. Proceedings No. 3, October 1968.

BONUS, Mr. J. L.—Managing Director, Mining Association of Canada. Proceedings No. 62.

BORTH, Mr. L. A.—President of Engineering, Litton Systems (Canada) Ltd. Proceedings No. 70.

BÖTTCHER, Dr. C. J. F.—Chairman, Science Policy Council. The Netherlands. Visit to Europe.

BOUCHER, Mr. Jean—Director, Canada Council. Proceedings No. 1, March 1968, and Proceedings No. 41.

BOULET, Dr. Lionel—Director of Research, Quebec Hydro-Electric Commission. Proceedings No. 73.

BOXALL, Mr. D. G.—Scientific Consultant (Materials), Office of Science and Technology, Department of Industry, Trade & Commerce. Proceedings No. 42.

BRADBURY, Mr. L. S.—Director of Industrial Development Service, Dept. of Fisheries and Forestry; Proceedings No. 17.

BRAY, Lt. Com. A. R.—Canadian Forces Headquarters. Proceedings No. 80.

BREGHA, Mr. Francis G.—Associate Professor, School of Social Work. University of Toronto. Proceedings No. 39.

BRIDGEO, Dr. W. A.—Dean, Faculty of Science, St. Mary's University, Halifax, N.S. Proceedings No. 45 & 49.

BRISING, Mr. L. H.—Managing Director, Swedish National Development Corporation, Visit to Europe.

BROHULT, Prof. Sven—Swedish Industrial Research Expert. Visit to Europe.

BROOKS, Dr. Harvey—Dean of Engineering & Applied Physics. Harvard University, and Chairman of the National Academy of Sciences Committee on Science and Public Policy. Visit to Europe.

BROWN, Dr. G. Malcolm—Chairman, Medical Research Council, Proceedings No's. 8, March 1968 and 30 and 53.

BROWN, Mr. R. K.—Deputy (Scientific), Office of Science & Technology, Dept. of Industry, Trade & Commerce, Proceedings No. 42.

BROWNE, Mr. S.—Assistant Secretary for Research and Technology, U.S. Department of Transport. Visit to U.S.

BRYCE, Mr. R. B.—Deputy Minister; Dept. of Finance, Proceedings No. 34.

BUNDOCK, Dr. J. B.—Principal Medical Officer, Special Projects, National Health & Welfare, Proceedings No. 13, Nov. 1968.

BURKE, Professor F. Eric—Department of Management Sciences, Univ. of Waterloo, Ontario. Proceedings No. 75.

BURSILL, Dr. C.—Executive Director and Deputy Chairman, New Brunswick Research and Productivity Council, Proceedings No. 50.

BURT, Dr. M. D. B.—Associate Professor, Department of Biology, University of New Brunswick, Fredericton, N.B. Proceedings No. 45 and 49.

CADIEUX, Mr. Marcel (Q.C.)—Under-Secretary of State, Dept. of External Affairs. Proceedings No. 38.

CAESAR, Dr. C. H.—Deputy Manager of Research, Imperial Oil Limited. Proceedings No. 67.

CALDBICK, Dr. G. D.—Director of Treatment Administration. Department of Veterans Affairs. Proceedings No. 14, Nov. 1968.

CAMPBELL, Dr. Duncan R.—Acting Director, Planning and Evaluation Branch, Department of Manpower and Immigration, Proceedings No. 28.

CAMPBELL, Mr. H. C.—Chief Librarian, Toronto Public Libraries. Proceedings No. 76.

CAPON, Mr. F. S.—Vice-President, Du Pont of Canada Limited. Proceedings No. 65.

CAREY, Mr. William—ex Assistant Director for Science & Technology U.S. Bureau of Budget. Visit to U.S.

CARRIÈRE, Brigadier-General Jean P.—President, Engineering Institute of Canada. Proceedings No. 56.

CARROLL, Dr. John—Associate Professor of Computer Science, University of Western Ontario, London, Ontario. Proceedings No. 47 and 49.

CARSON, Mr. J. J.—Chairman, Public Service Commission. Proceedings No. 29.



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CHAGNON, Dr. M.—Vice-Rector (Academic Affairs) University of Ottawa, Proceedings No. 47.

