The Role and Function of Government Laboratories and the Transfer of Technology to the Manufacturing Sector

ANALYZED

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by Arthur J. Cordell and James Gilmour

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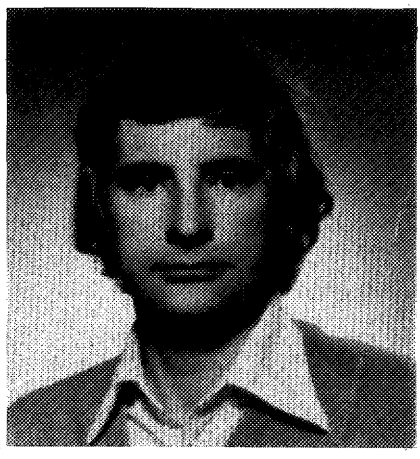

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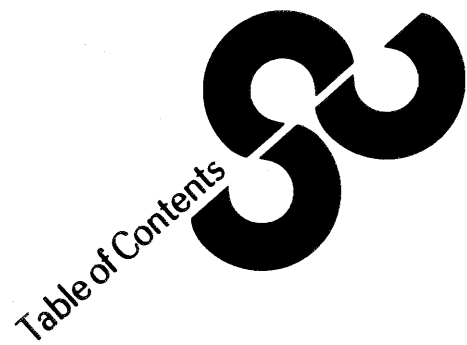

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Foreword

This study was carried out during 1974 with the support and guidance of a Science Council Committee chaired by Dr. Mervyn Franklin.* The results of this study were the principal source of information for Science Council Report No. 24, Technology Transfer: Government Laboratories to Manufacturing Industry, which was issued in December 1975.

One of the central problems of Canadian innovation is the inadequate linkage between the market place and much of the research conducted in this country. This study deals mainly with one element of that problem, i.e., the transfer of technology from federal laboratories to the secondary manufacturing industry. The importance of this element arises from the high proportion of the Canadian R & D effort that takes place in federal laboratories.

In our earlier Report No. 15, Innovation in a Cold Climate: The Dilemma of Canadian Manufacturing, the Science Council stressed the need for more innovation and drew attention to many of the impediments. Today, the "climate" is much colder and, at a time when industrial innovative effort is low, the need for effective transfer of technology already available in federal laboratories is correspondingly greater.

It has been conventional wisdom to ascribe the weakness of the technology transfer process to the low interest and understanding, within government laboratories, of industry's needs and difficulties. Indeed, the central thrust of industrial criticism bears upon the lack of understanding, among federal scientific personnel, of the market pressures to which all innovative effort is subjected. Much of this criticism is valid, and major changes will need to be made in both policy and procedural areas in order to move technology more rapidly and efficiently from the laboratories to the market place.

---

* The members of the Government Laboratories and Technology Transfer Committee are Dr. L.A. Cox, Ms. S.O. Fedoruk, Mr. L. Hynes (until his untimely death in February 1975), Dr. J.L. L'Heureux, Dr. W.G. Schneider, and Mr. J.J. Shepherd.

Yet, as the study indicates, the major weakness in the technology transfer process may lie in the poverty of industrial attitudes to the government research institutions: the failure to fully appreciate the mission of the laboratories; the absence of persistent association with the federal government research community; and in general, the low level of demand pull by industry on government research. All these factors give evidence of industrial weakness in the exploitation of federal government research efforts. This industrial deficiency is at once a product of a "branch plant" structure and of negative management attitudes.

It is essential that the deficiencies in both sectors be corrected. Canada cannot afford the consequences of sectoral polarisation and of fragmentation of its research and development effort. The accent must be on action, not on a continuing debate of these problems.

As with all background studies published by the Science Council, this study represents the views of the authors and not necessarily those of the Council.

J.J. Shepherd
Executive Director
Science Council of Canada

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This study represents the combined efforts of a number of people. Mr. Leo Derikx, on secondment from the Department of the Environment, contributed a great deal to the industrial aspects of the study. In his interviews with manufacturing firms he was assisted by Mr. James Dubroy (now with the Department of Supply and Services). Both Ms. Phyllis Colvin and Mr. Michael Kelly, working as research assistants, spent long hours helping to put the mass of material into a readeable framework. The authors would especially like to thank Dr. Mervyn Franklin, Dean of Science, University of New Brunswick, who as Chairman of the Committee on Government Laboratories and Technology Transfer contributed enthusiasm, ideas and insights.

A.C.
J.G.

I. Background to the Study

Chapter 1. Background to the Study

1. Historical Perspective: Government and Scientific Activities

This opening chapter contains a review of some of the events which have helped shape the nature and scope of current discussions surrounding federal government activities in the sciences. The reader should keep in mind that a review chapter such as this must repeat some of the earlier controversies and the statistical detail associated with them. Although we hesitate to re-state some of the earlier discussions which, with hindsight, can be dismissed as the conventional wisdom of the day, we do think they should be briefly examined so that the reader may be made aware of the kinds of discussions which have characterized Canadian science policy in the past decade.

Over the years much that has been written about what government laboratories should be doing and how well they should be performing in one area or another is, we feel, not based on the historical conditions within which each laboratory was established; rather, it appears that those who assert that laboratories should be doing more or less of any activity have a highly simplified model of the government scientific establishment that does not correspond to reality.

This report is mainly directed at the intramural scientific activities of the federal government. As one way of measuring the performance of federal government laboratories and establishments we have chosen to examine the effectiveness of technology transfer to the manufacturing sector. A number of areas are not examined in this report: the provincial research councils, universities and areas of industry other than manufacturing. To have included these would have made this somewhat bulky report even more lengthy.

Of immediate interest is why and how federal government laboratories came into existence in Canada. Why were they considered important? Under what conditions did governments of the day consider the case for government expenditure on scientific activities?

In general, government expenditures can be justified whenever they provide a public good. Public goods are usually commodities or services that everyone wants but which the private sector is unable to supply. The commonly cited example used in economics is the provision of a lighthouse to warn ships of dangerous waters. A private firm would not erect such a lighthouse since it could not extract a payment from the users. An old saying is that "...government should do for the people what needs to be done, but which they cannot, by individual effort, do at all, or do so well, by themselves."

It is in this context that government expenditures for scientific activities in a wide range of areas have been perceived to be necessary and desirable. The individual farmer cannot afford to conduct research on new varieties of crops, hence government can and must conduct such research and make the results known to farmers; society as a whole will benefit. Other areas where government expenditures have long been accepted are national defence, the postal system, roads, waterways, etc. Slowly but surely the role of government has expanded and the dividing line between what can only be done by government and what ought to be done by government has become blurred. The expanded role of government in social welfare, maintenance of the economy, international matters, and elsewhere has spilled over into the area of scientific activities.

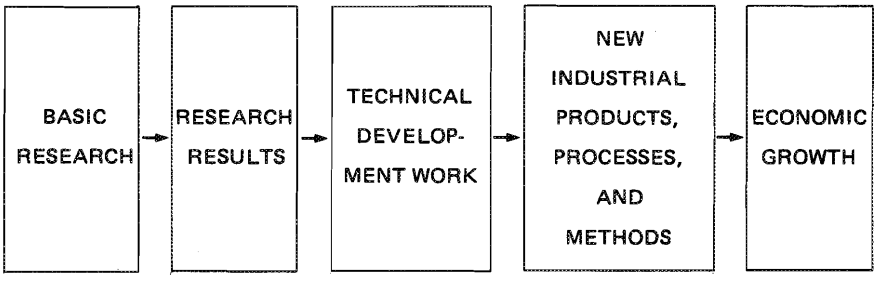
The earliest ventures by government in the scientific area were to provide public goods. As the notion of the public good expanded to include the state of the nation's economy, the government was drawn into providing support for industrial activities. Science and technology have become an important part of the growth and maintenance of an industrial state. Technological change, dependent on specialized education, has been cited as providing up to 75 per cent of the increase in gross national product.

Although both science and technology have been with mankind for a very long time it is only within the last few hundred years that science has played a significant role in the development of technology. In the earliest days technological development influenced scientific understanding but as scien-

tific information accumulated and the study of science was systematized and extended, a gradual shift occurred and science began to be utilized for the development of technology. The present power of technology is evident in the number of research establishments maintained by major corporations. This harnessing of technology to create new products and production techniques has only occurred during the past 150 years. It was not until about 1850 that the practical application of science made itself felt; indeed the organized research laboratory as part of industry is only about 75 years old. The relative newness of technology as a factor in production is undoubtedly a cause of the concern with which it is regarded.

Currently the role of research, development, innovation and their relationship to gross national product is in question.[1] Some writers argue that R & D will lead to economic growth while others state flatly that no such relationship exists. N.H. Lithwick notes that "the evidence lends no support whatever to the proponents of R & D as a source of growth".[2]

In the halcyon days of the 1950s a very simplistic model of the relationship of R & D to economic growth was held almost as an article of faith by many writers in the field of industrial research policy. The type of interaction that was seen is as follows:



However, the link between R & D and economic growth was gradually perceived to be much more complex. More and more factors were seen to be of importance: innovation, marketing, size of the domestic market, etc. None the less, the belief that technological innovation is somehow related to economic growth persists, although those expressing this belief declare that it is not known exactly how the entire mechanism works. But that it does somehow work is held to be beyond doubt.

The Report of the Senate Special Committee on Science Policy (the "Lamontagne Report") cites studies by both the Economic Council and the Science Council which substantiate this view, and concludes:

> "Thus, technological innovation is recognized as an important determinant of economic growth - and indeed the whole history of the growth of industrialized nations shows this - and there is a strong consensus that the low innovative capacity of Canadian industry must be radically improved if Canada's economy is to grow at the desired rate and if less reliance is to be placed on exports of raw materials and primary products to achieve that goal."[3]

For the purposes of this report it is assumed that the final word has not yet been written on the relationship between R & D, innovation, technological change and changes in gross national product.[4] The fact is that government does spend over $680 million per year on in-house scientific activities (1974-1975) and about $335 million per year for scientific activities in industry, universities and non-profit institutions. The intent of this report is to examine how and why the laboratories do what they do and, furthermore, to examine the degree to which laboratories of the federal government are of use to the goods-producing sector in Canada.

The main vehicles for intramural federal government science activities are the scientific establishments attached to particular federal departments. Certain Crown corporations also play a central role in Canadian research activity, the two most prominent in the scientific area being Atomic Energy of Canada Limited, and the National Research Council. However, in this report there are only a few areas where the distinction between federal departments and Crown Corporations has implications for the findings and analysis presented. Consequently the discussion except where specifically noted, refers to all federal scientific establishments.

We have chosen to examine the federal scientific establishments as a whole rather than

single laboratories within an establishment. An establishment may consist of a single laboratory but usually consists of a cluster of laboratories, ranging from a few to dozens. In addition all establishments have a large number of non-scientific supporting activities which allows them to be effective in their particular area of research.

2. Historical Development of Government Laboratories in Canada

The federal government has been involved in a variety of scientific activities for over one hundred years. In 1867, the federal government took over the Meteorological Service which had been active in Canada since 1839. The Geological Survey was inaugurated shortly after Confederation. The mission of the Survey was to explore and report on the mineral wealth of the country. Federal support for astronomy started in 1885 when surveys were begun to define tracts of land needed for the construction of railways in British Columbia. Federal support in this area consisted of building small observatories in various centres in Canada, culminating in the completion of a 15-inch telescope in Ottawa in 1905, thus beginning the work of the Dominion Observatory. In 1918 the Dominion Astrophysical Observatory was completed in Victoria; at that time its 72-inch telescope was the largest in the world. Other activities of the government included the establishment of the Board of Management of the Biological Stations in 1898 which later became the Fisheries Research Board. In 1884 a select committee of the House of Commons examined the problems of agriculture and recommended the establishment of an experimental farm. Forestry research was scattered but was finally brought together by the Forestry Branch of the Department of the Interior with the establishment of the first formal experimentation station in Petawawa in 1917. Activities of the government were largely involved with resource development, the improvement of cereal grains, the establishment of standards and the testing of materials.

Government recognition of the growing need for industrial research coincided with the First World War. At the same time it is now recognized that the Canadian scientific community had become a

strong and cohesive force.[5] Scientists and businessmen urged government to become involved in the needs of the industrial sector. The Honorary Advisory Council for Scientific and Industrial Research was formed in 1916 to recommend policies to the government and to supervise the distribution of research grants to universities and industry. The Honorary Advisory Council evolved into the National Research Council (NRC)

The terms of reference for the Honorary Advisory Council were:

(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 cooperation in solving the various problems and industrial research which, from time to time, present themselves;

(b) To coordinate 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.

The early years of NRC are a story of shifts of power within bureaucracies, a series of sincere efforts to aid industry and successive attempts to actually construct a laboratory.* Even before NRC had its own laboratories it attempted to supply expertise to various sectors of industry in Canada.[6] At that time Canada already had scientific facilit-

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* The clashes with already well-established bureaucracies in other scientific fields tended to mould NRC's activities in such a way that there evolved an implicit policy that it would avoid working in any field where a government department was active. For example, NRC's action in 1920 in starting an Associate Committee on Industrial Hygiene evoked the following, brief letter from the Deputy Minister of Public Health: "You are not so smart as you think you are."

ies to serve the primary industries of agriculture, mining, fishing and forestry; the new need was to provide for the emergent secondary and manufacturing industries.

Actual construction of laboratories on a large enough scale to conduct industrial research began on 28 February 1930. By June 1935 the Sussex Drive Laboratories were in operation. The staff consisted of 153 of which 54 were considered as professional. NRC had a budget of $550 000 and its four operating divisions were biology and agriculture, chemistry, physics and engineering, and research information.

The Report of the Senate Special Committee on Science Policy (Vol. 1) details the problems encountered in this early governmental scientific foray into industrial research. (See especially pp. 20-53.) The problems of coordination, funding, and the degreee to which NRC should conduct research, support industrial and university research and provide a national centre of excellence where young scientists could be inspired, continue to this day.

From 1916 to 1939 the scientific expenditures of the government continued to grow at a slow but steady pace. In 1939 the scientific budget had reached $5 million. NRC accounted for about $880,000 of the total.

As World War One had an impact on the government in terms of the need to conduct scientific research, World War Two brought about a dramatic shift in the role of science and scientists. The war years saw a substantial rise in the scale of governmental scientific activity. Expenditures increased 700 per cent to about $35 million in 1945. More important than dollars was the widely held notion that science could accomplish virtually anything it set out to do. NRC became accustomed to initiating scientific programs suggested by its own scientists rather than by scientists or industrialists in the outside community. Doern argues that the wartime environment of urgency and secrecy[7] led to little consultation with the outside world.

> "The government science sector tended to make relatively less real use of the advisory committees and other machinery which they had

consciously created in earlier periods to link themselves with their scientist colleagues in the non-governmental science community. Vis-à-vis their scientist colleagues outside the government, government scientists, especially at NRC, enjoyed a position of great power and status."[8]

Within months after the start of the war the staff of NRC had expanded to almost 2000 and its yearly budget was close to $7 million. Major decisions were also made on the building of new laboratory facilities. As in the past, many of the new government laboratories were located in the Ottawa area; the move toward centralization appears to have been both scientifically and politically motivated.

"From the early days, government laboratories were, wherever possible, located near Ottawa in order to ensure what later came to be called a 'critical mass'. An additional pressing reason was that agencies looking toward survival found it prudent to keep as many of their experts as possible within easy reach of the Treasury Board."[9]

The end of the war and the early post-war years saw a definite pattern emerging: the power and remoteness of science and a definite centralization of the scientific establishment in Ottawa. Science was an important factor in winning the war; the weapons research that had taken place at NRC led to the establishment of a separate facility to continue armament-related research - the Defence Research Board. Perhaps more important was the development of a nuclear energy capability at Chalk River and the later formation of Atomic Energy of Canada Limited. In 1944, Eldorado Mining and Refining Limited was founded as a Crown corporation for the mining and refining of uranium ore and for the production of nuclear fuels. The Atomic Energy Control Board was formed in 1946 for the regulation and control of atomic energy in Canada. In 1947 the NRC subsidiary Canadian Patents and Developments Limited was founded, mainly to make NRC (and later all Public Service) inventions available to industry. A number of science-related institutional developments took place in the early post-war period, but the critical event was the government's decision to continue and enlarge the major program

in nuclear power. "The decision which then had to be made was whether the Chalk River project should be continued or be run down along with the rest of the war machine. The decision to continue was a crucial one because it ushered in Big Science in Canada."[10]

Big Science had the same impact in Canada as elsewhere; it led to ever-growing expenditures for governmental scientific activities. Operating expenditures for R & D rose to over $94 million in 1951-52 and more than doubled by 1961-62 to almost $222 million.[11]

The early post-war years were years of growth, centralization and little coordination or control. For NRC and for the main government departments and Crown corporations with a scientific mandate:

> "There was less and less disposition to follow the earlier instructions it had given its own committees, namely, to look for the sector (industry, university or government) which could best perform the research. In a period of general expansion it became relatively easy for new programs to be started, on the initiatives of the working level divisions, but it became exceedingly difficult to evaluate their impact and to stop projects, should that be necessary."[12]

However, research continued to grow and three broad classes of governmental research were recognized.

- "Research in support of, or carried on in association with, the administrative or operational activities of departments; examples are mining, agriculture, forestry, and fisheries.

- Research for which the government acknowledges a special interest or responsibility, although unconnected with direct operations; oceanography and astronomy are examples.

- Research unrelated to any specific practical objective but directed towards increasing general scientific knowledge, which may be described as pure basic research."[13]

For a variety of reasons NRC was held by many not to have successfully aided the development of a strong industrial research component in Canada.[14] Some of the reasons for the lack of success are explored later in this chapter and elsewhere in this report.

Doern elaborates the three main roles of NRC; they were (and are) to support and promote industrial research, to coordinate the federal government's scientific activities, and to aid the development of scientists by supporting their research activities. NRC placed an increasingly heavy emphasis on the last of these notes. Although NRC's industrial research and coordinative roles were partly fulfilled they did not meet the needs which were already apparent in the late 1950s.[15]

By the decade of the 1950s the pattern of governmental scientific activities had become firmly established. The growth of government involvement had been tremendous. The apparent lack of coordination of expenditures drew criticism from many observers, and the question of allocation of resources, to achieve the optimum benefit for the country, was raised again and again. The role and function of government laboratories was reviewed by the Glassco Commission. The Glassco findings are well known (cf. Lamontagne, Vol. 1, pp. 90-92). Of particular interest is a statement regarding government 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."[16]

It is difficult to prescribe the amount of money which should be spent by government in the various areas of science.

> "Much government science is in areas of national interest which are not amenable to cost-benefit calculations, do not lead to economic growth in any direct sense, and are not of interest to the business community. Nevertheless if not adequately attended to they could choke off the whole economy. Examples are environmental pollution, transporta-

tion aids (water, land, and air), resource conservation (forests, wildlife), military science, and medical services. What research should be done in these social problem areas, and on what scale, are questions particularly difficult to settle."[17]

The industrial area was held by Glassco and Lamontagne to have been neglected. Much of the blame has been laid at the door of NRC since its original mandate contained an explicit direction to stimulate Canadian industrial growth. The relative failure to achieve the development of an indigenous high technology industry in Canada has been blamed on the inability of governments since 1916 to have government laboratories operate with this objective. The failure has been cited many times by many writers, task forces and commissions.

The role of government laboratories in stimulating industrial research had never been clearly defined. The Lamontagne Committee found this to be one of the major failures in governmental science policy. This is quite explicitly noted in its Report (Vol. 1, p. 245):

> "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."

Although some of the fault should be accepted by NRC, it is our view that the failure to develop a sound technologically sophisticated manufacturing base is a structural problem: the configuration of the Canadian economy itself. (See section 3 of this chapter.) In addition, NRC naively assumed that the growth of industrial research and development was dependent on the supply of trained scientists. It assumed that "supply would create its own demand." In the world of economics before Keynes, this view

was held as well. The cure for economic depression was to increase supply: prices (and therefore wages) would fall, and the economy would begin to pick up. Keynes showed that to stimulate an economy out of a depression or to avoid a depression itself the government must concentrate on the demand side. Demand should be encouraged by government expenditures, capital investment, consumption and increased exports; thus the economy would be stimulated and would supply the additionally needed materials.