CHAMBERLAIN, Mr. Ross E.—Assistant to the Vice-President, Engineering, Dominion Bridge Company, Canadian Institute of Steel Construction. Proceedings No. 59.

CHANNON, Miss Geraldine—Projects and Information Officer, Canadian Teachers Federation. Proceedings No. 51.

CHAPMAN, Dr. R. A.—Director General, Food and Drug, National Health & Welfare. Proceedings No. 13, Nov. 1968.

CHARLES, Mr. F. R.—Secretary-Treasurer, Canadian Patents & Development Limited. Proceedings No. 7.

CHEESMAN, Mr. William J.—President and Chief Executive Officer, Canadian Westinghouse Company Limited. Proceedings No. 68.

CHORNY, Professor Merron—Past President, Canadian Council of Teachers of English. Proceedings No. 58.

CHUTTER, Mr. S. D. C.—General Manager, Canadian Construction Assoc. Proceedings No. 59.

CINADER, Dr. B.—President, The Canadian Society for Immunology. Proceedings No. 53.

CLARK, Dr. S. D.—Member, The Royal Society of Canada. Proceedings No. 54.

CLARKE, Reverend Dr. E. M.—Head of Department of Physics, St. Francis Xavier University. Antigonish N.S. Proceedings No. 45.

CLEGHORN, Dr. Robert A.—Chairman of the Research Committee, Canadian Psychiatric Association. Proceedings No. 60, and No. 2. 1970.

CLUNIE, Dr. J. C.—Consultant and Former Technical Director, Chemcell Limited. Proceedings No. 69.

COCHRAN, Mr. J.—Director, Canadian Construction Association. Proceedings No. 59.

COGAN, Mr. J.—Senior Vice-President, Imperial Oil Ltd. Proceedings No. 67.

COLBORNE, Mr. G. F.—Manager, Research and Development Division, Eldorado Nuclear Ltd. Proceedings No. 6, Oct. 1968.

COLL, Mr. A. E.—Executive Director, Central Mortgage and Housing Corporation. Proceedings No. 33.

CONNELL, Dr. G. E.—Chairman, Department of Bio-Chemistry, University of Toronto, Toronto, Ontario. Proceedings No. 47.

COOK, Dr. L. G.—Délégué Général, National Research Council. Proceedings No. 21.

COOK, Dr. William H.—Executive Director, National Research Council, and Past President, Biological Council of Canada. Proceedings No. 21 and 52.

COOK, Sir William—Chief Advisor for Projects and Research in the Ministry of Defence. U.K. Visit to Europe.

COPE, Mr. R. R.—Commissioner, Research Division, Canadian Transport Commission. Proceedings No. 20.

COPP, Dr. J. H.—President, National Cancer Institute of Canada. Proceedings No. 53.

CORMACK, Dr. G. D.—Associate Professor, Faculty of Engineering, Carleton University. Proceedings No. 47 and 49.

DRURY, Hon. C. M.—Minister of Industry. Proceedings No. 12, 1968.

DUBÉ, Mr. Y.—President, Social Science Research Council of Canada. Proceedings No. 57.

DUBRIDGE, Dr. Lee—Director U.S. Office of Science and Technology and Chairman of U.S. President's Science and Advisory Committee. Visit to U.S.A.

DUCKWORTH, Dr. H. E.—Vice-President (Academic) University of Manitoba, Winnipeg, Manitoba. Proceedings No. 48 & 49.

DUCKWORTH, Mr. John—Managing Director of the National Research and Development Corporation. U.K. Visit to Europe.

DUFFETT, Mr. Walter E.—Dominion Statistician, Dominion Bureau of Statistics. Proceedings No. 24.

DUNBAR, Dr. M. J.—Professor, McGill University, Arctic Institute of North America. Proceedings No. 62.

DUNBAR, Miss Moira—Governor, Arctic Institute of North America. Proceedings No. 62.

DUPRÉ, Dr. J. S.—Director of the Centre for Urban and Community Studies, University of Toronto. Proceedings No. 43 & 49.

DUTTON, Professor H. M. M.—Head, Physics Department, Bishop's University, Lennoxville, Quebec. Proceedings No. 46.