To implement the policy that supply creates its own demand, NRC saw its role to be the development of a high degree of in-house competence and the stimulation of university activities in the areas of scientific research.[18] Considerable attention was also given to maintaining the pureness of the environment within which the scientist worked. Undirected research was thought to be the best means by which scientists of high calibre could be produced. Theoretically such scientists would then come into the job market and would be hired by industry to conduct industrial research. We now know that to increase the employment of highly qualified manpower in the industrial sector there must be a sufficient demand for people possessing these unique skills.

Thus for almost fifty years (1919 to the early 1960s) the apparent science policy to aid in the development of the manufacturing sector was more or less constant. The role of the university was to concentrate on basic science and to turn out the finished product - scientists. Government laboratories were expanded for a wide variety of reasons, not the least of which was to provide employment opportunities for graduate scientists.

3. The Unique Configuration of Canadian Industry

Previous Background Studies for the Science Council of Canada have recorded in some detail the way in which Canadian industry differs from that of its industrialized neighbours.[19] Almost forty years ago, however, in a little noted but stimulating work,[20] the problem of creating and sustaining an innovative indigenous secondary manufacturing sector had already been explored. At the heart of the problem was the high degree of direct foreign investment in Canada.

The Canadian tariff, a policy which predates NRC and the seemingly endless debates on industrial strategies, was the major force which attracted direct investment into Canada. Tariffs were designed to encourage production of goods in Canada. Little thought was apparently given to the development of an indigenous technological capability nor, for that matter, did anyone seem to care about where the industrial research and development was performed which resulted in sophisticated product and process developments.

Over the years the nature of worldwide manufacturing has changed. Most important has been the increase in amount of research and technology that is now found in the manufacturing sector. It is fashionable to divide manufacturing into industry and high technology industry. The latter category is the fastest growing component, containing chemicals, electronics, computers, and various forms of transportation including aircraft. Canadian industry has followed world industrial patterns and secondary industry has come to predominate over primary industry. However, the built-in problem was that the most research-intensive sectors of Canadian industry have relied on the fairly free flow of science, technology and production processes from foreign parent firms.[21]

Canadian experience with foreign ownership predates the worldwide phenomenon of the multinational firm. In the late 1950s and early 1960s, the 1936 findings of Marshall, Southard and Taylor were apparently repudiated by the researches of Safarian and the propositions set forth in the OECD survey of Canadian science policy.[22] It was alleged that there was little difference between foreign and domestically owned corporations as far as R & D was concerned. The conventional wisdom of the late 1960s held that Canada's poor record in industrial R & D and innovation was unrelated to foreign investment patterns. The central problem cited was the relatively low amount of industrial R & D performed by Canadian industry and the relatively high degree of R & D performed in government laboratories compared with other industrialized countries. As noted in Table I.1, the most recent data available indicate that this relative international disparity persists. Government financed R & D was

TABLE I.1 - Percentage Distribution of National R & D Expenditures by Sectors of Performance and Country, 1969

Country	Business Enterprise	Government	Higher Education	Private Non Profit
Switzerland	84.7	4.2	11.0	[1]
Sweden	66.0	14.8	19.1	0.1
U.S.A.	69.5	14.1	12.7	3.7
Germany	68.2	4.7	17.5	9.7
Belgium	56.4	10.5	32.5	0.5
U.K.	64.7	24.5	8.3	2.5
Japan	67.3	12.1	19.0	1.5
Netherlands	62.1	11.4	17.9	8.7
France	55.5	29.2	14.2	1.0
Canada	36.6	34.5	28.9	[2]

[1] data not available and not included in another column or line or in the total.

[2] data not separately available but included in another column or line and in the total.

Source: OECD, Directorate for Scientific Affairs, International Survey of the Resources Devoted to R & D in 1969 by OECD Member Countries: Statistical Tables and Notes, vol. 5, Total Tables, Paris, June 1973, Table T.1.2(A).

also found to be concentrated in government labs rather than in industry. This situation also persists and is especially evident in a comparison of Canada and the United States. Table I.2 contains the most current information available.

In the late 1960s and early 1970s the preoccupation with international comparisons reached a peak. Canadian performance in a wide variety of areas was measured against that of a number of other countries. One such area had to do with the amount of gross national product that was spent on research and development. The argument of the time was that one sign of a mature industrialized economy with a high-technology orientation would be that at least 2 per cent or more of gross national product was allocated to research and development. Canada ranked low relative to other countries on this criterion, and the most current data available (Table I.3) indicate that the performance of Canada in this area is virtually unchanged.

The immediate response to the data by those concerned with science policy was to devise policies and programs that would increase expenditures on R & D as a percentage of GNP and induce or coerce the industrial sector to spend more on R & D. In fact, we see in Table I.3 that the Canadian growth rate was greater than in any of the other eight countries with which it is compared. (Note the decline in Sweden.) However, as shown in Table I.4, the industrial sector has been rather unresponsive to the wide variety of incentives offered by government.

Industrial share of national R & D expenditures fell from 46 per cent in 1957 to a low of almost 29 per cent in 1960. After a rise to 43 per cent in 1965, the industrial share of national R & D declined to 38 per cent in 1971.

The prescriptions were administered to remedy a problem that was not fully understood. In large part, the data gathered were in aggregative form. Merely looking at aggregate data and prescribing massive doses of expenditure, however, missed and continues to miss the point of why such a statistical situation came about in the first place. Looking at the problem without investigating how it came to be was not and, it is argued, will not be

TABLE I.2 - Role of Government in Financing and Performing R & D in 1968-1969

Country	Percentage of all R & D Funds Supplied by Government	Sector of Performance of Government Financed R & D (percentages)		
		Government	Higher Education	Industry
Belgium	-	-	-	-
Canada	54	63	27	9
France	50	56	3	40
Germany	39	11[1]	43	23
Japan	14	86	6	6
Netherlands	38	29[1]	47	6
Norway	58	33	51	15
Sweden	40	34	42	24
U.K.	51	43	13	41
U.S.A.	58	25	15	56

[1]high "private non-profit" figures account for the percentage remainders (23% for Germany; 18% for the Netherlands).

Source: OECD, Directorate for Scientific Affairs, International Survey of the Resources Devoted to R & D in 1969 by OECD Member Countries: Statistical Tables and Notes, vol. 5, Total Tables, Paris, June 1973, Tables T.1.1.(A), T.1.2.(A), T.1.3.(A), T.1.4.(A), T.1.5.(A), T.1.6.(A).

TABLE I.3 - Share of GNP Devoted to Total R & D

Country	I Year	Percentage	Rank	II Year	Percentage	Rank	Percentage Change Columns I to II
Japan	1960	1.3	6	1969	1.5	6	15.4
France	1962	1.5	4	1969	1.9	4	26.7
Germany	1961	1.2	7	1969	1.7	5	41.7
Norway	1960	0.7	9	1969	1.0	9	42.9
Sweden	1961-2	1.7	3	1969	1.3	8	-23.5
Netherlands	1959	1.4	5	1969	2.1	3	50.0
U.K.	1961-2	2.4	2	1968	2.4	2	0
U.S.A.	1961-2	2.8	1	1969	2.8	1	0
Canada	1961	0.9	8	1969	1.4	7	55.6

Source (1960-62 figures): N.H. Lithwick, Canada's Science Policy and the Economy, Methuen, Toronto, 1969, Table 1, p.5.
Source (1968-69 figures): Organisation for Economic Cooperation and Development, Directorate for Scientific Affairs, International Survey of the Resources Devoted to R & D by OECD Member Countries, Statistical Tables and Notes, vol. 5, Total Tables, Paris, June 1973, Table T.

TABLE I.4 - Distribution of National R & D Expenditures in $ Millions by Sector of Performance in Canada, 1957-1971

Year	Government	Industry	Universities	Other	Total
1957	134.9(44.3)[1]	140.1(46.0)	25.9(8.5)	3.8(1.2)	304.6(100)
1958	141.0(42.8)	150.5(45.7)	33.8(10.3)	3.8(1.2)	329.1(100)
1959	151.2(48.9)	116.3(35.7)	43.3(14.0)	4.3(1.4)	309.2(100)
1960	172.4(53.6)	92.7(28.8)	51.8(16.1)	4.8(1.5)	321.7(100)
1961	199.0(50.7)	130.5(33.2)	57.8(14.7)	5.5(1.4)	392.8(100)
1962	187.9(46.5)	140.3(34.7)	69.6(17.2)	6.1(1.5)	403.9(100)
1963	189.0(42)	181(40)	79(18)		449.0(100)
1964	211.0(39)	227(41)	110(20)		548.0(100)
1965	243.0(36)	287(43)	143(21)		673.0(100)
1966	268.0(34)	317(41)	194(25)		779.0(100)
1967	315.0(35)	338(38)	239(27)		892.0(100)
1968	341.0(36)	341(36)	262(28)		944(100)
1969	349.0(33)	392(37)	305(30)		1046(100)
1970	362.0(34)	402(38)	302(28)		1066(100)
1971	408.0(35)	436(38)	316(27)		1160(100)

[1]Figures in parentheses are percentages.

Note: The differences between the figures of the Lamontagne Report and those from Statistics Canada 13-403 result from rounding off the figures from Statistics Canada. The "Other" category has not been included in the second set of numbers - the total being the sum of the efforts of government, industry, university and private non-profit institutions.

Source: (1957-1962) Canada. Report of the Senate Special Committee on Science Policy, Chairman, the Honourable Maurice Lamontagne, A Science Policy for Canada, vol.1, A Critical Review: Past and Present, Queen's Printer, Ottawa, 1970.

Source: (1963-1971), Statistics Canada, Biennial, Research and Development Expenditures in Canada, 1963-1971, Information Canada, Ottawa, February 1974, cat. no. 13-403.

productive. The statistical imbalance is not the cause of Canada's problem but is, rather, the effect of a broader underlying problem intrinsic to the structure of the economy itself.

The discussion and recommendations set forth in Volume II of the Lamontagne Report (pp. 413-424) demonstrate that the aggregative approach is still assumed to be valid. On pages 417-420, the Committee concludes:

> "We note that in 1969 Canada's gross expenditure for R & D had reached only 1.3 per cent of its GNP. Given the situation in other industrialized countries and their targets for the early 1970's, it is evident that our country is already lagging and that this gap will widen further in the 1970's if steps are not immediately taken to increase our speed. ...(1) In view of our demonstrated needs the Canadian goal ought to be 3 per cent of GNP by the end of the 1970's. This objective however, would be unrealistic. As we have already seen R & D expenditures are of such a nature that they cannot usefully be increased too rapidly. It takes time to prepare good research programs and train the required manpower. The Committee believes this target of 3 per cent should be set for 1985 and approached by stages. Thus, we consider that 2.5 per cent of our gross national product should be devoted to national research and development expenditures by 1980, and we suggest that one of the first tasks of the Canadian Government should be to set an R & D target for 1975 that can be regarded as a practicable stepping stone to the 1980 target."

It is fair to ask whether Canadians receive any benefits when R & D as a percentage of GNP increases.

In the late 1960s and early 1970s a new way of looking at the Canadian economy gained rapid acceptance, and a new analytical point of departure emerged: how does ownership affect the behaviour and performance of industry in Canada? The acceptance of the proposition that foreign ownership can affect the behaviour and performance of the Canadian economy is no doubt due to the increased act-

ivities of the multinational corporations and to the proliferating literature on the subject. Studies of the multinational firm, a series of background reports by the Science Council, and the "Gray Report" itself have finally led to an understanding of the implications which arise when a nation's manufacturing sector is slightly, partially or significantly foreign owned.[23] To understand the unique international position of Canada we must briefly review the behaviour and performance of the foreign-owned subsidiary in the research-intensive sectors of the Canadian goods-producing industry.

The final output of industrial R & D activity is an innovation of some type. If a firm has the power to innovate new products or processes profitably then it will engage in R & D in order to implement and accelerate the innovative process. If the innovative activities of the firm do not depend on its own R & D but on the R & D conducted elsewhere in the global activities of the corporation of which it is a part, then it has little incentive to perform R & D in its country of operation; it can rely largely on the transfer of technology within the firm itself. The key to understanding why the Canadian situation is unique is to understand the degree to which foreign-owned firms possess true innovative potential.

Innovation is an activity characterized by risk. Typically, a great many of the ultimate benefits from R & D are process or product innovations. The latter may involve the development of a new product or a change in a product which can then be marketed more economically. Process innovations have to do with productivity and efficiency, and usually result in ways to produce products at lower costs. One final outcome of innovations of all types is that they help the company, and therefore the country, to be more competitive in world markets. New products can be used to break into new markets abroad, even where long established corporations have been dominant. Process innovation often lowers costs so dramatically that on the basis of price alone the company can enter and achieve a significant position in markets abroad. However, it has been found that the R & D activities of a significant number of foreign-owned subsidiaries in Canada appear to be mainly concerned with introduc-

ing products and processes created abroad into the Canadian market. The function is essentially one of scaling down technology designed for longer production runs in foreign market areas. Some minor product modifications to suit either the tastes or climate in Canada might also be undertaken. Thus for many foreign-owned subsidiaries innovation becomes regarded as merely the introduction into Canada of a product which has already been designed and successfully marketed elsewhere.

To understand the subsidiary's role in R & D one must always remember that it is but one part of an international firm whose activities may be North American, North Atlantic or worldwide. The role of R & D and the capacity for innovation are determined in almost every case by the organizational model used by the total firm and the extent to which North American operations are rationalized.

In the total mix of activities which are undertaken by an international firm, some are centralized and others are decentralized. Some operations lend themselves to tighter control than others. The multinational firm will seek to centralize control of the R & D program. Central control does not conflict with the operation of laboratories around the world which respond, and feed information, to the central laboratories. An international research capability may be undertaken for a variety of reasons: to take advantage of local skills, to obtain access to lower costs, to establish 'listening posts' abroad, etc. Research capability is also a necessary part in the process of transfer of technology.

For purposes of analysis, one can identify two predominant types of research operations in Canadian subsidiaries. First is what has come to be called the International Interdependent Laboratory. This consists of a laboratory which mainly conducts research (with little development) that is closely connected to the international research program of the multinational corporation. This operation may or may not interact with the Canadian manufacturing facilities, depending partly on the extent to which there is production rationalization.

A second type of research operation is the Support Laboratory. In this operation the main

activities are: (a) to act as a technical service centre, i.e., to examine why a product may fail to penetrate the Canadian market or to help with the adaptation of the product to the Canadian market; and/or (b) to be the translator of foreign manufacturing technology, i.e., to implement the process of 'technology transfer' and to adjust production technology for shorter runs in the Canadian market.[24]

In large part the success of the multinational corporation can be ascribed to its ability to manage technology. Having invested large sums of money in the development of a new product or process, it is in the interest of the corporation to maximize its returns on this investment by transferring the new technology into production in as many locations as possible. The "higher" the technology, the bigger the investment needed and hence the greater the incentive to establish production subsidiaries abroad, behind tariff walls. This logic may well lie at the root of the large concentration of foreign ownership in Canada's high technology manufacturing sector.

The typical Canadian subsidiary possesses little "technological depth"; it is not set up in a manner which permits it to innovate but receives most of its technology from its parent - production drawings, materials specifications and even specialized parts flow into the Canadian operation from abroad. As an example of this lack of depth, at least one of "Canada's" chief automobile manufacturers imports a team of engineers from the United States each year to carry out annual model change modifications to its production line. In such conditions there is little scope for individual management initiative and the spirit of the entrepreneur is stifled.

The advantage of technology transfer to the branch plant is a substantial reduction in the overhead charges associated with the generation of new technology. In turn this allows the subsidiary to exist while having only a small share of the Canadian market, a share too small to support a domestic corporation that depends on generating its own technology.

Our industries are thus fragmented and inefficient. Instead of capital being invested in a limited number of production units, each with the size and sophistication needed to be competitive on world markets, it has been scattered among a large number of small and inefficient plants. The inefficiency of these plants is to some extent due to an inherent lack of sophistication and to the limited capacity of the production equipment used; but equally important is the fact that much of the equipment is utilized at well under its normal capacity because of short production runs or simply because of limited sales. The Canadian market is intrinsically quite small so that in order to have units of above-critical size, a limited number of firms would have to exist. It is quite clear that we cannot achieve efficient scales of operation with such a large number of firms in any one industry.[25]

In many instances the fact of foreign ownership inhibits the entrepreneurial and management function. It can penalize the individual who wants to accelerate his part of the world-wide corporation particularly when such ambitions do not fit the strategy developed by the long range planners at corporate headquarters. One outcome is that the experience of the manager in the subsidiary is often limited; he may not be exposed to many basic managerial functions, such as finance.

The Canadian subsidiary interacts closely with its parent. Technology transfer, capital, marketing plans, salary increases for top management, transfer of personnel to head office and to third countries, remittance of profits, transfer prices, export markets, and so on make up the bulk of the interaction. The relationship with a world-or continent-wide parent firm at once expands and contracts the potential of the subsidiary. Transfer of technology and managment systems can make it a very effective competitor in the Canadian market; but these same transfers also make it a dependent entity. Impact in the market is paid for by inhibition of the entrepreneurial function. Top management in the subsidiary is rewarded by, and often advances to, the top corporate function in head office. Aims and aspirations are conditioned by this fact.[26]

Students of the innovation process both within Canada and abroad have generally agreed that Canada ranks low in performance when compared to other industrially advanced countries. A study published by the OECD alleges that Canada has not provided a significant innovation since World War II.[27] The same study asserts that Canada scores low in other performance indicators relating to technological innovation, including monetary receipts for patents, licenses and know-how; number of patents taken out in foreign countries; and export performance in research intensive industries.

The Canadian patent situation is revealing. Despite the fact that not all forms of technology are patented or patentable, patent statistics are often used as an indicator of technological innovation. About 95 per cent of patents issued in Canada are registered to foreign owners, of which two-thirds are owned by residents of the United States. In a list of 25 countries, Canada is first in percentage of patents which are foreign owned and last in the percentage of patents owned by nationals of the issuing country.[28]

The high degree of technology transfer in Canada is caused mainly by the transfer from one arm of a multinational firm to the Canadian subsidiary. The foreign-owned firm attached to a technology pipeline has an advantage over its Canadian counterpart that has to develop its own technology or, alternatively, has to license it from abroad. It has been asserted that Canada has achieved substantial rates of growth in its GNP <u>because</u> of the availability of foreign technology. At least one writer has shown that there exists a relationship between productivity, growth and degree of foreign ownership.[29]

In an economy where the high technology sector is largely foreign owned or controlled, firms with ready access to foreign technology pose the following problem. Why should they attempt to augment their technology base by engaging in transfer activities with Canadian government laboratories? They already engage in technology transfer with their parent and affiliated laboratories and, moreover, since they are part of a larger entity with little or no incentive to innovate, the technology they are now receiving is probably sufficient for their purposes. This point is, of course,

critical and is treated in depth in Chapter V of this study.

The rather lengthy examination of the peculiar situation which characterizes much of Canadian industry was necessary in order to understand more fully our poor innovative performance and the way in which our R & D is allocated between government, university and the private sector. It also, we believe, helps to explain why such a relatively low percentage of our GNP is spent on R & D activities. Of greater importance we finally begin to see why NRC was unable to fulfil that part of its original mandate which dealt with building a strong industrial research base in Canada. NRC had no attraction for foreign firms that had access to excellent and relatively cheap technology from their parent companies and that did not need to sustain a large R & D effort of their own.[30]

The past frustrations of NRC should serve to remind policy makers of the reluctance of the predominantly foreign-owned manufacturing sector to investigate and actively seek technology transfer from government laboratories. This is not to say that the historical failure to transfer technology can be blamed on foreign ownership alone. The role, function, time frame, staffing procedures and incentive mechanisms which exist in government laboratories have also contributed to the problem. The private sector, by its very nature, has a different time horizon and will only seek to learn of and accept new technology under certain circumstances. Merely to say that technology should be transferred from government labs to industry is easy; to effect this most complex process is more difficult. The technology transfer process is a gestalt; we can only understand how and why it does or does not work by carefully examining its various parts. We can then identify the pitfalls involved in the technology transfer process and can evaluate how realistic it is to expect the process to work from government to industry.

In Chapter II we shall see the amount, distribution and type of governmment scientific activity in Canada. Chapter III deals with the structure and behaviour of government laboratories, and Chapter IV is aimed solely at the phenomenon of technology transfer and the problem and prospect of transfer

from government laboratories. In Chapter V we return to the industrial sector for a rigorous and comprehensive examination of technology transfer as viewed from industry.

II. The Scientific Activities of the Federal Government: Expenditure Trends, Regional Distribution of Activities

Chapter II. The Scientific Activities of the Federal Government: Expenditure Trends, Regional Distribution of Activities

1. Introduction: Some Definitions

Conveying an overall impression of the spatial distribution, size and activities of all federal in-house research establishments is a formidable task. This is because of the variety and complexity of the federal research establishments; there are no simple 'natural' categories or ordering methods which apply to the federal research effort, and as we shall see in Chapter III, no single conceptual model is applicable to the entire system. Yet there are threads of organization and order running through the federal research system: the first of these is, of course, the order imposed by departmental and institutional organization.

It has been argued by Simon Reisman, former secretary to the Treasury Board, before the Lamontagne Commission[1] that federal government research establishments cannot be isolated from their departmental affiliation for purposes of analysis or budget formation. This view is justified, since most research establishments derive their goals and functions directly from their parent departments; the research establishment is seen largely as one way to meet the mandate of the department. As will be seen in the next chapter there is much to be said for this point of view.

Although one certainly cannot ignore departmental mandates in speaking of government laboratories, one of the basic assumptions of this study is that the government research effort can be separated from its departmental base and in some sense analysed as a self-contained unit. There are certain advantages to this assumption, one of them being that it allows an aggregate picture of the federal research effort to be assembled in order to trace the expenditure trends and the growth and decline of research areas within the federal government; another is that by taking the federal research effort to be central to the present study, all the connections the research establishment has with industry, universities, provincial governments, and other government departments (or agencies), as well as within its parent department, come into focus.

Departmental affiliation is important and is kept in mind at all times in this report. Of course, not all government research establishments are associated with departments in a direct manner, e.g., the National Research Council and Atomic Energy of Canada Limited and the research establishments associated with certain federal agencies. However, the approach of this study allows these laboratories to be incorporated into a total picture of federal intramural scientific activities.

One of the first noteworthy points about the federal research effort taken as a whole is the extraordinary concentration of research manpower and expenditure in the Ottawa-Hull area, known as the National Capital Region (NCR). In 1974, fully 11 119 of the 26 750 employees (42 per cent) involved in the federal research effort were employed in the NCR. In 1973-74, $264.9 million of a total of $649.6 million (41 per cent) in federal expenditures on scientific activities was spent in the NCR, which clearly emerges as the largest centre for federal research in Canada. (See Appendix: Tables A.1, A.2, A.3 and A.4 and particularly the totals listed under the NCR category, which includes Ottawa and Hull.)

The remaining 58 per cent of the federal research effort is undertaken in the various regions of Canada. The distinction between the NCR and other regions, although in many respects quite arbitrary, has been employed to break down the analysis of the federal research effort into manageable sections. The first portion of this chapter presents an examination of broad trends in the federal research program: expenditure growth, allocation, the reorientation of government research efforts by department and the division between intramural and extramural federal expenditures on scientific activities. The second section of the chapter treats, in some detail, the scientific activities carried on by the federal government within the NCR. The third section discusses federal research efforts in the regions of Canada. Finally, the debate on a possible imbalance in the regional distribution of resources, which has emerged in the last few years, will be considered.

Before discussing some of the overall trends of the federal research program, a word should be

said about the definitions employed in this study. The definitions are those commonly used by the Ministry of State for Science and Technology (MOSST) and Statistics Canada: the all-embracing expenditure category is 'Scientific Activities in the Natural Sciences'. Expenditures on scientific activities are those on research and experimental development. Expenditures on related scientific activities include scientific data collection, scientific information services, testing and standardization, feasibility studies and scholarship programs.[2] The abbreviation R & D refers to current and capital expenditures on basic, applied and developmental research, and RSA applies (unless otherwise stated) to current and capital expenditure on related scientific activities previously described. Scientific expenditures are examined according to performer: intramural performers "are the federal departments and agencies that conduct scientific work in their own establishments using their own personnel".[3] Extramural performers include Canadian industry (business and government enterprises, non-profit institutions serving industry and industrial research centres), Canadian educational institutions, Canadian non-profit institutions, other Canadian performers (provincial and municipal governments, provincial research councils and foundations and individuals not working in another sector) and foreign performers (foreign governments, and companies located abroad). The performance category called 'administrative extramural programs' (AEP) includes those expenditures which are assigned within the federal agency for extramural programs. For purposes of analysis, intramural expenditures and administrative costs for extramural programs have often been grouped together in order to gain a measure of all 'in-house' expenditures and to ensure that Industry, Trade and Commerce (which possesses no intramural capacity, but does fund substantial extramural projects) is included in the roster of federal institutions with important research funding capacities.* The AEP category only adds insignificant increments to the in-house expenditures of most departments and agencies.**

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* This distinction should be kept in mind when reading the tables and graphs in this chapter and in the Appendix to this study.

** Cf. Table II.10.

Manpower categories are defined by MOSST as Executive, Scientific and Professional, Administrative and Foreign Service, Technical, Administrative Support and Operational, following six occupational categories applied in the general classification system used in the Public Service. The only categories that concern us in this chapter are the Scientific and Professional Category, the Technical Category, and what is listed in the tables as an 'Other' Category which includes administrative and administrative support personnel. As a final note to clarify the definitional basis for the charts presented in the following pages, it should be remembered that expenditure data cover the federal government fiscal year beginning April 1 of one year and ending March 31 of the following year.

For the sake of brevity we have frequently employed the abbreviations given in the following list.

An Abbreviation Key for the Federal Government Departments and Agencies involved in Scientific Activities:

DOE - Department of the Environment
DND - Department of National Defence
NRC - National Research Council
AGR - Department of Agriculture
EMR - Department of Energy, Mines and Resources
AECL - Atomic Energy of Canada Limited
DOC - Department of Communications
NHW - Department of National Health and Welfare
CCA - Department of Consumer and Corporate Affairs
MOT - Ministry of Transport
NM - National Museums of Canada
DPW - Department of Public Works
ITC - Department of Industry, Trade and Commerce
IDRC - International Development Research Centre
MRC - Medical Research Council
INA - Department of Indian Affairs and Northern Development
CPDL - Canadian Patents and Development Limited
SLSA - St. Lawrence Seaway Authority
NFB - National Film Board
EA - Department of External Affairs
VA - Department of Veterans Affairs
DREE - Department of Regional Economic Expansion
CBC - Canadian Broadcasting Corporation
CAL - Canadian Arsenals Limited
CMHC - Central Mortgage and Housing Corporation
AECB - Atomic Energy Control Board
CIDA - Canadian International Development Agency

2. Macro Allocation Trends by Performer and by Activity (R & D Compared with Related Scientific Activities)

In the fiscal year 1974-75 the federal government is expected to spend in excess of $1 billion on activities in the natural sciences (the projection is in fact for $1,065,842,000 for 1974-75 - see Table II.1. This figure represents an approximate doubling of the expenditure level for scientific activities in 1965-66. But one has only to examine Table II.2 to realize that the distribution of federal funding among government, industry, universities and other institutions has not been stable over the nine-year period under consideration.

In 1965-66 the Federal Government utilized 71 per cent of its scientific budget within its own establishments, but within the next five years this percentage dropped and then stabilized at around 65 per cent after 1971-72. Canadian industry has absorbed a fairly constant percentage of the total federal natural science budget, about 18 per cent. In contrast, the sector entitled 'Canadian Universities and Non-Profit Institutions' has demonstrated a marked rise and decline - the pattern peaking in 1969-70 with 18.3 per cent of the total. Other Canadian performers such as the provincial governments and the provincial research councils and foreign performers have absorbed increasing though still small amounts of the federal fund.

For our purposes, two points are noteworthy from Table II.2. First, the federal government now spends about two thirds of its scientific budget within the walls of its own establishments; this represents a change from former years when higher amounts were spent within government. Hayes attributes this to the "financial restraints of the lates sixties". It has been federal policy to hold back intramural expenditures, especially in construction. The amount spent in government research establishments dropped from three-quarters of the total (1963-64) to less than two-thirds.[4] Second, the policy of assisting and encouraging industry through federal R & D aid, which finally crystallized in the 'Make or Buy' policy of 1972, does not seem to have had any really significant impact on the total amount of funds flowing from the federal government to Canadian industry. Indeed, in the two

Table II.1 - Total Expenditures on Activities in the Natural Sciences, by Performer.

PERFORMER	1965-66	1966-67	1967-68	1968-69	1969-70	1970-71	1971-72	1972-73	1973-74	1974-75
					($ '000)					
FEDERAL GOVERNMENT	310,075	343,154	395,591	435,908	450,272	489,331	530,683	597,514	649,835	693,754
CANADIAN INDUSTRY	78,218	87,222	87,469	111,559	115,228	151,776	157,406	164,726	194,514	185,791
CDN UNIV & N-PRFT	46,358	62,624	91,254	113,447	128,246	130,206	138,518	138,753	150,636	150,396
OTHER CDN PERFORMERS	1,094	1,228	1,908	3,037	1,718	1,940	2,240	7,585	10,033	11,978
FOREIGN	944	1,645	2,352	4,452	4,557	4,139	8,043	11,405	15,197	23,923
TOTAL	436,689	495,873	578,574	668,403	700,021	777,392	836,890	919,983	1,010,215	1,065,842

Source: Statistics Canada, Science Statistics Section, Federal Government Activities in the Natural Sciences, Fiscal Years 1965-66 to 1974-75, (Historical Series), 15 May 1974, p. 3.

TABLE II.2 - Total Percentage Expenditures by the Federal Government on Activities in the Natural Sciences, By Performer

PERFORMER	1965-66	1966-67	1967-68	1968-69	1969-70	1970-71	1971-72	1972-73	1973-74	1974-75
Federal Government	71.0	69.2	68.4	65.2	64.3	62.9	63.4	64.9	64.3	65.1
Canadian Industry	17.9	17.6	15.1	16.7	16.5	19.6	18.8	17.9	18.3	17.5
Cdn. Univ. and Non-Profit Inst.	10.6	12.7	15.8	17.0	18.3	16.8	16.5	15.1	14.9	14.1
Other Canadian Performers	0.3	0.2	0.3	0.4	0.2	0.2	0.3	0.8	1.0	1.1
Foreign	0.2	0.3	0.4	0.7	0.7	0.5	1.0	1.3	1.5	2.2
Total	100	100	100	100	100	100	100	100	100	100

Source: Table II.1.

years before the introduction of 'Make or Buy' the industry percentages were the highest they had ever been (although they were still not extraordinary) and in 1972-73 the percentage dropped off again to its "normal" level.

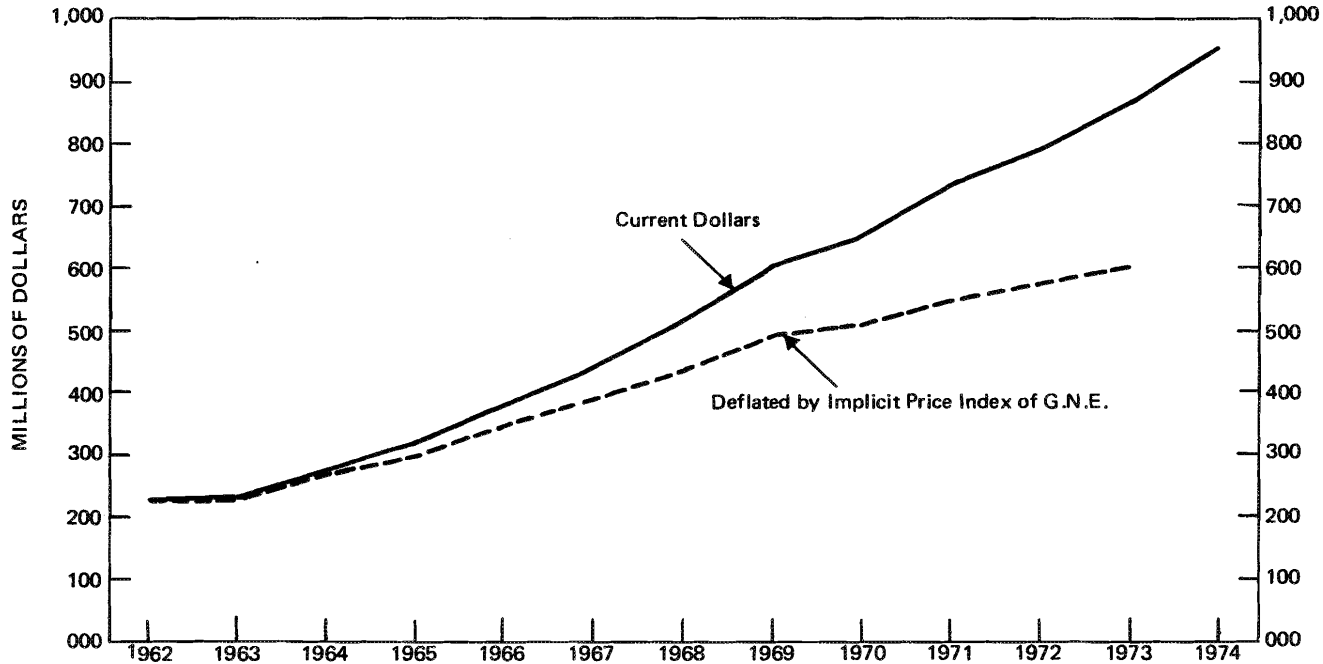
The much more substantial percentage changes have been the drop in federal intramural expenditure since 1965-66, and the fluctuating budgetary fortunes of the Canadian universities. The money which ten years ago would have gone to in-house activities has been absorbed by Canadian universities, Canadian non-profit institutions, other Canadian performers and foreign concerns.

The federal government is the largest single supplier of research funds in Canada, and Table II.1 demonstrates that there has been an extraordinary growth in federal expenditures on scientific activities since 1965. It should be remembered, however, that the real growth in scientific expenditures is considerably less than indicated by the figures owing to inflation. As things stand, it is possible to discount the inflationary factor to some degree, as shown in Figure II.1. If inflationary pressures are taken into account, the rise in the scientific estimates is considerably less spectacular for the period we are considering.

The breakdown into types of activities of the total federal science budget is shown in Table II.3. When these data are expressed in percentage terms (Table II.4) one can perceive the growth and decay patterns characteristic of the various sectors of expenditure. Table II.4 clearly shows that the percentage of funds devoted to R & D in all performance sectors has declined in the decade from 1965 to the present, largely as a result of a continuous decline in R & D capital spending. Certain sectors under RSA have expanded while the R & D sector was being cut back; the Scientific Information sector has grown as had the Feasibility Studies sector. There has also been a marginal rise in capital spending in this area.

If we now look at the same categories, focussing this time on the federal intramural level (Tables II.4 and II.5), we can see that the per-

Figure II.1 - Current Expenditures on Scientific Activities, 1962 to 1974



Source: Statistics Canada, Federal Government Activities in the Natural Sciences 1972-74, Information Canada, Ottawa, Cat. no. 13-202 Annual, October 1973, p. 12.

Table II.3 - Total Expenditures on Activities in the Natural Sciences, by Activity

SCIENTIFIC ACTIVITY	1965-66	1966-67	1967-68	1968-69	1969-70	1970-71	1971-72	1972-73	1973-74	1974-75
					($ '000)					
RESEARCH & DEV'T:	339,137	381,195	450,139	523,882	539,140	587,893	615,275	655,232	722,095	760,228
CURRENT EXPS	287,668	333,404	394,788	466,557	495,001	546,552	570,807	611,813	678,905	712,866
CAPITAL EXPS	51,469	47,791	55,351	57,325	44,139	41,341	44,468	43,419	43,190	47,362
RELATED SCI ACT:	97,552	114,678	128,435	144,521	160,881	189,499	221,615	264,751	288,120	305,614
CURRENT EXPS:	90,790	105,130	117,729	132,188	147,706	178,774	204,814	244,426	267,625	285,845
SCI DATA COLL	46,000	52,912	58,650	61,357	71,519	84,970	77,210	93,652	102,247	108,970
SCI INFORMATION	17,914	20,967	23,385	26,724	31,846	37,417	62,871	67,139	75,336	83,600
TEST & STAND	20,853	22,548	23,467	26,714	28,444	39,251	38,030	50,055	54,068	59,614
FEASI STUDIES	880	1,244	2,252	6,253	4,249	5,471	14,031	21,113	21,191	19,350
SCHOLARSHIPS	5,143	7,459	9,975	11,140	11,648	11,665	12,672	12,467	14,783	14,311
CAPITAL EXPS	6,762	9,548	10,706	12,333	13,175	10,725	16,801	20,325	20,495	19,769
TOTAL EXPENDITURES	436,689	495,873	578,574	668,403	700,021	777,392	836,890	919,983	1,010,215	1,065,842

Source: Statistics Canada, Science Statistics Section, Federal Government Activities in the Natural Sciences, Fiscal Years 1965-66 to 1974-75, (Historical Series), 15 May 1974, p. 1.

Table II.4 - TOTAL PERCENTAGE EXPENDITURES ON ACTIVITIES IN THE NATURAL SCIENCES, BY ACTIVITY

Scientific Activity	1965-66	1966-67	1967-68	1968-69	1969-70	1970-71	1971-72	1972-73	1973-74	1974-75
R & D	77.7	76.9	77.8	78.4	77.0	75.6	73.5	71.2	71.5	71.3
Current Exps.	65.9	67.2	68.2	69.8	70.7	70.3	68.3	66.5	67.2	66.9
Capital Exps.	11.8	9.6	9.6	8.6	6.3	5.3	5.3	4.7	4.3	4.4
Related Sci. Act:	22.3	23.1	22.2	21.6	23.0	24.4	26.5	28.8	28.5	28.7
Current Exps.	20.8	21.2	20.3	19.8	21.1	23.0	24.5	26.6	26.5	26.8
Sci. data coll.	10.5	10.7	10.1	9.2	10.2	10.9	9.2	10.2	10.1	10.2
Sci. inform.	4.1	4.2	4.0	4.0	4.5	4.8	7.5	7.3	7.5	7.8
Test.& stand.	4.8	4.5	4.1	4.0	4.1	5.0	4.5	5.4	5.4	5.6
Feas. studies	0.2	0.3	0.4	0.9	0.6	0.7	1.7	2.3	2.1	1.8
Scholarships	1.2	1.5	1.7	1.7	1.7	1.5	1.5	1.4	1.5	1.3
Capital Exps.	1.5	1.9	1.9	1.8	1.9	1.4	2.0	2.2	2.0	1.9
Total	100	100	100	100	100	100	100	100	100	100

Source: Table II.3.