DWYER, Mr. P. M.—Associate Director, Canada Council. Proceedings No. 1, March 1968.

DYCK, Dr. Harold J.—Chairman, Planning & Policy Studies; Human Resources Research Council of Alberta. Proceedings No. 51.

DYKE, Deputy Minister Lorne—Department of Industry & Commerce, Province of Manitoba. Proceedings No. 61.

DYMOND, Dr. W. R.—Assistant Deputy Minister, Program Development, Department of Manpower and Immigration. Proceedings No. 28.

EAGLES, Dr. Blythe A.—President, Canadian Society of Microbiologists. Proceedings No. 52.

EDGE, Mr. C. G.—Vice-President, Corporate Development, Chemcell Limited. Proceedings No. 69.

EMBLING, Mr. J.—Deputy Under-Secretary of the Department of Education and Science. U.K. Visit to Europe.

ENGLISH, Dr. H. Edward—Director, School of International Affairs, Carleton University, Ottawa, Ontario. Proceedings No. 75.

ENGLISH, Dr. W. N.—Head, Division of Applied Physics. British Columbia Research Council. Proceedings No. 50.

ENGSTRÖM, Prof. Arne—General Secretary Science Advisory Council of Sweden. Visit to Europe.

ERRINGTON, Mr. R. F.—Vice-President (Commercial Products) Atomic Energy of Canada Limited. Proceedings No. 5, Oct. 1968.

EVANS, Dr. John R.—Member, The Association of Canadian Medical Colleges. Proceedings No. 53.

FAIRHOLM, Mr. C. I.—Director. Policy, Planning and Programming. Department of Indian Affairs and Northern Development. Proceedings No. 31.

FAVRE, Dr. Henri A.—Member, Fisheries Research Board. Proceedings No. 17.

FEHRM, Dr. E. M.—Director General, Swedish Board of Technical Development. Visit to Europe.

FELLEGI, Dr. Ivan P.—Director, Sampling and Research Staff. Dominion Bureau of Statistics. Proceedings No. 24.

FISHER, Mr. A. D.—Vice-President, Planning, Engineering and Research Division. Steel Company of Canada Ltd. Proceedings No. 71.

FISHER, Dr. K. C.—Commissioner, Survey of Biology, Science Secretariat of the Privy Council. Proceedings No. 52.

FITZGERALD, Sister Mary Evelyn—Chairman, Department of Chemistry, Mount St. Vincent University, Halifax, N.S. Proceedings No. 45.

FLOWERS, Sir Brian—Chairman, Science Research Council. U.K. Visit to Europe.

FLYNN, Mr. H.—Science Advisor, Science Secretariat of the Privy Council. Proceedings No. 12, 1968.

FORGET, Professor C.—Centre de Documentation, Laval University. Proceedings No. 76.

FORWARD, Dr. F. A.—Consultant on Research Administration, University of British Columbia, Vancouver, B.C. Proceedings No. 48 & 49.

FOWLER, Mr. R. M.—President, Canadian Pulp and Paper Association. Proceedings No. 63.

FRAPPIER, Dr. Armand—Director, Institut de Microbiologie, Université de Montréal and Canadian Society of Microbiologists. Proceedings No. 52.

FREEMAN, Mr. George E.—Chief, Research Department. The Bank of Canada. Proceedings No. 23.

FREITAG, Mr. John D.—President and General Manager, Litton Systems (Canada) Limited. Proceedings No. 70.

FREY, Dr. Kurt—Secretary General of Standing Committee of Lünder Ministers for Education and Culture of West Germany. Visit to Europe.

FROST, Dr. S. B.—Dean of the Faculty of Graduate Studies, and Research, McGill University, Montreal, Quebec. Proceedings No. 46.

FRY, Mr. James L.—Director of Program Division responsible for Economic Measures and Scientific Research, Treasury Board, Proceedings No. 26 & 36.

FULTON, The Hon. James G.—Member of U.S. House Science and Astronautics Committee. Proceedings No. 1, 1970.

GAUDRY, Dr. Roger—Vice-Chairman, Science Council of Canada. Proceedings No. 12, Apr. 1968.

GAUVIN, Dr. W. H.—Member, National Research Council; Manager, Noranda Research Centre. Proceedings No. 3, Oct. 1968 and Nos. 21 & 62.