TABLE II.5 - Total Intramural Expenditures on Activities in the Natural Sciences, by Activity ($'000s)

Scientific Activity	1965-66	1966-67	1967-68	1968-69	1969-70	1970-71	1971-72	1972-73	1973-74	1974-75
R & D	220 969	240 311	281 210	305 754	307 490	320 176	342 325	369 615	400 272	425 722
Current Exps.	169 500	192 520	225 859	248 429	263 351	278 835	297 857	326 196	357 082	378 360
Capital Exps.	51 469	47 791	55 351	57 325	44 139	41 341	44 468	43 419	43 190	47 362
Related Sci. Act:	89 106	102 843	114 381	130 154	142 782	169 155	188 358	227 899	249 563	268 032
Current Exps.	82 344	93 295	103 675	117 821	129 607	158 430	171 557	207 574	229 068	248 263
Sci. data coll.	44 292	50 401	56 737	59 214	67 295	79 239	69 661	86 674	94 754	102 236
Sci. Inform.	17 169	19 913	22 062	25 900	30 642	36 320	69 322	65 359	73 214	81 106
Test. & stand.	20 071	21 749	22 614	26 665	28 334	39 030	37 084	49 735	53 332	58 996
Feas. studies	680	1 044	2 052	5 767	3 052	3 554	3 169	5 415	7 392	5 524
Scholarships	132	188	210	275	284	287	321	391	386	431
Capital Exps.	6 762	9 548	10 706	12 333	13 175	10 725	16 801	20 325	20 495	19 769
Total	310 075	343 154	395 591	435 908	450 272	489 331	530 683	597 514	649 835	693 754

Source: Science Statistics Section, Statistics Canada, Federal Government Activities in the Natural Sciences, Fiscal Years 1965-66 to 1974-75, Information Canada, 1974, cat. no.13-202. Table was assembled from the Historical Series in toto.

centage cut in total intramural R & D expenditures is even more drastic than for the federally funded sector taken as a whole. The reduction began in the fiscal year 1968-69. Again the fall in the R & D percentages can be largely accounted for by decreases in the percentages for capital expenditures. Although the overall intramural scientific budget in absolute terms has been increasing fairly dramatically (Table II.5) the proportion of it which is devoted to capital outlay is decreasing. Table II.6 shows that the absolute value of capital expenditures on intramural R & D began to decrease after 1968-69; in recent years it has again started to rise although more slowly.

In order to obtain an accurate total picture of what occurred at the aggregate level during these nine years, the manpower factor must be taken into account. Table II.7 presents manpower data for the decade in question and relates these data to capital, current and total intramural expenditures on R & D. The manpower figures incorporated in Table II.7 refer only to the Scientific and Professional category; thus the 'per capita' columns provide a rough guide to the amount of money which has been spent annually per professional researcher in each of the three categories: current, capital, and total R & D expenditures. The picture is fairly bleak. Per capita capital intramural R & D expenditures have declined over the decade in question. This means that over the entire government R & D system, professionals are receiving absolutely less each year for equipment and plant. Under such circumstances capital intensive programs must be cut back or eliminated.*

The R & D budget is broken down into its current and capital components after it is allocated as a whole. After 1968, R & D budgets diminished as a percentage of the overall science budgets, although they still rose in absolute terms. Research managers were caught in a salary-equipment squeeze. Even though the research population was frozen at 6480 man-years for three years, the total intramural R & D budget did not rise enough each year to cover increased salaries and inflation-induced cost increases. After 1968 managers had to cut into cap-

* The implications of this for creative research are more thoroughly explored in Chapter III.

TABLE II.6 - Total Percentage Intramural Expenditures on Activities in the Natural Sciences, by Activity

Scientific Activity	1965-66	1966-67	1967-68	1968-69	1969-70	1970-71	1971-72	1972-73	1973-74	1974-75
R & D	71.2	70.0	71.1	70.1	68.3	65.4	64.5	61.9	61.6	61.4
Current Exps.	54.6	56.1	57.1	57.0	58.5	57.0	56.1	54.6	54.9	54.5
Capital Exps.	16.5	13.9	14.0	13.1	9.8	8.4	8.4	7.3	6.7	6.9
Related Sci. Act:	28.8	30.0	28.9	29.9	31.7	34.6	35.5	38.1	38.4	38.6
Current Exps.	26.6	27.2	26.2	27.0	28.8	32.4	32.3	34.7	35.3	35.8
Sci. data coll.	14.3	14.6	14.3	13.6	14.9	16.2	13.0	14.5	14.6	14.7
Sci. Inform.	5.6	5.9	5.6	5.9	6.8	7.4	11.6	10.8	11.3	11.7
Test. & stand.	6.5	6.3	5.7	6.1	6.3	8.0	7.0	8.3	8.2	8.5
Feas. studies	0.2	0.3	0.5	1.3	0.7	0.7	0.6	1.0	1.1	0.8
Scholarships	-	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Capital Exps.	2.2	2.8	2.7	2.9	2.9	2.2	3.2	3.4	3.1	2.8
Total	100	100	100	100	100	100	100	100	100	100

Source: Table II.5.

TABLE II.7 - Scientific and Professional Manpower and Intramural R & D Expenditures

Year	Total Scientific[1] & Professional Manpower (man-years)	Current Intramural Expenditures ($ millions)	Capital Intramural Expenditures ($ millions)	Total Intramural Expenditures ($ millions)	Per Capita Current Intramural Expenditures ($ thousands)	Per Capita Capital Intramural Expenditures ($ thousands)	Per Capita Total Intramural Expenditures ($ thousands)
1965	5250[2]	169.5	51.5	220.9	32.3	9.8	42.1
1966	5530[2]	192.5	47.8	240.3	34.8	8.6	43.5
1967	6100[2]	225.9	55.4	281.2	37.0	9.1	46.1
1968	6480[2]	248.4	57.3	305.8	38.3	8.8	47.2
1969	6480[2]	263.4	44.1	307.5	40.6	6.8	47.5
1970	6480[2]	278.8	41.3	320.2	43.0	6.4	49.4
1971	6530	297.9	44.5	342.3	45.6	6.8	52.4
1972	6840	326.2	43.4	369.6	47.7	6.3	54.0
1973	6910	357.1	43.2	400.3	51.7	6.3	57.9

Note: The per capita figures presented in this chart are necessarily very rough owing to the fact that the Scientific and Professional category could not be broken down according to activity. There is no doubt that a proportion of the Scientific and Professional class are involved in extra R & D activities such as the co ordination of scientific data collection or the drafting of feasibility studies. One could easily question the magnitude of the sums quoted in the per capita columns, but it would be more difficult to criticize the trends indicated by these columns. Even in the extreme case where all of the increase (1660 man-years) in scientific and professional manpower from 1965 to 1973 was assigned to extra R & D activities, the per capita capital budget would be lower ($8.2 thousand) in 1973 than in 1965 (although not by as much as cited in the table). The extreme figure still indicates a capital 'squeeze'.
The total manpower figures generally apply to intramural activities although some small percentage of the scientific and professional population is engaged in administering extramural programs.

Source: Statistics Canada, Cat. no.13-202, p.52, for the manpower figures (derived from the graphical presentation)
[1] excluding military personnel [2] estimated figures Statistics Canada Historical Series for the Expenditure data.

ital budgets to meet their current expenses. And even after 1971, when the research population began to grow again and capital expenditures were allowed to climb marginally, the increased R & D budget could only accommodate the new personnel at sharply reduced capital expenditure levels per professional.

Thus the toal federal R & D research program is growing in terms of population and expenditures over the decade but the research budget of the individual research officer has remained static or declined. In the same interval the research officer's salary has risen in line with his promotions, thus creating a problem for the laboratory manager who must divert resources from capital requirements to meet current expenditure requirements. Indeed, per capita total intramural R & D expenditures have only risen 27 per cent since 1965, and since 1973-74 dollars are running about 30 per cent behind 1963-64 dollars in terms of value, the expenditure rise has barely kept pace with inflation, much less covered salary and operating cost increases. The result is that capital budgets have suffered to boost current expenditures.*

Another way of looking at the problem is to deduct salaries and wages from the current expenditures item under both R & D and RSA in Table II.5. From 1965-66 through 1974-75, salaries and wages increased from 60 per cent of current expenditures to 80 per cent. We see in Table II.8 that, in current dollars, the figure for R & D peaked in 1968-69 and has been declining since. The RSA area is doing better, growing rather rapidly from 1965-66 to 1972-73 and peaking in 1973-74. The amounts shown represent funds left over for transportation and communications, information, professional and special services, rentals, utilities, materials and supplies. If the amounts in Table II.8 were expressed in constant dollars the R & D columns would be falling steadily from 1966-67.

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* And, of course the capital expenditure dollar buys less now than it did ten years ago.

Table II.8 - Current Expenditures Minus Salaries and Wages (in $'000s)

Year	R & D	RSA
1965-66	67 800	32 938
1966-67	72 734	35 247
1967-68	80 315	36 867
1968-69	82 826	39 281
1969-70	81 955	40 334
1970-71	80 583	45 787
1971-72	79 468	45 771
1972-73	79 788	50 773
1973-74	79 451	50 968
1974-75	75 672	49 653

Source: Table II.5.

The research dollars which have been diverted from R & D at the intramural level have been shifted, as with the R & D expenditures for the total federally funded research system, into RSA. This shift indicates that the federal government is becoming increasingly concerned with scientific services rather than with internal scientific performance.

There are many gaps in this aggregate picture of the federal research effort over the last decade. Let us summarize what we have learned, and then examine the gaps in our information.

First, it is apparent that the growth rate for the R & D activity sector - and particularly the growth rate for R & D capital budgets - has declined relative to the growth rate for total expenditures on scientific activities for all federally funded performers. R & D expenditures are rising in absolute terms but more slowly than in the past.

This pattern is particularly evident when the federal intramural sector is isolated. The R & D component has grown very slowly in comparison with the rise in total expenditures, and R & D intramural capital expenditures have even experienced a decline since 1968. Moreover, when manpower statistics are brought into the picture the intramural research establishments are seen to be running as hard as they can to stay in the same place, or even a foot behind. Not only is there a capital squeeze but, as seen in Table II.8, there is an increasing scarcity of those items used in R & D work which help to make the scientist and engineer productive. The shortage imposed may make sense in terms of bookkeeping, but in the absence of contrary evidence, one suspects that the shortage of current funds has led to a decline in the overall productivity of the federal scientific work-force.

Second, it becomes apparent that scientific services activities are benefitting from the declining growth rates of the R & D sector, both for the performers taken as a whole and for the federal intramural sector.

Third, we have discovered that, taken as a group, Canadian universities, non-profit institutions, foreign concerns, and 'other' Canadian institutions are benefitting (relative to the federal government establishments) from a reallocation of funding. On the other hand, Canadian industry is neither benefitting nor losing in percentage terms.

It is ironic that the government R & D sector is suffering from a capital shortage in the face of burgeoning total expenditures, and that despite a declared pro-industry, pro-contract policy, Canadian industry to date does not seem to be benefitting particularly from federal funding allocations.

One major gap in our information is that we are unable to measure with any accuracy the return on the investment in scientific activities at the federal level. At present, it is not known whether the federal intramural research effort is more productive per dollar in 1974 than in 1965. Furthermore, estimates of productivity cannot be made without a detailed knowledge of exactly what federal funds are being spent on and without the development of methodologies to assess the value and relevance of the resulting research product. This latter is a major problem in laboratory management and evaluation, particularly in the case of basic research, and is the best argument the scientific community has brought forward for scientific autonomy: only scientists can evaluate scientific product and activity and they should be left alone to do so.

At the aggregate level we can only measure inputs to date - and those only very roughly. It is possible, however, at least to break them down according to department and region to gain an approximate picture of their distribution and therefore of the organizational constraints and realities of the federal research system.

In terms of total scientific expenditure, we see in Table II.9 that the Department of the Environment (DOE) leads all the others, with expenditures of almost $241 million in 1974-75. This includes both intramural and extramural activities in the natural sciences, current and capital R & D and all RSA. For the same year NRC is second with slightly over $160 million. The Department of

Table II.9 - Total Expenditures on Activities in the Natural Sciences, 1974-75, Includes Non-Program Costs

Dept or Agency	Current R & D	Capital R & D	Data Coll	Sci Info	Test & Stand	Feasi Studies	Schlrshp Progs	Total Curr RSA	Capital RSA	Total Expend
					($'000)					
Agriculture:	75 503	8 367	738	2 772	94	0	0	3 604	118	87 592
Administration	0	0	0	1 541	0	0	0	1 541	47	1 588
Cdn Grain Comm	738	63	738	277	94	0	0	1 109	71	1 981
Hlth of Animals	2 466	600	0	13	0	0	0	13	0	3 079
Research	72 299	7 704	0	941	0	0	0	941	0	80 944
A.E.C.B.	7 425	0	0	0	0	0	0	0	0	7 425
A.E.C.L.	89 890	3 679	1 131	2 464	1 832	80	0	5 498	0	99 067
Cdn Arsenals Ltd.	162	0	0	0	0	0	0	0	0	162
C.B.C.	282	1	0	0	0	0	0	0	0	283
C.I.D.A.	4 100	0	3 700	0	0	10 000	4 500	18 200	0	22 300
Cdn Pat & Dev Ltd	59	0	0	862	0	0	0	862	0	921
C.M.H.C.	865	0	0	0	0	0	0	0	0	865
Communications	24 772	6 101	0	323	0	600	0	923	0	31 796
Cons & Corp Affairs:	0	0	0	7 978	1 556	0	0	9 534	70	9 604
Consumer Affairs	0	0	0	0	1 556	0	0	1 556	70	1 626
Intel Property	0	0	0	7 978	0	0	0	7 978	0	7 978
E.M.R.:	37 407	3 280	24 010	13 703	1 064	691	0	39 468	2 020	82 175
Earth Sciences	10 253	2 367	16 378	11 128	58	0	0	27 564	1 409	41 593
Min & Energy Res	27 154	913	7 632	2 575	1 006	691	0	11 904	611	40 582
Environment:	87 099	14 949	76 040	37 754	3 441	4 857	59	122 151	16 435	240 634
Atoms Env Serv	6 154	1 597	37 206	27 046	224	0	49	64 525	7 776	80 052
Env Mgt Service	51 180	8 341	18 443	3 790	3 089	4 752	10	30 084	3 535	93 140
Env Prot Serv	58	50	636	224	128	105	0	1 093	435	1 636
Fisheries	17 990	1 277	4 462	893	0	0	0	5 355	0	24 622
Marine Sciences	11 717	3 684	15 293	5 801	0	0	0	21 094	4 689	41 184
External Affairs	2 159	0	0	505	0	0	66	571	0	2 730
I.A.N.D.	1 718	318	257	195	0	27	0	479	9	2 524
Ind. Trade & Commerce	102 714	0	0	0	0	0	503	503	0	103 217
I.D.R.C.	9 880	0	0	2 405	65	0	0	2 470	0	12 350
M.R.C.	39 658	0	179	171	0	0	1 308	1 658	0	41 316
National Defence:	55 834	4 024	0	2 110	41 505	0	0	43 615	269	103 742
Defence Research	45 587	4 024	0	2 110	0	0	0	2 110	75	51 796
Defence Services	10 247	0	0	0	41 505	0	0	41 505	194	51 946
Natl Film Board	346	25	0	39	97	0	0	136	0	507

Table II.9 - (Continued)

Dept or Agency	Current R & D	Capital R & D	Data Coll	Sci Info	Test & Stand	Feasi Studies	Schlrshp Progs	Total Curr RSA	Capital RSA	Total Expend
					($'000)					
Natl Hlth & Welfare:	26 839	564	396	267	3 491	7	631	4 792	131	32 326
Health Care	15 960	0	9	3	1	7	407	427	0	16 387
Health Protection	9 787	495	387	251	3 490	0	0	4 128	131	14 541
Med Services	91	0	0	0	0	0	0	0	0	91
Nmed use drugs	1 001	69	0	13	0	0	224	237	0	1 307
Natl Museums	2 602	264	1 329	797	0	0	0	2 126	177	5 169
N.R.C.	134 044	2 955	541	11 152	5 776	904	7 244	25 617	432	163 048
Public Works	1 009	35	239	38	603	2 119	0	2 999	88	4 131
Reg Econ Expansion	3 148	0	0	0	0	0	0	0	0	3 148
S.L.S.A.	387	0	0	0	0	0	0	0	0	387
Transport:	4 642	2 800	410	65	99	65	0	639	20	8 101
Air Transport	1 684	2 800	35	27	53	28	0	143	0	4 627
Marine	979	0	350	38	0	37	0	425	20	1 424
Surface Trans	442	0	25	0	46	0	0	71	0	513
T.D.A.	1 537	0	0	0	0	0	0	0	0	1 537
Veterans Affairs	322	0	0	0	0	0	0	0	0	322
Total	712 866	47 362	108 970	83 600	59 614	19 350	14 311	285 845	19 769	1 065 842

Source: Statistics Canada, Science Statistics Section, Federal Government Activities in the Natural Sciences, Fiscal Years 1972-73, 1973-74, 1974-75, (1974 Survey Results), 15 May 1974, p. 63.

National Defence (DND) follows with almost $104 million, and the Department of Industry, Trade and Commerce (ITC), with its large industrial research assistance programs is next with slightly over $103 million. Finally, there is Atomic Energy of Canada Limited (AECL) with slightly over $99 million, the Department of Agriculture (AGR) with $87.5 million and the Department of Energy, Mines and Resources (EMR) with over $82 million. These are the seven large research institutions within the federal government and all others are small in comparison. For example, the next two institutions of any size are National Health and Welfare (NHW) and the Department of Communications (DOC) with about $32 million each. The remaining institutions are small even in comparison with these latter two.*

It is important to note that unless explicitly stated, DND includes expenditures by the Defence Research Board (DRB). The changed status of DRB, i.e. the assignment of its laboratories to DND, is explained later in this chapter.

Our primary concern is, of course, with the federal in-house research effort. The size distribution of the various federal institutions is changed when only the in-house category is considered. To begin with, ITC cannot be considered as a major intramural contender since it does not possess an internal research program, only a small administrative budget for controlling extramural contracts and grants. In 1974-75 ITC employed a $4 million administrative budget to disburse $97 million of its total $103 million to Canadian industry through the IRDIA and PAIT programs, making it the largest single research funding source for Canadian industry. The changed order of significance is seen in Table II.10 when we consider only the in-house research effort for 1974-75:** DOE with over $224 million, AGR with almost $87 million, DND with slightly over $85 million, followed by EMR (over $77.5 million), AECL (over $75 million) and NRC (over $73 million). DOC and NHW are substantially lower with $17 million and $14.5 million

* The data depicted in Table II.9 can be found for the earlier fiscal years 1972-73 and 1973-74 in the Appendix; see Tables A.5 and A.6.