GENDRON, Dr. Pierre—President, Pulp and Paper Research Institute of Canada. Proceedings No. 63.

GIGNAC, Mr. Jacques—Head, Cultural Affairs Division, Department of External Affairs. Proceedings No. 38.

GILCHRIST, Mr. W. McK.—President, Eldorado Nuclear Ltd. Proceedings No. 6, Oct. 1968.

GOBLE, Mr. Norman H.—Deputy Secretary-Treasurer, Canadian Teachers' Federation. Proceedings No. 51.

GOLDBERG, Dr. Simon A.—Assistant Dominion Statistician, Dominion Bureau of Statistics, Proceedings No. 24

GOLDEN, Mr. D. A.—President, Air Industries Association of Canada. Director, Atomic Energy of Canada Ltd. Proceedings No. 5, Oct. 1968 and Nos. 70 and 72.

GOLDSMITH, Mr. Maurice—Director of Science of Science Foundation, London, England, Proceedings No. 35.

GORHAM, Dr. P. R.—Canadian Society of Plant Physiologists and Biological Council of Canada. Proceedings No. 52.

GRACE, Dr. N.—President, The Chemical Institute of Canada; General Manager, Dunlop Research Centre. Proceedings No. 55, 65 & 77, and No. 2 (1970).

GRAHAM, Dr. James H.—Secretary, The Royal College of Physicians and Surgeons of Canada. Proceedings No. 53.

GRAY, Dr. J. L.—President, Atomic Energy of Canada Limited, Proceedings No. 5, Oct. 1968.

GRAY, Dr. J. A. B.—Secretary of the Medical Research Council. U.K. Visit to Europe.

GREEN, Dr. J. J.—Director of Government Relations. Litton Systems (Canada) Limited. Electronics Industries Association. Proceedings No. 63 & 70.

GREENSHIELD, Dr. J. E. R.—Agricultural Institute of Canada. Proceedings No. 61.

GRENIER, Dr. Pierre—Head, Professional Affairs, Chemical Institute of Canada. Proceedings No. 55.

GRIFFIN, Dr. John D.—General Director, Canadian Mental Health Association. Proceedings No. 60.

GUINDON, Rev. Dr. Roger, O.M.I.—Ex-President, Association of Universities and Colleges of Canada. Proceedings No. 44.

HAGEN, Dr. Paul B.—Dean, Faculty of Graduate Studies, University of Ottawa, Ottawa, Ontario. Proceedings No. 47 & 49.

HAILEY, Mr. A. R. T.—Manager, Engineering Laboratory, Canadian General Electric Co. Ltd. Canadian Electrical Manufacturers' Association. Proceedings No. 63.

HALL, Dr. G. E.—Research Consultant, John Labatt Ltd. Proceedings No. 74.

HAM, Dr. James—Dean, Faculty of Applied Science and Engineering, University of Toronto. Proceedings No. 39.

HAMEL, Mr. P. E.—Scientific Advisor, Atomic Energy Control Board, Proceedings No. 9, Nov. 1968.

HARE, Dr. F. Kenneth—Canadian Association of Geographers. Proceedings No. 57.

HARRISON, Dr. J. M.—Assistant Deputy Minister (Mines and Geosciences) Department of Energy, Mines & Resources. Proceedings No. 16.

HARROWER, Dr. G. A.—Vice-Principal (Academic) Queens University, Kingston, Ontario. Proceedings No. 47.

HART, Dr. J. F.—Head, Computer Science Dept., University of Western Ontario. Proceedings No. 47.

HART, Dr. John—Dean of Science, Lakehead University, Port Arthur, Ontario. Proceedings No. 47.

HARTOGH, Mr. A. F. K.—Director-General of European Co-operative (MFA). Visit to Europe.

HASEMANN, Dr. Karl Gotthart—General Secretary of Science Council. West Germany. Visit to Europe.

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MOBERG, Mr. Sven—Minister without Portfolio of the Ministry of Education of Sweden. Visit to Europe.

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POSTMA, Dr. John F.—Research and liaison Officer for Academic Development, Notre Dame University of Nelson, B.C. Proceedings No. 48 & 49.

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