** The data depicted in Table II.10 can be found for the earlier fiscal years 1972-73 and 1973-74 in the Appendix; see Tables A.7 and A.8

Table II.10 - Total Expenditures on Activities in the Natural Sciences, by Performer, 1974-75, Includes Non-Program Costs

DEPT OR AGENCY	IN-HOUSE	ADMIN EXTRAMURAL PROGRAMS	CANADIAN INDUSTRY	CDN UNIV & NON-PROFIT INST	OTHER CANADIAN	FOREIGN	TOTAL
			($ '000)				
AGRICULTURE:	86,742	0	0	838	12	0	87,592
ADMINISTRATION	1,588	0	0	0	0	0	1,588
CDN GRAIN COMM	1,981	0	0	0	0	0	1,981
HLTH OF ANIMALS	3,079	0	0	0	0	0	3,079
RESEARCH	80,094	0	0	838	12	0	80,944
A.E.C.B.	0	0	50	7,375	0	0	7,425
A.E.C.L.	75,339	0	22,812	826	75	15	99,067
CDN ARSENALS LTD	162	0	0	0	0	0	162
C.B.C.	283	0	0	0	0	0	283
C.I.D.A.	0	0	13,700	4,500	0	4,100	22,300
CDN PAT & DEV LTD	752	0	129	0	40	0	921
C.M.H.C.	0	20	495	0	350	0	865
COMMUNICATIONS	17,246	0	11,781	471	0	2,298	31,796
CONS & CORP AFFAIRS:	9,604	0	0	0	0	0	9,604
CONSUMER AFFAIRS	1,626	0	0	0	0	0	1,626
INTEL PROPERTY	7,978	0	0	0	0	0	7,978
E.M.R.:	77,616	81	2,806	1,265	295	112	82,175
EARTH SCIENCES	40,475	0	681	352	71	14	41,593
MIN & ENERGY RES	37,141	81	2,125	913	224	98	40,582
ENVIRONMENT:	224,335	262	4,817	4,930	6,290	0	240,634
ATMOS ENV SERV	78,863	163	326	700	0	0	80,052
ENV MGT SERVICE	79,960	99	3,351	3,560	6,170	0	93,140
ENV PROT SERV	1,556	0	80	0	0	0	1,636
FISHERIES	23,592	0	550	480	0	0	24,622
MARINE SCIENCES	40,364	0	510	190	120	0	41,184
EXTERNAL AFFAIRS	241	223	0	0	0	2,266	2,730
I.A.N.D.	1,087	160	270	1,007	0	0	2,524
IND TRADE & COMMERCE	0	3,937	96,950	1,830	500	0	103,217
I.D.R.C.	1,520	1,185	0	965	0	8,680	12,350
M.R.C.	19	937	0	38,333	17	2,010	41,316
NATIONAL DEFENCE:	85,161	1,887	13,289	3,078	0	327	103,742
DEFENCE RESEARCH	42,851	278	5,589	3,078	0	0	51,796
DEFENCE SERVICES	42,310	1,609	7,700	0	0	327	51,946
NATL FILM BOARD	507	0	0	0	0	0	507
NATL HLTH & WELFARE:	14,506	390	355	17,059	16	0	32,326
HEALTH CARE	179	315	1	15,891	1	0	16,387
HEALTH PROTECTION	14,129	0	304	93	15	0	14,541
MED SERVICES	91	0	0	0	0	0	91
NMED USE DRUGS	107	75	50	1,075	0	0	1,307
NATL MUSEUMS	5,169	0	0	0	0	0	5,169
N.R.C.	73,276	1,546	16,380	67,218	513	4,115	163,048
PUBLIC WORKS	2,956	60	305	10	800	0	4,131
REG ECON EXPANSION	84	0	0	0	3,064	0	3,148
S.L.S.A.	245	1	135	0	6	0	387
TRANSPORT:	5,603	290	1,517	691	0	0	8,101
AIR TRANSPORT	4,525	0	62	40	0	0	4,627
MARINE	754	22	648	0	0	0	1,424
SURFACE TRANSPORT	27	34	331	121	0	0	513
T.D.A.	297	234	476	530	0	0	1,537
VETERANS AFFAIRS	322	0	0	0	0	0	322
TOTAL	682,775	10,979	185,791	150,396	11,978	23,923	1,065,842

Source: Statistics Canada, Science Statistics Section, Federal Government Activities in the Natural Sciences, Fiscal Years 1972-73, 1973-74, 1974-75, (1974 Survey Results), 15 May 1974, p.6.

respectively. Comparative data for the three consecutive fiscal years 1972-73, 1973-74 and 1974-75 for in-house and AEP expenditures on activities in the natural sciences can be seen in Table II.11

Just as the departments and agencies under consideration have assigned differing amounts of money to intramural and total research activities, so the scientific budgets of these departments have grown at different rates. The most spectacular rise is, not surprisingly, that of DOE. The Fisheries and Forestry research budget jumped dramatically in 1969-70 when DOE acquired the following agencies with research budgets of their own: the Canadian Meteorological Service of MOT; the Air Pollution Control and Public Health Engineering Divisions from NHW; the Water Resources program from EMR; the Canadian Wildlife Service from INA and the Canadian Land Inventory from the Department of Regional Economic Expansion (DREE). In 1971 the greatly transformed Fisheries and Forestry Department was renamed the Department of the Environment; the eclectic nature of its formation explains the extraordinary size of its research budget.

The scientific budget for NRC has risen steadily during the 1963-72 decade although at present it is rising more slowly than between 1964 and 1968. The budget for AECL rose fairly rapidly until the beginning of the seventies but has now reached a plateau (around $95 million), or even a period of marginal decline. AGR's science budget has risen steadily over the decade as has that of MRC and ITC. DND reached a high point of $95 million for research in 1965-66, but has declined and stabilized at around $85 million since that time (although recently its research budget has started to rise again). The research budgets of EMR, MOT, INA and NHW suffered as a result of the formation of DOE from 1968 to 1971, but have since recovered slightly and stabilized at lower levels than those of 1968-69.**

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* The data depicted in Table II.10 can be found for the earlier fiscal years 1972-73 and 1973-74 in the Appendix; see Tables A.7 and A.8

** For graphs depicting the total costs of scientific activities and the total costs of research and development by department or agency for the years 1963-64 to 1971-72, see Appendix, Figures A.1 and A.2.

Table II.11 - Federal Intramural and Administrative Extramural Expenditures on Activities in the Natural Sciences by Department or Agency ($'000s)

Department or Agency[1]	1972-73	1973-74	1974-75 (estimates)
DOE	191 673	207 157	224 597
DND	78 030	80 750	87 048
AGR	71 766	77 897	86 742
NRC	72 555	75 752	74 822
AECL	64 438	73 121	75 339
EMR	65 517	70 553	77 697
DOC	13 496	15 924	17 246
NHW	12 975	13 122	14 896
CCA	7 642	8 775	9 604
DPW	4 746	5 651	3 016
MOT	3 665	5 389	5 893
NM	3 247	4 675	5 169
ITC	2 360	3 264	3 937
IDRC	1 503	2 633	2 705
DINA	774	1 531	1 247
MRC	708	862	956
CPDL	716	731	752
NFB	456	603	507
EA	443	456	464
VA	259	314	322
SLSA	248	236	246
CBC	55	175	283
CAL	120	157	162
DREE	146	100	84
CMHC	6	7	20

[1] See list of abbreviations.

Source: Statistics Canada, Science Statistics Section, Federal Government Activities in the Natural Sciences, Fiscal Years 1972-73, 1973-74, 1974-75 (1974 Survey Results), 15 May 1974, pp.43-48.

Now that a picture of the distribution and growth of the various federal research budgets is at hand, we should examine how the monies are distributed among the functions of the department. Table II.12 demonstrates that most departments and agencies spend the majority of their funds on in-house activities. There are exceptions to this rule, however. The case of ITC has already been noted. In addition, AECB divides all of its funds between Canadian industry and the university category with the vast majority ($7.4 million in 1974-75) going to the universities. DOC has a considerable industrial science investment, over $13 million in 1974-75. MRC allocates most of its funds to the universities and non-profit institutions, and NHW spends more than 50 per cent of its research budget in the same way. NRC devotes a third of its budget to the universities, largely in the form of research grants and scholarships, and a little less than a tenth of its budget to Canadian industry, in the form of grants or development contracts. AECL also supports research in Canadian industry, more than a quarter of its research budget. Finally, practically all of DREE's research budget falls into the 'Other Canadian' category: the support of the Prairie Farm Rehabilitation Centre.*

It is useful to know the differing overall mandates of these research departments, but we are primarily concerned with in-house expenditures. If we compare Table II.10 with Table II.12, and the 'in-house' and AEP columns, it can be seen that many departments are characterized by wide distribution of in-house funding. A number spend most of their in-house funds on R & D but many do not. The most noteworthy of the latter is perhaps DOE where less than half of its enormous intramural budget goes to R & D. Similarly, none of the intramural budget for CCA and only half of that for EMR goes to R & D; DND spends half of its in-house budget on non-R & D activities and NHW spends only about one-third of its budget on RSA. There are also a number of smaller agencies which show wide funding distributions. Thus in many of the largest research departments, R & D activities at the in-house level compete with substantial scientific service investment for shares in the total in-house budget.

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* The data depicted in Table II.12 can be found for the earlier fiscal years 1972-73 and 1973-74 in the Appendix; see Tables A.9 and A.10.

Table II.12 - Total expenditures on R & D in the Natural Sciences, by Performer, 1974-75, Includes Non-Program Costs

DEPT OR AGENCY	IN-HOUSE	ADMIN EXTRAMURAL PROGRAMS	CANADIAN INDUSTRY	CDN UNIV & NON-PROFIT INST	OTHER CANADIAN	FOREIGN	TOTAL
			($ '000)				
AGRICULTURE:	83,020	0	0	838	12	0	83,870
CDN GRAIN COMM	801	0	0	0	0	0	801
HLTH OF ANIMALS	3,066	0	0	0	0	0	3,066
RESEARCH	79,153	0	0	838	12	0	80,003
A.E.C.B.	0	0	50	7,375	0	0	7,425
A.E.C.L.	70,434	0	22,229	816	75	15	93,569
CDN ARSENALS LTD	162	0	0	0	0	0	162
C.B.C.	283	0	0	0	0	0	283
C.I.D.A.	0	0	0	0	0	4,100	4,100
CDN PAT & DEV LTD	0	0	19	0	40	0	59
C.M.H.C.	0	20	495	0	350	0	865
COMMUNICATIONS	16,723	0	11,381	471	0	2,298	30,873
E.M.R.:	38,398	81	719	1,206	195	88	40,687
EARTH SCIENCES	12,199	0	51	298	71	1	12,620
MIN & ENERGY RES	26,199	81	668	908	124	87	28,067
ENVIRONMENT:	88,722	262	4,311	4,708	4,045	0	102,048
ATMOS ENV SERV	6,590	163	326	672	0	0	7,751
ENV MGT SERVICE	48,861	99	3,220	3,381	3,960	0	59,521
ENV PROT SERV	108	0	0	0	0	0	108
FISHERIES	18,237	0	550	480	0	0	19,267
MARINE SCIENCES	14,926	0	215	175	85	0	15,401
EXTERNAL AFFAIRS	0	193	0	0	0	1,966	2,159
I.A.N.D.	626	160	270	980	0	0	2,036
IND TRADE & COMMERCE	0	3,937	96,950	1,327	500	0	102,714
I.D.R.C.	0	1,030	0	900	0	7,950	9,880
M.R.C.	0	899	0	36,807	15	1,937	39,658
NATIONAL DEFENCE:	41,377	1,887	13,189	3,078	0	327	59,858
DEFENCE RESEARCH	40,766	278	5,489	3,078	0	0	49,611
DEFENCE SERVICES	611	1,609	7,700	0	0	327	10,247
NATL FILM BOARD	371	0	0	0	0	0	371
NATL HLTH & WELFARE:	10,218	344	354	16,472	15	0	27,403
HEALTH CARE	163	293	0	15,504	0	0	15,960
HEALTH PROTECTION	9,870	0	304	93	15	0	10,282
MED SERVICES	91	0	0	0	0	0	91
NMED USE DRUGS	94	51	50	875	0	0	1,070
NATL MUSEUMS	2,866	0	0	0	0	0	2,866
N.R.C.	55,437	1,252	16,380	59,955	0	3,975	136,999
PUBLIC WORKS	960	24	50	10	0	0	1,044
REG ECON EXPANSION	84	0	0	0	3,064	0	3,148
S.L.S.A.	245	1	135	0	6	0	387
TRANSPORT:	5,094	290	1,367	691	0	0	7,442
AIR TRANSPORT	4,424	0	20	40	0	0	4,484
MARINE	346	22	611	0	0	0	979
SURFACE TRANSPORT	27	34	260	121	0	0	442
T.D.A.	297	234	476	530	0	0	1,537
VETERANS AFFAIRS	322	0	0	0	0	0	322
TOTAL	415,342	10,380	167,899	135,634	8,317	22,656	760,228

Source: Statistics Canada, Science Statistics Section, Federal Government Activities in the Natural Sciences, Fiscal Years 1972-73, 1973-74, 1974-75, (1974 Survey Results), 15 May 1974, p. 39.

What is the nature and breakdown of these non-R & D in-house expenditures? We have already noted that this sector of the in-house budget is increasing in importance both absolutely and proportionately. What, then, is this money being spent on? In examining Table II.13 it is appparent that the distribution of funds differs widely among the various departments. AGR spends the vast majority of its in-house funds on current R & D expenditures ($74.6 million in 1974-75) as do AECL and DOC. But EMR will spend $21.8 million on scientific data collection and $13.7 million on scientific information in 1974-75. These sums are a significant part of a total in-house budget of $77.6 million. Similarly DOE also has considerable data collection ($75.5 million in 1974-75) and scientific information ($37.6 million) activities. DND possesses a large testing and standardization budget ($41.5 million in 1974-75) as does NHW ($3.5 million out of a total in-house budget of $14.5 million in 1974-75). Finally, NRC possesses substantial investments in most RSA categories: $0.5 million in data collection, $10.2 million in scientific information, $5.8 million in testing and standardization and $0.9 million in feasibility studies in 1974-75.

Thus it is apparent that some departments are much more heavily involved in archival, collection and regulation work than others. Later we shall see that these breakdowns are related to departmental function.

To conclude this section on the aggregate statistics pertaining to the government research effort several separate points should be made. In Table II.15 we have compared the information contained in Tables II.1 and II.14. It can be seen that while the federal government itself devotes a considerable and increasing fraction of its own in-house budget to RSA, federal funding employed in Canadian universities and industry is used almost exclusively to conduct R & D. Industry and the universities employ more of their budgets for RSA today than they did in 1965, but the federal government is still by far the largest provider of scientific services.

Table II.13 - Total In-House Expenditures on Activities in the Natural Sciences, 1974-75, Includes Non-Program Costs

DEPT OR AGENCY	CURRENT R & D	CAPITAL R & D	DATA COLL	SCI INFO	TEST & STAND	FEASI STUDIES	SCHLRSHP PROGS	TOTAL CURR RSA	CAPITAL RSA	TOTAL EXPEND
					($'000)					
AGRICULTURE:	74,653	8,367	738	2,772	94	0	0	3,604	118	86,742
ADMINISTRATION	0	0	0	1,541	0	0	0	1,541	47	1,588
CDN GRAIN COMM	738	63	738	277	94	0	0	1,109	71	1,981
HLTH OF ANIMALS	2,466	600	0	13	0	0	0	13	0	3,079
RESEARCH	71,449	7,704	0	941	0	0	0	941	0	80,094
A.E.C.L.	66,755	3,679	1,118	2,464	1,323	0	0	4,905	0	75,339
CDN ARSENALS LTD	162	0	0	0	0	0	0	0	0	162
C.B.C.	282	1	0	0	0	0	0	0	0	283
CDN PAT & DEV LTD	0	0	0	752	0	0	0	752	0	752
COMMUNICATIONS	10,622	6,101	0	323	0	200	0	523	0	17,246
CONS & CORP AFFAIRS:	0	0	0	7,978	1,556	0	0	9,534	70	9,604
CONSUMER AFFAIRS	0	0	0	0	1,556	0	0	1,556	70	1,626
INTEL PROPERTY	0	0	0	7,978	0	0	0	7,978	0	7,978
E.M.R.:	35,118	3,280	21,749	13,694	1,064	691	0	37,198	2,020	77,616
EARTH SCIENCES	9,832	2,367	15,689	11,120	58	0	0	26,867	1,409	40,475
MIN & ENERGY RES	25,286	913	6,060	2,574	1,006	691	0	10,331	611	37,141
ENVIRONMENT:	73,773	14,949	75,476	37,586	3,410	2,657	49	119,178	16,435	224,335
ATMOS ENV SERV	4,993	1,597	37,206	27,018	224	0	49	64,497	7,776	78,863
ENV MGT SERVICE	40,520	8,341	18,249	3,705	3,058	2,552	0	27,564	3,535	79,960
ENV PROT SERV	58	50	556	224	128	105	0	1,013	435	1,556
FISHERIES	16,960	1,277	4,462	893	0	0	0	5,355	0	23,592
MARINE SCIENCES	11,242	3,684	15,003	5,746	0	0	0	20,749	4,689	40,364
EXTERNAL AFFAIRS	0	0	0	241	0	0	0	241	0	241
I.A.N.D.	308	318	257	195	0	0	0	452	9	1,087
I.D.R.C.	0	0	0	1,520	0	0	0	1,520	0	1,520
M.R.C.	0	0	19	0	0	0	0	19	0	19
NATIONAL DEFENCE:	37,353	4,024	0	2,010	41,505	0	0	43,515	269	85,161
DEFENCE RESEARCH	36,742	4,024	0	2,010	0	0	0	2,010	75	42,851
DEFENCE SERVICES	611	0	0	0	41,505	0	0	41,505	194	42,310
NATL FILM BOARD	346	25	0	39	97	0	0	136	0	507
NATL HLTH & WELFARE:	9,654	564	393	267	3,491	6	0	4,157	131	14,506
HEALTH CARE	163	0	6	3	1	6	0	16	0	179
HEALTH PROTECTION	9,375	495	387	251	3,490	0	0	4,128	131	14,129
MED SERVICES	91	0	0	0	0	0	0	0	0	91
NMED USE DRUGS	25	69	0	13	0	0	0	13	0	107
NATL MUSEUMS	2,602	264	1,329	797	0	0	0	2,126	177	5,169
N.R.C.	52,482	2,955	541	10,186	5,776	904	0	17,407	432	73,276
PUBLIC WORKS	925	35	239	38	603	1,028	0	1,908	88	2,956
REG ECON EXPANSION	84	0	0	0	0	0	0	0	0	84
S.L.S.A.	245	0	0	0	0	0	0	0	0	245
TRANSPORT:	2,294	2,800	375	65	47	2	0	489	20	5,603
AIR TRANSPORT	1,624	2,800	25	27	47	2	0	101	0	4,525
MARINE	346	0	350	38	0	0	0	388	20	754
SURFACE TRANSPORT	27	0	0	0	0	0	0	0	0	27
T.D.A.	297	0	0	0	0	0	0	0	0	297
VETERANS AFFAIRS	322	0	0	0	0	0	0	0	0	322
TOTAL	367,980	47,362	102,234	80,927	58,966	5,488	49	247,664	19,769	682,775

Source: Statistics Canada, Science Statistics Section, Federal Government Activities in the Natural Sciences, Fiscal Years 1972-73, 1973-74, 1974-75, (1974 Survey Results), 15 May 1974, p. 45.

Table II.14 - Total Expenditures on R & D in the Natural Sciences, by Performer

PERFORMER	1965-66	1966-67	1967-68	1968-69	1969-70	1970-71	1971-72	1972-73	1973-74	1974-75
					($ '000)					
FEDERAL GOVERNMENT	220,969	240,311	281,210	305,754	307,490	320,176	342,325	369,615	400,272	425,722
CANADIAN INDUSTRY	75,487	83,710	84,391	108,885	109,781	143,972	138,492	146,327	167,183	167,899
CDN UNIV & N-PRFT	41,364	55,508	81,665	102,624	116,447	118,527	125,469	125,773	135,032	135,634
OTHER CDN PERFORMERS	870	930	1,593	2,663	1,317	1,526	1,714	2,940	5,421	8,317
FOREIGN	447	736	1,280	3,956	4,105	3,692	7,275	10,577	14,187	22,656
TOTAL	339,137	381,195	450,139	523,882	539,140	587,893	615,275	655,232	722,095	760,228

Source: Statistics Canada, Science Statistics Division, Federal Government Activities in the Natural Sciences, Fiscal Years 1965-66 to 1974-75, (Historical Series), 15 May 1974, p. 15.

TABLE II.15 - Total Expenditures on R & D in the Natural Sciences as a Percentage of Total Expenditures on Activities in the Natural Sciences, by Performer

Performer	1965-66	1968-69	1971-72	1973-74
Federal Government	71.2	70.1	64.5	61.6
Canadian Industry	96.5	97.6	88.0	90.6
Canadian University and Non-Profit Inst.	89.2	90.4	90.6	89.6
Other Canadian Performers	79.5	87.6	76.5	54.0
Foreign	47.4	88.9	90.5	93.4

Source: Tables II.1 and II.14.

The total scientific expenditures as a percentage of the total budgetary estimates for federal departments with scientific budgets for 1972-73, 1973-74 and 1974-75 are shown in Table II.16. The columns labelled C demonstrate that for the past three years scientific expenditures have taken up a large (about 70 per cent) and fairly constant percentage of DOE's total budgets. A projected decline in ITC's total budget combined with a projected constant scientific budget has resulted in a projected jump in the percentage of ITC's total expenditures devoted to scientific activities in 1974-75. DND has a constant budgetary percentage for scientific activities of between 4 and 5 per cent. In the last three years EMR's scientific budget has grown as a percentage of its total budget (from 82 to 91 per cent). AGR devotes between 20 and 25 per cent of its budget to scientific activities, while NHW normally devotes less than 1 per cent of its total budget to scientific activities. DOC's scientific allocation has declined dramatically (87 per cent in 1972-73 to a projected 69 per cent in 1974-75). CCA's allocation is constant at about 22 per cent as is MOT's at about 1.6 per cent. DREE allocates about 0.6 per cent of its budget to scientific activities, EA about 2.5 per cent. DPW's percentage has declined from 2.2 to 0.8 per cent; INA's has been constant at about 0.4 per cent as has VA's at 0.1 per cent.

Table II.16 demonstrates the enormous diversity which characterizes the relationship between the scientific division of a department and the department as a whole. The various federal agencies display the same kind of diversity; some have large proportionate research efforts, others small. These varying proportions must be kept in mind in considering the interrelationships between the scientific sectors of the departments and agencies and the departments and agencies taken as complete entities.

3. Scientific Activities in the National Capital Region (NCR)

As noted earlier in this chapter, most of the federal departments and agencies conduct the majority of their scientific activities in the NCR. In 1973-

TABLE II.16 - Total Expenditures (estimated) on Scientific Activities as a Percentage of Total Departmental Expenditures as taken from the Estimates for the Federal Departments

Department	1972-73 A Total Budgetary Estimate for the Dept. ($ millions)[1]	B Total Scientific Expenditures (estimated) for the Dept. ($ millions)[2]	C Percentage B/A	1973-74 A Total Budgetary Estimate for the Dept. ($ millions)[1]	B Total Scientific Expenditures (estimated) for the Dept. ($ millions)[2]	C Percentage B/A	1974-75 A Total Budgetary Estimates for the Dept. ($ millions)[1]	B Total Scientific Expenditures (estimated) for the Dept. ($ millions)[2]	C Percentage B/A
DOE	285.3	198.4	69.5	293.9	219.3	74.6	351.0	240.6	68.5
ITC	261.7	91.8	35.1	284.4	103.3	36.3	157.0	103.2	65.7
DND	1 939.6	92.8	4.8	2 126.2	93.8	4.4	2 357.2	103.7	4.4
EMR	89.1	72.9	81.8	83.0	78.7	94.8	90.0	82.2	91.3
AGR	285.3	72.6	25.4	293.9	78.7	26.8	414.0	87.6	21.2
NHW	2 908.3	27.5	0.9	3 206.0	32.9	1.0	4 723.1	32.3	0.7
DOC	30.0	26.0	86.7	42.1	31.3	74.3	47.5	31.8	66.9
CCA	32.4	7.6	23.5	38.8	8.8	22.7	43.8	9.6	21.9
DOT	385.0	5.2	1.4	453.2	8.7	1.9	548.8	8.1	1.5
DREE	424.8	2.0	0.5	424.9	2.0	0.5	439.8	3.1	0.7
EA	110.1	2.3	2.1	126.3	2.5	2.0	157.0	2.7	1.7
DPW	358.2	8.0	2.2	461.6	8.1	1.8	518.9	4.1	0.8
DINA	472.7	2.0	0.4	592.7	2.8	0.5	626.4	2.5	0.4
VA	432.7	0.3	0.1	480.1	0.3	0.1	597.4	0.3	0.1

Sources: [1] The Main Departmental Estimates for the Fiscal Year ending 31 March of the year in question, General Summary (Table 2) from the Estimates for the Fiscal Year ending March 31, (1973, 1974, 1975), Information Canada.

[2] Statistics Canada, Science Statistics Section, Federal Government Activities in the Natural Sciences, Fiscal Years 1972-73, 1973-74, 1974-75 (1974 Survey Results), 15 May 1974, Cat. no.13-202, pp.4-6.

74, $264.9 million of a total $649.6 million federal scientific budget (intramural activities), or 40.8 per cent, was spent in the NCR. This section shows the diversity of scientific activities which are undertaken in the NCR; it also describes the general scientific organizational structures characteristic of each of the federal departments and agencies, so that when we come to discuss the federal regional research effort we shall have some kind of institutional context to work with.

The largest concentration of manpower and resources for scientific activities in AGR occurs in the NCR.* The scientific activities of AGR are divided among four main branches, three of which are represented in the NCR - the Administration Branch, the Research Branch and the Health of Animals Branch.** The research role of the Administration Branch - and particularly of the Ottawa headquarters - is the maintenance of an up-to-date and comprehensive collection of reference materials on bio-agricultural and related issues. The Administration Branch centre in Ottawa is also the Canadian depository for FAO, UN, and U.S. Department of Agriculture publications. The reference service of the Administration Branch is connected with the CAN/SDI (Selective Dissemination of Information) program of the Canada Institute for Scientific and Technical Information of the NRC in Ottawa.[5]

The Research Branch is the major research arm of AGR. Most of AGR's sizeable R & D budget is spent within this Branch. The Ottawa section is itself divided into numerous research institutes which are briefly described below.

The first of these is the Animal Research Institute, which conducts a broad program of research aimed at increasing the productivity of Canadian livestock and poultry and improving the quality of such animal products as meat, milk, and eggs.

The second institute is the Chemistry and Biology Research Institute which is concerned with

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* See Appendix: Figures A.7 and A.8.

** The fourth 'research' branch of AGR, the Canadian Grain Commission, will be discussed in the next section of this chapter.

plant biology, parasitology, plant breeding and biological analysis. This institute is particularly important since it possesses a high degree of technical expertise in analytical chemistry and consequently processes samples from other AGR research institutes.

The Entomology Research Institute provides a comprehensive identification and information service, in the form of published indexes and guides, for insects, arachnids and nematodes occurring in Canada. It also conducts research into such fields as taxonomy, biosystematics and faunistics. The main purpose of the institute is the acquisition of information about insects which are potentially beneficial or harmful to agricultural enterprise.

A fourth institute is the Food Research Institute, whose principal role is to obtain and apply knowledge of food composition, quality and processing techniques to Canadian agriculture crops and dairy products.

The Plant Research Institute serves as a taxonomic research centre and an information and identification service with reference to the flora of Canada.

The Soil Research Institute conducts research into the chemical, physical and biological aspects of soil conservation and improvement, concentrating on such topics as urban and animal waste disposal, metal reactions, nutrient accumulation and transmission and other activities.

The Engineering Research Service supports biological research and agricultural production by conducting studies of new engineering concepts, systems and equipment. The Statistical Research Service assists the biological and agricultural scientific activities of the rest of the department by developing mathematical and statistical models; members of this Service advise and assist other scientists in the designing and evaluation of models.

Finally, the Ottawa Research Station of the Research Branch, located at the Central Experimental Farm, serves as a research centre for livestock and crop breeding problems characteristic of east-

ern Ontario and northern Quebec. This station coordinates the work of associated experimental farms at Smithfield, Thunder Bay and Kapuskasing.

This concludes the description of the Research Branch's activities in the NCR. But we have still to discuss the activities of the other sizeable research division of AGR, the Health of Animals Branch. This Branch has only one division operating within the Ottawa-Hull area, the Animal Pathology Division which carries on research into animal diseases, provides diagnostic and other services and acts as consultant on the registration, licensing and use of biologicals and other veterinary and pest-control products sold in Canada.

While AGR spent slightly less than half of its intramural budget in the Ottawa area during fiscal 1973-74, DOC spent all its scientific budget in the NCR ($15.9 million in 1973-74). In this, DOC resembles CCA, EA and ITC in terms of its spending patterns. These federal departments in which the research effort is concentrated in the NCR, may be contrasted with AGR, DOE, DND and EMR, which each possess substantial regional research investments, and with NHW, DPW, and MOT which have very much smaller regional research programs.

Before looking at DOE, DND and EMR, let us first examine the activities of those departments which only possess research programs in the NCR. DOC maintains a Communications Research Centre in Ottawa which is aimed at improving and expanding the tele-communications network and its services. DOC performs research in cooperation with universities and private industry concentrated on the development of communications spacecraft programs, in particular the Communications Technology Satellite, a joint NASA - DOC project. The Centre also investigates such areas as the long-distance propagation of radio waves, advanced electronics, space mechanics, micro systems and hardware, integrated circuitry and computer communications.

Consumer and Corporate Affairs maintains a Standards Branch in Ottawa which develops programs to ensure compliance with standards in its area of responsibility. It participates in national and international standards development where consumer

interest is involved. The Department also has responsibility for the Ottawa-located Patent Office which reviews the close to 30 000 patents submitted yearly.

External Affairs finances a small research centre in Ottawa, and also spends a comparable amount outside the country.

Industry, Trade and Commerce's intramural research expenditures in the Ottawa area consist of the unit assigned to the administration of scientific extramural programs under IRDIA, PAIT and DIP.

We can now turn to those departments which conduct most of their scientific activities in Ottawa but do possess regional research programs.

National Health and Welfare has extensive NCR operations (a total of $10.6 million was spent on intramural activities in 1973-74). The NCR effort is organized into a number of research programs. The first of these is the Administration Program which is responsible generally for the long range planning of research activities of the department. Another branch of the Administration Program is the Health Care Program which is responsible among other things for conducting studies and providing technical and professional consultive services to the provinces and other bodies. It is concerned with the construction and operation of health facilities.

The second major research division of NHW is the Health Protection Program. This program is divided into five subdivisions: the Food Research Laboratories, which conduct research and provide information services in the areas of food chemistry, nutrition, microbiology and toxicology; the Drug Research Laboratories, which conduct investigations in the areas of drug toxicology, pharmacology, pharmaceutical chemistry and drug statistical services; the Environmental Health Directorate, which investigates the health relationship between a human being and his or her environment, concentrating on such problems as human birth defects, congenital deformities, radiation influences on health and air and water pollutants; Epidemiology Services maintains surveillance of both infectious and non-communicable diseases and provides a

central service to all Health Branches of the Department which will include adequate research, medical, field study and statistical components; and finally, the Laboratory Centre for Disease Control has the responsibility for licensing biological drugs and medical devices for chronic, non-microbial and communicable diseases.

Public Works also conducts most of its work in Ottawa. The Testing Laboratories of the Department of Public Works are designed to serve as the central testing facilities of the Federal Government. They include laboratory and field testing facilities and specialized consulting services in many diversified fields. Standardization, investigations of new materials, materials research and sub-surface investigations of building sites are among the many activities of the Testing Laboratories. In addition to the testing laboratories, which have been renamed Research and Development Laboratories, the Department has extensive design and construction groups.

Finally, MOT possesses a fairly extensive Ottawa operation with an expenditure of $4.4 million on scientific activities in 1973-74. MOT Research Headquarters in Ottawa is concerned with the review of various transportation proposals submitted to it from the transport administrations; it is currently involved in the operation of a demonstration service for STOL aircraft.

Two transportation administrations of MOT have research programs which are located in the NCR. The first of these is the Canadian Air Transport Administration which has responsibility for all aspects of Canada's airways and federal airports. This administration is subdivided into a number of divisions. The Telecommunications and Electronics Research Division conducts research in three areas: computer systems, radar and video navigation and satellite communications. The Air Traffic Services Simulation Centre is concerned with the development of simulated air traffic control environments for the testing of new techniques. The Aviation Planning and Research Division conducts studies in the three areas of mathematical modelling, economic analysis and technological review, and environmental impact of air transport facilities. And finally,

the Architectural R & D Division has two major subsections - one responsible for specific problems concerning the planning and operation of airports - and the other responsible for the definition of airport functions and the projection of future needs.

The other Administration subsection of MOT with an office in the NCR is the Marine Transportation Administration which carries out engineering studies, applied research, standards, and planning and programming related to marine transportation facilities in waterways where the Ministry has responsibility.

At this point we should briefly mention INA which does not really fit into any of the categories defined above. INA possesses a small administrative research office in Ottawa but most of its research is conducted north of 60 (the Inuvik Research Laboratory).

We can now turn to the 'big four' departments which have substantial regional investments. The case of AGR has already been discussed, so we can now consider the internal organization and NCR facilities of DOE, DND and EMR.

As has already been shown, DOE has the largest intramural budget for scientific activities of any federal department or agency. These funds are widely dispersed, with a particular concentration in Ontario outside the NCR. (See Appendix Figures A.11 and A.12.) Only about a sixth ($39.2 million in 1973-74) of DOE's intramural budget was spent within the NCR. However, almost the full organizational structure of DOE's scientific program is represented in microcosm in the NCR.

The scientific activities of DOE are divided into two main programs: the Fisheries and Marine Program and the Environmental Services Program.

Four branches of the Fisheries and Marine Program are represented in the NCR. The Marine Sciences Directorate conducts research into problems associated with the physical and chemical properties of Canada's adjacent marine environment. The work of the Directorate is carried out through two branches, the Hydrography Branch, which is concern-

ed with charting the economic geography of heavy shipping areas in Canada's coastal waters; and the Oceanography Branch, which is concerned with developing an everexpanding archive of data concerning Canada's marine environment. Each of the foregoing branches is supported in its work by the Ships Branch, which designs and regulates the operation of a fleet of research vessels.

The various branches of the Fisheries and Marine Program reflect the various research concerns which DOE inherited from the Fisheries and Forestry Department and Energy, Mines and Resources. Similarly, the sub-divisions of the Environmental Services Program (ESP) reflect research concerns taken over from a wide variety of institutional sources during the formation of DOE.

The first subdivision of ESP is the Environmental Protection Service (EPS). This service has a headquarters in the NCR which serves largely to coordinate a number of regional institutions described in the next section. EPS is responsible for the regulation and protection of Canada's natural environment in all its aspects, and to this end DOE maintains bacteriological and chemical laboratories in Ottawa to which samples for analysis are submitted from all over the country. EPS also operates an Air Pollution Control Directorate (of which the Emission Testing Laboratory for motor vehicles is a part) and a Water Pollution Control Directorate. Both of these Directorates have NCR offices and laboratories.

The second subdivision of ESP is the Environmental Management Service (EMS). This service groups together many research facilities from a wide variety of sources. There is the Canadian Forestry Service (inherited from Fisheries and Forestry) which has a headquarters in Ottawa. It also encompasses the Forest Fire Research Institute and the Chemical Control Research Institute, both in Ottawa. The latter is involved in pesticide research for the forestry sector. One of the regional branches of CFS, the Eastern Forest Products Laboratory, is also located in Ottawa; this laboratory conducts research into wood engineering, wood protection, wood production and wood products, with particular emphasis being placed in all cases on the special problems of eastern forests in Canada.

The Inland Waters Directorate part of the Environmental Management Service is responsible for the regulation and maintenance of inland waters in Canada. It addresses itself to monitoring, assessment and research in water quality, water resources and water resource management. The Ottawa offices act as a coordinating centre for the regional offices of the IWD and the three branches into which the Directorate is divided. The first of these is the Water Resources Branch which consists of the Water Survey of Canada and the Glaciology and Hydrology Research Divisions. The second is the Water Quality Branch which is responsible for collecting and organizing data on the chemical and physical qualities of Canada's water systems. The third is the Water Planning and Management Branch which concerns itself with water resource planning, using the other two branches as an information base.

A third part of EMS is the Canadian Wildlife Service: the units of the Canadian Wildlife Service in the National Capital Region include the Eastern Regional Headquarters (which conducts research on migratory birds and wildlife in the NWT and National Parks) and the Laboratory in Vanier consisting of a Pathology Unit, Bioelectronics Unit and a Toxic Chemicals Laboratory.

To conclude, the final part of EMS with an Ottawa location is the Lands Directorate, which conducts federal-provincial surveys of land use and capability for agriculture, forestry, recreation and wildlife.

We can now turn to a consideration of the next large research operation in Ottawa, that of the Department of National Defence (DND). Until April 1974, the major research arm of DND was the Defence Research Board (DRB). Since that date the laboratories formerly associated with DRB have line responsibility within DND and report to the Assistant Deputy Minister (materials). The DRB now functions only in an advisory capacity. The research activities formerly carried out by the DRB will be referred to from time to time, especially in an historical context. It should be noted, however, that whenever we refer to the scientific activities of DND we are referring, in almost every case, to those laboratories and activities that were maintained and performed by DRB.

The former DRB laboratories have a regional orientation. (See Appendix Figures A.13 and A.14.) They consist of five large regionally located research establishments. There are, however, an additional two institutions located in the NCR. The first of these is known as Defence Research Establishment Ottawa. For many years, the Establishment has been responsible for research on power sources and along with the Defence Research Establishment Suffield, on defence against nuclear, chemical and biological attack. More recently it has also become responsible for the Board's northern research activities and for supervising and supporting defence communictions studies carried out chiefly by the Communications Research Centre of the Department of Communications.

The DND also maintains a Defence Research Analysis Establishment in the NCR. The Establishment conducts research into the merits and disadvantages of present and projected weapons systems, strategic plans and problems and military tactics. The major contribution of this centre to defence research is its ability to marshall varied expertise to explore and analyse a problem as a whole.

In addition to the former DRB establishments, DND maintains a Defence Services Program (DSP) with a number of offices in Ottawa. These Ottawa offices are paralleled by four regional Technical Services Agencies described in the next section. The DSP consists of two parts, the first being the Quality Engineering Test Establishment which is itself divided into five sections. These are the Chemical Section, which conducts chemical analysis of all types of materials; the Electrical and Electronics Section, which tests and evaluates electronic and electrical components and materials; the Environmental and Applied Physics Section, which tests and evaluates durability of products; the Mechanical and Metallurgical Section which is involved in vehicular and machine testing; and the Standards Section.

The Lands Engineering Test Establishment (LETE) is the other section of the DSP. The Establishment, at facilities just outside Ottawa, conducts tests on vehicles for the Department of

National Defence. These may be prototype vehicles under development or other vehicles being considered for purchase by the department. LETE also does evaluations of various airfield support equipment such as snowplows and sweepers. LETE also operates an electronics laboratory on the grounds of the National Research Council for testing electronic equipment used in communications.

The final department with extensive research activities in the NCR is EMR. The department spent $51.8 million of a total intramural budget of $70.6 million (1973-74) in the Ottawa-Hull area; this concentration of scientific resources is second only to that of the National Research Council in the Ottawa area. (See Appendix Figures A.9 and (A.10)

The scientific work of EMR is divided among three research branches: the Mines Branch, the Geological Survey of Canada and the Earth Physics Branch.

The research activities of the Mines Branch are directly related to the mandate of the department to regulate and assist the mining industry in Canada. The Mines Branch identifies mineral deposits of economic interest; it encourages the increased production of mineral materials through advancing mining techniques; and it encourages the development of new refining and recovery methods and the abatement of mining-induced pollution. The work of the Branch is conducted in eight centres: Mineral Processing, Extraction Metallurgy, Mineral Sciences, Fuels Research, Mining Research, Metals Reduction and Energy, Physical Metallurgy and Technical Services. All of these centres are located in the NCR.

The second major research division of EMR is the Geological Survey of Canada - the oldest continuing research establishment in the Canadian government. The Geological Survey of Canada surveys the materials and attributes of the landmass of Canada, its composition, forms and natural processes as potential resources and conditioners of terrain use and development.

Five of the GSC's seven divisions are located in the NCR; these are the Geological Information

Processing, Central Laboratories and Technical Services, Resource Geophysics and Geochemistry, Terrain Sciences, and Regional and Economic Geology. The remaining two divisions are the Institute of Sedimentary and Petroleum Geology at Calgary and the Atlantic Geoscience Centre at Dartmouth.

Finally, the Earth Physics Branch of EMR performs geophysical, seismic, gravity, geothermal, geodynamic and geomagnetic studies of the earth's crust and interior. It provides data and information on seismic risk, the gravity field and gravitational anomalies, geothermal characteristics including temperature aspects of permafrost, the dynamical characteristics of the earth, the magnetic field and its variations, magnetic anomalies. Activities include the monitoring of earthquakes and nuclear explosions, earth tilts, strains, shifts, tides and polar motions, and the magnetic field. The Earth Physics Branch is divided into three divisions: Seismology, Gravity and Geomagnetism (all having offices in the NCR).

This concludes our review of the NCR research activities of the 'big four' federal government departments. However we have yet to examine the federal agencies and, in particular, the two large Crown corporations, NRC and AECL.

NRC spends nearly $70 million dollars yearly in the NCR, and is thus the largest single scientific organization located in the NCR. In many ways it is the hub of the Ottawa research community and, in a broader sense, of the whole of Canada.

The activities of NRC are so extensive, diverse and multi-functional that any quick overview of this scientific organization is bound to be sketchy and inadequate. The NRC laboratories located in the NCR are divided into seven divisions: the Division of Biological Sciences, the Division of Building Research, the Division of Chemistry, the Division of Mechanical Engineering, the National Aeronautics Establishment, the Division of Physics, and the Radio and Electrical Engineering Division. In addition to these research divisions, the recently formed Canada Institute for Scientific and Technical Information (CISTI) encompassing the National Science Library (NSL) and the Technical Information Service, absorb a large fraction of the NRC intra-

mural budget.* In the following paragraphs each division will be described briefly.

The Division of Biological Sciences reflects the research interests of two former organizations which were joined to create it: the Biochemistry Laboratory and the Division of Biology. Research is conducted in such areas as environmental impact (environmental effects on organisms and their constituents), food biology and technology, radiation biology and molecular biology (x-ray crystallography, molecular biophysics, immunochemistry, nucleic acidprotein interactions and bio-organic synthesis). The expertise that was amalgamated in the formation of the Biological Sciences Division allows interdisciplinary approaches to be taken with many of these research areas.

One of the most interesting Divisions of NRC is the Division of Building Research which acts as an information source for the building industry (through the publication of the Canadian Building Digest and other series, and the handling of five thousand enquiries yearly from industry), as an advisory agency for the construction industry (technical support to CMHC, assistance in production and revision of the National Building Code of Canada, and service on approximately three hundred technical committees) and as a research agency concerned with construction. The research functions of the division are handled through six research section: Building Materials, Building Physics, Building Services, Building Structures, Fire Research and Geotechnology.

The Division of Chemistry is a third division of NRC in the Ottawa area. The work of the Division covers a broad spectrum ranging from short term programs, aimed at practical application to the natural resource and chemical industries, to long-term fundamental investigations in selected areas of scientific and technological importance. The fields of research include: analytical chemistry,

* CISTI was officially inaugurated on 16 October 1974. The Institute brings together the NRC's two major information delivery systems: the Technical Information Service and the activities previously conducted under the umbrella of the National Science Library.

chemical engineering, spectroscopy, colloids, polymers, high pressure, hydrocarbons, kinetics, photochemistry, catalysis, metallic corrosion and oxidation, metallurgical chemistry, molecular structures, organic spectrochemistry, organic synthesis, textile chemistry, theoretical studies and thermochemistry.

The Division of Mechanical Engineering is divided into six sections. These are Transportation Engineering, which is responsible for reviewing a wide variety of land, air and water transportation vehicles and environments; the Manufacturing Technology section, which investigates problems related to industrial instrumentation in a wide variety of industries; the Standards and Standardization unit, which is concerned with the evaluation of industrial products, particularly oils and greases of various weights; the Computers unit, which investigates the application of digital and hybrid computation techniques to machine design and operation problems; Engineering and Biological Control Systems, which is involved with the industrial application of control theory - mechanical, electronic, and fluidic - to measurement of the performance of human operators; and Medical and Surgical Instrumentation, which serves as an evaluation and research centre for improved medical technology.

The National Aeronautics Establishment (NAE) of NRC conducts aeronautical research to meet the needs of military and civil aviation with studies of problems in aerodynamics, aircraft structures and materials and flight mechanics. The recent contraction of the aircraft industry has caused some of NAE's resources to be shifted into other areas, notably research in road and motor vehicles safety, in material technology in various applications of non-aeronautical aerodynamics and in certain ecological problems.

The Physics Division of NRC has three principal mandates: (1) the maintenance of basic standards and the calibration of physical instruments to maintain standards applicable to government, industry and the universities; (2) the pursuit of research programs in areas of physics, particularly space physics, metal physics, plasma physics, photogrammetry and spectroscopy; and (3) the provision of information, advice and technical assist-

ance to industry concerning a wide variety of industrial products, services and standards.

The Radio and Electrical Engineering Division comprises:

(a) the Astrophysics Branch which conducts basic research programs in radio and optical astronomy and phenomena of the upper atmosphere, as well as Canada's national radio observatory, the Algonquin Radio Observatory;

(b) a section which carries out work on fundamental mathematical research and a wide range of practical applications of electronics and electrical engineering; and

(c) the Engineering Design Section and Model Shop where much of the mechanical design and construction of research apparatus is carried out.

The Technical Information Service (TIS) of CISTI acts as a clearing house for technical inquiries directed to NRC from business, industry, government or the universities. Sometimes the staff of TIS are able, from their own background and expertise,to respond immediately to an outside request or query; if not, the TIS officer has the resources of the 800 000 volumes in CISTI available, as well as of the entire NRC scientific community. The TIS in Ottawa serves to coordinate many regional TIS establishments.

The other large scientifically oriented Crown corporation, AECL, only spends a small fraction of its intramural budget in the NCR ($5.7 million of $73.1 million in 1973-74). There are only two offices of AECL located in Ottawa. One is the Commercial Products Group, which is responsible for developing new applications for radiation and radioisotopes, for manufacturing and marketing radioactive products and related machinery, and for the provision of services. Medical institutions and government laboratories are major consumers of these products and services.

The other Ottawa-located AECL office is known as Heavy Water Projects which coordinates the design and use of heavy water facilities. A high priority is the development program to increase production of the Canadian General Electric Plant at Point Tupper, Nova Scotia. The office has been involved in the design of new facilities for the Glace Bay plant.

NRC and AECL are not the only federal agencies with research offices located in the NCR. Canadian Patents and Development Limited conducts all its scientific activities in the Ottawa area. Its offices are responsible for the evaluation and patenting of the products of all publicly financed R & D. The Central Mortgage and Housing Corporation maintains a tiny research establishment in the Ottawa area. The International Development Research Centre spent $2.6 million on research in the NCR in 1973-74.

The St. Lawrence Seaway Auth y has a small Economics and Research Branch in t NCR (budget of $0.083 million in 1973-74). And finally the Medical Research Council (MRC) maintains NCR offices. Practically all of its $0.8 million budget of 1973-74 was spent on administering extra-mural programs in medical research.

> The primary function of the Council is to promote and support research in the health sciences in Canada. To this end it maintains a balanced programme of support to research trainees and research investigators, to the costs of research programmes in Canadian universities, hospitals and related institutes, and to promotional activities designed to stimulate new research efforts in significant areas.[6]

MRC distributed $35.4 million to Canadian universities and non-profit institutions in 1973-74.

It is obvious from the foregoing descriptions that there is an immense and diverse government scientific community in the NCR. Aside from the organizational variables already described, there is little on the surface to tie this community together. One is even hesitant to call it a community without any concrete idea of the interrelationships which exist.

There are obviously interface points where contact would be beneficial and probably productive; for instance between the NRC's Division of Biology and AGR's Food Research Institute or Chemistry and Biology Research Institute; between the

NRC's physics section and the Commercial Products Group of AECL; between certain subdivisions of DOC and MOT; and between the biological and chemical branches of NRC and corresponding groups at NHW and DOE. Such contacts exist because they have been documented but at present we do not possess any survey information about the ways in which the community as a whole functions, the major pathways of communication or the social variables governing the interrelationships within the community. Without such information one can do little more than trace the organizational pattern as has been done above. But it must be remembered that that pattern is infused and overlaid with a multitude of inter-personal and inter-group contacts and relationships.

4. Scientific Activities Regional Description*

The diversity which characterizes the federal research institutions within the Ottawa area is repeated, if not enhanced, in the regions of Canada. Certain government departments, notably AGR, DND and more recently DOE, have been heavily involved in promoting pure and applied research in the provinces. Over the years, the administrators of federal research programs have perceived that certain research needs are best, or most cheaply met in locations outside the NCR. Sometimes a regional research institution is established because certain problems inherent to the region are considered to be unique or sufficiently important to merit special attention on location. In other cases, a research institution is located beyond the Ottawa-Hull area because the region can provide conditions which are particularly suitable for the development of a research program of national or international significance. Whatever the case, as with the research establishments in the NCR, the regional research institution is best understood in terms of its own unique goals and functions; it must be remembered that no two regional institutions have exactly the same set of aims or the same set of products.

* The regional distinctions made in this chapter are drawn along provincial lines since the data was collected on a provincial basis.

A regional research establishment may be a multi-million dollar institution aimed at promoting a major scientific program of national importance*. Or it may be a small departmental research station with a budget of several thousands of dollars and goals which are specifically keyed to the economic requirements of a particular region.* Conversely, a research institution may be large and regionally-oriented or small and nationally-oriented.

The range of goals and functions defined by these extremes might seem to limit the usefulness of aggregate statistics in accurately describing the federal research effort in the regions. Recently, a number of commentators and politicians, particularly in Quebec, have severely criticized the distribution of federal research resources on the basis of the aggregate figures covering total federal research expenditures in the regions. Many of these criticisms appear to lose much of their validity in the light of an examination of manpower, expenditure and functional distributions within, as well as among, provinces. Such factors as the regional orientation of the federal research effort, the economic impact of even 'regionally directed' research institutions, and the degree of federal

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* The Chalk River Nuclear Laboratories together form a research establishment of this kind. These laboratories conduct large research programs designed to further our ability to apply knowledge gained in the fields of atomic and nuclear physics to peaceful scientific and economic purposes. Projects include work devoted to NRX and NRU nuclear reactors, neutron-scattering and mass spectrometers, computer technology, electron microscopes, x-ray, 110-, ESR and EPR spectrometers, stress and tensile testing machines, electron and particle accelerators.

** The Health of Animals Laboratory in Winnipeg with a budget of $30,000 in 1971 is an example of such a small-scale regionally oriented research enterprise. The research program of the laboratory is primarily devoted to the testing and diagnosis of local animals for the dpeartment, the ongoing aim being the prevention of stock loss through disease in local animal populations. Another small station which serves a unique regional purpose is the avalanche research unit at Roger's Pass in British Columbia.

funding of 'provincial' endeavours must be taken into account before perceived inequities can be evaluated. Some of the dangers involved in too quickly extrapolating from the aggregate figures will be discussed in the following section.

Nevertheless, the aggregate figures do reveal certain general trends in the distribution of federal research resources across Canada; they also provoke questions about the presence or absence of a federal policy dealing with scientific research carried on in the provinces. At the very least, they provide a suitable jumping-off point into the debate which surfaced in 1970 concerning the national allocation of federal scientific activities. As described above, certain departments and agencies are much more heavily involved in regional scientific investment than others. For example, DOC, CCA, EA, ITC, NHW and MOT conduct all, or nearly all, of their scientific research and administrative operations in the NCR. Indeed, there are really only four federal departments with substantial or wide-spread regional investments: AGR, EMR, DOE and DND. Among the federal agencies and Crown corporations, only NRC has substantial regional investments. A number of agencies (AECL, CAL, CBC, NFB) have located their central research establishments beyond the NCR, but they do not have 'regional' research policies *per se*. The St. Lawrence Seaway Authority, because of the nature of its mandate, possesses two research institutions along the Seaway in Ontario and Quebec; however, most of its research is conducted in Ottawa. All the other agencies (CPDL, CMHC, IDRC, MRC) have located their research organizations in the NCR. When speaking of the regional federal research effort, therefore, one is really speaking about the work of the four federal departments mentioned above and of the NRC.

Tables II.17 and II.18 present the percentage distributions of manpower and expenditures for the four regionally oriented federal departments. From these figures it is obvious that in general capital-manpower ratios are fairly constant across the four departments. It is also obvious that even among the four regionally oriented federal departments there is a wide range of regional commitment. In 1973-74, EMR spent only 15 per cent of its research budget in the regions, although this was widely, if unevenly, distributed. By contrast AGR

Table II.17 - Percentage Distribution of Intramural Scientific Manpower and Expenditures in Four Federal Departments with Regional Investments, 1972-73

Department[2]	BC	Yukon and NWT	Alberta	Sask.	Man.	Ont.[3]	NCR	Que.[4]	NB	NS	PEI	Nfld.	Unallocated	Total
	Manpower[1]													
AGR	7.3	-	12.1	9.6	8.2	9.2	35.6	7.4	3.6	3.8	2.3	0.9	-	100
EMR	1.7	0.4	6.5	-	-	1.0	77.8	0.1	-	3.0	-	-	9.6	100
DOE	15.1	0.3	8.2	0.7	6.4	25.9	17.3	5.1	7.4	10.8	-	2.3	0.3	100
DND	4.1	-	17.8	-	-	12.4	22.1	36.5	-	7.1	-	-	-	100
	Expenditures[5]													
AGR	6.9	-	11.6	8.0	8.9	9.4	29.8	6.0	2.9	3.1	1.8	0.8	10.7	100
EMR	1.7	0.8	7.9	1.1	-	0.9	75.8	0.2	-	3.6	-	-	7.9	100
DOE	12.7	0.5	6.7	0.7	6.6	31.8	19.1	4.4	4.3	9.8	-	2.3	1.3	100
DND	5.7	-	18.6	-	-	13.7	25.0	28.9	-	8.1	-	-	-	100

Notes: [1] Percentages are based on absolute intramural manpower figures expressed in full-time equivalents. The total includes continuing employees on strength as of 30 September 1972, as well as term, casual and seasonal employees for 1972-73.
[2] See list of abbreviations.
[3] Excluding Ottawa.
[4] Excluding Hull.
[5] Percentages based on figures representing intramural plus administrative extramural costs.

Source: Derived from Tables A.1 and A.2 of the Appendix.

Table II.18 - Percentage Distribution of Intramural Scientific Manpower and Expenditures in Four Federal Departments with Regional Investments, 1973-74

Department[2]	BC	Yukon and NWT	Alberta	Sask.	Man.	Ont.[3]	NCR	Quebec[4]	Atlantic Provinces[5]	Total
	Manpower[1]									
AGR	7.6	-	11.6	9.8	8.7	9.2	35.1	7.6	10.4	100
EMR	1.8	0.8	6.1	-	-	0.9	87.0	0.2	3.1	100
DOE	14.8	0.8	8.0	0.7	6.8	28.8	15.0	4.7	20.2	100
DND	6.2	-	15.5	-	1.0	15.8	24.1	30.1	7.2	100
	Expenditures[6]									
AGR	6.8	-	9.9	7.8	7.9	8.1	44.6	6.4	8.6	100
EMR	1.6	0.7	8.3	0.1	-	0.8	85.0	0.2	3.3	100
DOE	13.2	0.4	6.5	0.5	5.9	32.3	20.7	4.8	15.7	100
DND	6.5	-	16.9	-	1.0	16.4	23.0	28.1	7.9	100

Notes: [1]Percentages are based on absolute intramural manpower figures expressed in full-time equivalents. The total includes continuing employees on strength as of 30 September 1973, as well as term, casual and seasonal employees for 1972-73.

[2]See list of abbreviations.

[3]Excluding Ottawa.

[4]Excluding Hull.

[5]The Atlantic provinces are not differentiated in this set of figures as they are with the 1972-73 data. Percentages are based on absolute intramural scientific expenditures less the non-program costs.

Source: Derived from Tables A.3 and A.4 of the Appendix.

spent a full 55.4 per cent of the research budget in the regions (in past years the percentage was higher). DOE and DND are approximately on a par with 79.3 and 77 per cent of their total research budgets going to the provinces.

The inter-regional distribution of federal research resources in each of the big four departments is uneven. The only department with a consistent policy in this respect is AGR, where approximately equal sums of money (about $6 million in 1973-74) are allocated yearly to each of the provinces west of Ontario, Quebec receives slightly less yearly, and if the Atlantic Provinces are grouped together (as they are in the 1973-74 figures), this whole eastern region is seen to receive approximately the same amount as one western province. The 1972-73 figures for AGR illustrate the disaggregated eastern picture; from the 1972-73 presentation it is apparent that, province by province, the jurisdictions east of the NCR receive far less research support than those west of it. The reasons underlying this distribution will be discussed in the next section.

Turning now to EMR, it can be seen that the regional investment of this department is low but widespread, with concentration in Alberta and Nova Scotia. By contrast, DOE has substantial regional investments; a great deal of money is spent on research in Ontario, sizeable amounts in BC, Alberta, Manitoba and Nova Scotia, and slightly smaller amounts in Quebec, New Brunswick and Newfoundland. DND has substantial investments in BC, Alberta, Ontario, Quebec and Nova Scotia corresponding to the Pacific, Western Ontario, Quebec and Eastern arms of the DND research effort.

We can briefly summarize the total expenditure values for the federal in-house research effort in each of the provinces. In dollar terms, BC, Alberta, Manitoba, Quebec and Nova Scotia are about on a par; Ontario receives more than twice the amount received by the previous five; and little money is spent in the North, Saskatchewan, New Brunswick, PEI and Newfoundland. These are the comparative, total figures that form the statistical basis for most of the criticism directed at the federal government, criticism which accuses both the government as a whole and specific departments of favouritism in their research allocations (part-

icularly of favouritism benefitting Ontario at the expense of the rest of Canada). But before examining this problem, an extensive description of the institutional base for these aggregate statistics will be given.

The differences in the regional distribution patterns for research investment are best explained in terms of the special goals of each department and the historical development of each research organization. The subject of the roles, goals and functions of the various government agencies and departments is dealt with in Chapter III. Here we shall deal with the activities of a variety of the regional research establishments.

Let us begin by commenting very briefly on the regional activities of departments and agencies in which the only major research establishment is located beyond the NCR. CAL spends about $100 000 each year at St. Paul l'Ermite in Quebec on research into explosives and accompanying apparatus. Also in Quebec, the NFB and CBC invest several hundred thousand dollars yearly in production research. The NFB lab concentrates on computer applications in film production technology; the CBC has a facility devoted to the operational problems of broadcasting, concentrating particularly on the evaluation of equipment for purchase. The Prairie Farm Rehabilitation Centre in Saskatoon conducts research into the problem of land use adjustment and water development. Even though under the control of DREE this facility has shifted its emphasis from the problems of physical resources to those of rural population adjustments.[7] The Department of Veterans Affairs - which has no Ottawa research establishment - operates a series of research programs concerned with geriatrics in hospitals across the country. Finally, INA operates a research laboratory at Inuvik (with a budget of just over $1 million in 1973-74). The laboratory's facilities are made available to anyone conducting scientific research in the North, particularly university personnel. The actual research activities of the laboratory are limited, but a program of land use research in the North is being carried out employing geologists, hydrologists, geographers and others.

A description of these institutions serves to demonstrate once again the variety of the federal in-house research effort. None of the programs described is momentous, but each fulfils a specific and often very necessary role in Canada's research structure. These institutions are not regionally oriented - with the possible exception of the Prairie Farm Rehabilitation Centre; rather they are establishments which have been located in the regions for internal purposes. Most do not even benefit particularly from their regional location, and for our purposes they might as well be located in Ottawa.

In addition to the above-mentioned institutions, there are those regional research establishments that are set up by departments or agencies which conduct most of their research in the NCR. NHW, with a large Ottawa research organization, sponsors small research efforts in the western provinces under a $100 000 health development grant. A much larger sum ($350 000) has also been allocated by NHW through the Medical Services Branch to encourage the development of a health care delivery program in the Yukon and NWT which will be on a par with programs of this type in the remainder of Canada.* In addition, PW has two small research institutions in Ontario and Quebec. The SLSA has three facilities, two in Ontario (Cornwall and St. Catherines) and one in Quebec (St. Lambert), which concern themselves with improving the navigation system of the St. Lawrence, engineering research, and the possibility of extending the navigation season. Finally, MOT has a fairly large research establishment in Montreal known as the St. Lawrence Ship Channel Division which serves as a data collection agency for the St. Lawrence River System.**

These regional spin-offs from central Ottawa research establishments often benefit the region in which they are located. The NHW units were established because of a perceived lack of health research coverage across Canada. The special information which these units generate will be of use in raising the health standards of particular regions

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* Particular emphasis has been placed on research into infant mortality.

** The collected data are employed in hydraulic and engineering studies in Ottawa.

of Canada. Similarly the SLSA and MOT units which serve as research centres for Seaway problems will benefit Ontario and Quebec, if not the rest of Canada. Yet there is also a national mandate being fulfilled in these instances - the preservation of a nationally important waterway. These research institutions recognize national and local goals; a description of their activities serves to clarify the distinction made earlier between external and internal, regional and non-regional, needs and goals.

The two largely scientifically oriented Crown corporations created by the federal government (NRC and AECL) also have substantial investments outside the NCR. However, only NRC has any kind of real regional mandate. AECL has two very large regional establishments. The first is the Chalk River Nuclear Establishment (Ontario) where the laboratories "conduct programmes of basic and applied research and engineering development in such fields as nuclear physics, material sciences, radiation, and environmental effects of radio-isotope contamination and radiation exposure."[8] The second is the Whiteshell Nuclear Research Establishment located at Pinawa, Manitoba, and is "geared to an improved understanding of the nuclear power process and the behavior of materials used in the nuclear power system. The main programmes are concerned with nuclear physics, material sciences, radiation and radio- chemistry, and with the genetic and other biological effects of radiation exposure on living organisms."[9] In addition to the foregoing, AECL runs a series of power projects at Sheridan Park in Ontario with the objective of improving "nuclear power systems design, nuclear consulting services, development and testing of major equipment items for nuclear power plants and project management of the Douglas Point and Gentilly nuclear power stations, the Bruce heavy water plant, and the Nelson River transmission system."[10] In the fiscal year 1972-73 Chalk River had a budget of $41.6 million, Sheridan Park $3.6 million, and the Pinawa establishment $15.7 million. These are all, therefore, substantial projects, Chalk River being the largest nuclear research project in Canada. However, none of these centres has a regional mandate. They are located where they are for internal reasons (most often defence), and although they may have a sizeable influence on local employment it is difficult

to trace any economic benefits to the province that flow directly from them. Moreover their mission is wholely national in scope - the creation of a nuclear capacity for peaceful purposes in Canada. Their research programs were never intended to have, or designed to fulfil, regional objectives.

Such is not the case with NRC. Certain agencies of NRC, such as the Prairie Regional Laboratory and the Atlantic Regional Laboratory, have historically been very conscious of the needs and aspirations of the regions in which they are located, to the point where research programs have often been specifically directed to particular economic or technological problems of the area. But the regional work of NRC also includes projects which have been regionally located due to special conditions in the area; these projects have very low (or no) economic or social regional spin- offs. A brief review of NRC activities in the regions will reveal these distinctions.

In Ontario, NRC operates the Algonquin Radio Observatory at Lake Traverse; this is a national observatory which can be used by all Canadian scientists. The Lake Traverse location was chosen because of the area's freedom from radio noise of terrestrial origin. Thus the observatory cannot be classified as a regionally oriented facility.

NRC also runs a Building Research Unit (BRU) and a Technical Information Service (TIS) in Toronto. The BRU serves the construction industry through the provision of technical and product information; TIS undertakes the same function for secondary industries. In the sense that those industries with head offices or plants in or near Toronto would be much more likely to employ these services than those outside the area, the two services have a partial regional bias; their mandate is, however, a national one.

In Quebec, there is another TIS in Montreal with the same functions as its Ontario counterpart. The other NRC research institution in Quebec is the Space Research Facilities Branch at Great Whale River. The non-regional character of its work is best indicated by the following description: "The station conducts geomagnetic studies, operating in close proximity to the seismic and geomagnetic

recorders of EM & R. Various physical quantities are recorded for Canadian and American scientists on a continuous basis. It serves as a ground station in some international experiments."[11]

NRC has concentrated its research efforts in British Columbia in the astrophysical field. Victoria is, of course, the location of the Dominion Astrophysical Observatory, "the principle federal laboratory for astrophysical research using optical telescopes."[12] Also in British Columbia one finds the Dominion Radio Astrophysical Observatory at Penticton which is devoted to the study of the radio emissions of astronomical objects, particularly those in the low frequency range of 10 to 200 MHz. The success of this observatory in detecting these low frequency signals is dependent on the unusually quiet nature of the Penticton site. Both observatories are characterized by national and international mandates in pure science.

Again in British Columbia one finds two much smaller research units where the regional mandate is explicit. The Regional Station for Building Research in Vancouver has the specific goal of "the identification and solution of the problems of the construction industry, peculiar to the climate and geographical conditions of British Columbia."[13] Similarly, the research field station at Roger's Pass is devoted to avalanche research, a problem of unique importance to BC. Obviously regional needs were perceived which neither industry nor the non-profit sector could fulfil and NRC stepped in.

In Saskatchewan the regional orientation is clearly represented in the work of the Prairie Regional Laboratory, where investigations of agricultural products and processes of potential or actual importance to the region have yielded distinct economic returns (the most notable recent case being the development of rapeseed). "Areas of research include the physiology of root rot control, biologically active compounds from micro-organisms, the micro-biodegradation of organic compounds, nitrogen fixation, plant cell research, biologically active compounds from plant sources, plant leaf waxes, rapeseed, wood extractives, fermentation technology, and the production and utilization of sealed peas."[14]

The BRU in Saskatoon also has a regional mandate (similar to that of BC) to solve construction problems characteristic of the region.*

The TIS in Winnipeg has the same mandate as TIS units previously mentioned. In addition, the BRU in Thompson, Manitoba is concerned with regional building problems, particularly those involving permafrost. The remaining two federal research institutions in Manitoba are of a non-regional nature; the Space Research Facilities at Fort Churchill is the major launching site for the Space Research Facilities branch of NRC** and another facility operates at Gillam for launching sounding rockets.

Turning now to the eastern provinces, NRC has research institutions only in Nova Scotia. The most important of these is the Atlantic Regional Laboratory in Halifax. As well as conducting basic research into such areas as the biophysics of water and aqueous solutions and the physiological chemistry of narcotic and hallucinogenic substances, the laboratory investigates topics of potential economic importance to the region:

- the chemistry of natural products, aimed at developing new methods of synthesizing large quantities of organic compounds of biological importance
- high temperature chemistry, as related to iron and steel making processes
- marine botany, the biochemistry and physiology of algae with a view to the exploitation of seaweed as a natural resource
- microbiology, as related to pasture soil and animal rumen.[15]

And the Building Research Station in Halifax conducts research into construction problems characteristics of the Maritimes such as the performance of cladding materials in wet, maritime climates.[16] Finally, north of 60 NRC operates a space research facility at Resolute. This temporary site is used

* Construction problems associated with a cold, dry climate and Prairie soils.

** The Fort Churchill unit is involved in launching sounding rockets, balloons carrying experiments (either physical or meteorological) and in studying such phenomena as the aurora borealis from the ground (photographic and spectro-photometric methods).

to launch scientific payloads in a region unaffected by the Van Allen Belt.

This description completes the discussion of the departments and agencies with small regional interests. There has obviously been no overall pattern imposed on these research efforts in the past. The institutions answer particular and often very specialized needs of the region, or they satisfy some internal need of the agency which is best met in the region. Except in the cases of the Veteran Affairs hospitals, the TIS services and the BRU establishments there is little repetition of function in institutions across the country. Indeed, the overall impression is that most of the regional research institutions are largely self-contained; where liaison does occur, it probably occurs most frequently with Ottawa. The picture is of a far-flung Ottawa-centred map of institutions.

One organizational and locational fact that deserves further investigation is the 'nodal' nature of the federal research effort, i.e., its characteristic concentration in certain urban centres. For example, Saskatoon and the Halifax-Dartmouth area both accommodate a wide variety of federal laboratories: Saskatoon has AGR's Health of Animals Institute, NRC's Prairie Regional Laboratory, DREE's Prairie Farm Rehabilitation Centre and DOE's Canadian Wildlife Service Unit for the region; Halifax-Dartmouth has one of EMR's Geological Survey laboratories, NRC's Atlantic Regional Laboratory, DND's Defence Research Establishment Atlantic, DOE's Fisheries and Marine Services and Environmental Management Services Units, plus the Nova Scotia Research Council (a nonfederal agency). Neither Saskatoon nor Halifax-Dartmouth are intrinsically obvious centres for research concentration and one wonders whether any benefits result from this. It would be interesting to determine the degree of internal interchange which occurs in a regional community of federal research institutions. Do these clusters of labs actually function as research communities, or does the regional institution have its closest scientific connections with Ottawa? If these groups do not function as a community, then the rationale for laboratory concentration becomes questionable, on a scientific basis, in either Halifax or Ottawa.

The disparate goals and functions of the regional research establishments outside the 'big four' federal departments have been described. Within these four the degree of continuity and organization is much more marked than within the other departments and agencies with regional efforts. They may be separated from the other departments and agencies not so much by the monetary value of their regional investment, but by the dispersion and the coordination of their regional commitment. These departments have research branches in every main regional division in Canada, and the regional branches form a highly significant part of the research mission of the whole department. Furthermore, the functions of these research branches are coordinated with the needs of the department as a whole, with the special attributes of the region and often with the needs of the region itself.

Let us begin with a description of the regional research activities of DND. Of special interest are the research activities formerly run by the Defence Research Board (DRB) for DND but which, as of April 1974, have become part of DND itself.

The regional commitment of resources in the DRB had a distinct historical basis. The necessity for an organization with the functions of the DRB was clearly perceived in the early months of World War II when defence planners found the supply lines from Britain across the North Atlantic to be increasingly vulnerable. Before the outbreak of the war Canada was almost exclusively dependent upon British research expertise in defence matters; but with the knowledge that ties with Britain were in danger and that the United States would maintain its initial neutrality, DND set up a number of research and development establishments during the early years of the war.[17] Universities and NRC also participated in the defence research program geared to the war effort. The DRB was created after the war when the ongoing necessity of a research arm for DND became strikingly obvious. Naturally the new Board built on the institutional initiatives of the war period; the research and development establishments which had been founded during the war at Halifax, Nova Scotia; Valcartier, Quebec; Ottawa, Ontario; and Suffield, Alberta were incorporated into the new organization. Those

institutions were originally founded in these particular locations for strategic or tactical reasons. After the war, efforts were made to maximize the utility of the regional establishments by emphasizing those projects which suited certain regional conditions as well as those basic research projects with no regional connections.

At present, there are five major research establishments outside the NCR. The first of these is the Defence Research Establishment Atlantic (DREA), located in Dartmouth, Nova Scotia. This unit specializes in problems associated with maritime defence. In the 1950s the unit was particularly concerned with preservation techniques against underwater corrosion of ships' hulls, and with the development of an ocean-going hydrofoil craft, a project which culminated in the construction of HMCS Bras D'Or. At present, DREA scientists are primarily concerned with three research areas: "research in underwater sound transmission, reverberation and signal characteristics associated with the acoustic detection and tracking of submarines by ships and aircraft; the hydrodynamics of underwater equipment such as hydrofoils and streamlined bodies, and the application of relevant science in direct response to requests from the Canadian Forces including those for improvements in equipment and techniques, the prime concern of the Service Projects units."[18] DREA also operates two research ships, one being the CNAV Quest "an ultra-quiet, modern 2200 ton ship strengthened for operations in ice."[19]

The second research establishment is the famous Defence Research Establishment Valcartier (DREV), the largest of the regional research centres. This establishment specializes in the evaluation and design of armaments. A current project is the STUP, or Spinning Tubular Projectile investigation, and DREV scientists are also working on elastomeric binders for castable composites. DREV is also a centre of expertise in laser technology (DREV developed high-power lasers which operate at atmospheric pressure) and laser applications to military technology, particularly target tracking. Finally, DREV is involved in surveillance and detection studies, especially with the long-range patrol aircraft (LRPA) program. As a part of this project, "the DREV experience of several years in

the analysis of anti-submarine search and tracking operations by digital computer simulation methods is being applied to the analysis of anti-submarine warfare by the proposed new LRPA. The method previously had been employed with a computer model called DATUM for the analysis of equipment and operational tactics from conventional surface ships, with or without helicopters and hydrofoil ships. It is necessary to adapt some parts of the DATUM model for application to the operations of fixed-wing patrol aircraft in the anti-submarine role. A study is in progress on the relative cost and performance of various types of sonobuoys that may be used from the LRPA for detecting and tracking submarines..."[20]

The Defence and Civil Institute of Environmental Medicine is located in Downsview, Ontario. Much of its research material is made available to other departments in support of civil aviation. The particular mandate of this institute is to determine the impact of the environment on man in his military role - on land, at sea, in the air or in the ocean depths. The work includes training programs for environmental survival and assessment programs to gauge the problems which man will encounter in hostile environments. Particular emphasis has been placed on arctic survival; researchers are now working on the development of heated arm gloves for manual work in cold climates and survival suits for pilots flying over arctic seas. Other scientists are investigating the effect of prolonged, loud noise on human hearing, the evaluation of various land vehicles, and human visual response.

The Defence Research Establishment Suffield was created during World War II to provide support for the training of British combat groups in Canada. Today, the Suffield labs are responsible for maintaining Canada's expertise in the area of biological, chemical and nuclear warfare defence. The researchers at Suffield at present concern themselves with such problems as the disposal of hazardous materials, impulse noise protection, the disposal of the 700 tons of mustard gas which were stored at Suffield during World War II, protection levels provided by decontamination and protection equipment used by the Armed Forces, and assisting in the evaluation of a particular type of sea to air missiles.

Finally, at the Defence Research Establishment Pacific (DREP), Esquimalt, one project is the development of a comprehensive submarine detection program. Aspects of this program include the detection and analysis of ambient sea noise in northern seas, and work in fluid dynamics research. There is also the set of projects concerned with low-frequency electromagnetics. The establishment also conducts research on materials, with particular emphasis on explaining material failures in the Pacific armed forces. DREP possesses its own floating research laboratory, the CNAV Endeavour which is most frequently employed by DRB personnel, but is also used by civilian oceanographic agencies.

In addition, DND maintains four Technical Services Agencies in Toronto, Montreal, Edmonton and Halifax. These agencies are responsible for maintaining contact defence contracts, insuring quality standards in the repair of equipment, and insuring the quality of materials being purchased by the department.

The Canadian Forces also operate two experimental and test ranges in British Columbia: the Rocky Point range is responsible for supplying and testing torpedoes for the Pacific fleet; the Nanoose range is used for the testing, evaluation and design of torpedoes and sonobuoys.

A description of the regional research facilities of DND (including those formerly operated by DRB) demonstrates once again the diversity of purpose which these institutions fulfil. The research system is centrally coordinated, as one would expect from the national nature of its mandate. DREA and DREP carry on maritime research and DRES is responsible for biological and chemical tests which are most suitably performed in relatively arid, flat regions, yet these establishments only marginally benefit the region in which they are located. They are examples of regional institutions with internal missions to which the choice of site is keyed (or alternatively the projects are chosen for the site).

We turn now to other departments with large regional components; the first of these is the Department of the Environment. As can be seen from

examining the regional distribution of its scientific activities expenditures, the resources of DOE are widely, although not evenly, spread throughout the regions of Canada. We find particular resource concentrations in British Columbia, Alberta, Manitoba, Ontario and Nova Scotia.

The regional research institutions are, of course, associated with the internal administrative divisions of DOE which have already been described. In the Environmental Services Programs, whose mandate is to supply meteorological services to Canadians - from fishermen to farmers to pilots and to the general public - the research effort of the Atmospheric Environment Service (AES) is widely distributed and oriented toward such problems as "atmospheric processes, air quality and environmental interrelationships in addition to continuing research in direct support of weather forecasting and observing stations.[21]

The table below gives an indication of the AES regional effort:

Province	AES Branch	Total Expenditures in 1973 ($000's)[22]
Ontario	AES, Toronto	41 414
Quebec	AES, Dorval	4 005
British Columbia	AES, Vancouver	3 642
Alberta	AES, Edmonton	4 915
Manitoba	AES, Winnipeg	7 270
New Brunswick	AES, Moncton	4 442

The centres listed collect and process meteorological data from numerous small data collection agencies supervised by the main centres. Toronto, the head office of AES is the largest of the centres listed and has additional special functions. This office conducts most of the research for the Atmospheric Environment Services. It houses a wind tunnel, a satellite data laboratory and receiving station, and processing computers, and conducts research in such areas as dynamic meteorology, radiation and climatology. Most of the training and instrument development programs for the Service are also carried out in Toronto. As well as acting as a regional data collection and coordination office the Winnipeg unit operates a mini-computer, which automates the data filing and provides a regional analysis and prediction service.

There are three sub-directorates of the Environmental Service Program with important regional research mandates: the Canadian Forestry Service (CFS); the Inland Waters Directorate (IWD); and the Canadian Wildlife Service (CWS).

The CFS is engaged in research to aid in the preservation and best utilization of Canada's renewable forestry resources. This includes such projects as soil research, fertilizer studies, genetics and tree biology, studies of harvesting and reforestation practices, tree inventories, forest insects and diseases and new wood properties development. The Great Lakes, Laurentian, Pacific, Northern, Maritime and Newfoundland Forest Research Centres are located in Sault Ste. Marie, Ste-Foy, Victoria, Edmonton, Fredericton and St. John's respectively.

In addition to the regionally oriented Forest Research Centres the CFS sponsors national services: the Insect Pathology Research Institute at Sault Ste. Marie is aimed at solving national problems of insect control; the Petawawa Forest Experimental Station at Chalk River conducts a large research project of national scope concerned with soil culture and forest management problems; and the Forest Products Laboratory in Vancouver concerns itself with the mechanical stress properties of Canadian lumber. This last institution does possess a regional mandate in that it retains close connections with the BC and Alberta forest products industries.

The IWD has responsibility for the management of national and international inland waters. The directorate consists of four branches and four regional offices. It also has coordinating responsibilities for all elements located at the Canada Centre for Inland Waters, Burlington, Ontario. The Water Quality Branch is responsible for national water quality research, investigation and data network programs. The Water Resources Branch plans and manages national water quantity research, investigation and data network programs. The Water Planning and Management Branch concerns itself primarily with comprehensive water resource planning throughout Canada and cooperates with provincial agencies in implementing programs under the Canada

Water Act. The Canada Centre for Inland Waters Branch is responsible for national research programs in lakes, hydraulics, and other aspects of water quality and water resources.[23]

The Canada Centre for Inland Waters at Burlington, Ontario, is the most important research-oriented institute in the IWD. The Centre serves as an interdisciplinary base for water studies involving the IWD, the Fisheries and Marine Service, and the Environmental Protection Service. The coordinating role is fulfilled by the IWD.

The Canada Centre for Inland Waters establishment is directly involved in such crucial projects as the assessment and control of pollution in the Great Lakes (in conjunction with American agencies), the development of contingency plans for Great Lakes oil spills, and research into the biological states of other inland water systems such as the Bell-Nottaway system, Hudson Bay and the Mackenzie system.

In order to facilitate research work in water management and quality, the IWD conducts a national water survey. The work of the Guelph Water Survey division gives an indication of the activities of the other water survey units. Water resources data on flows, water levels, reservoirs, and sediment samples from a total of 364 gauging stations are collected and published. Additional studies are carried out on network design, flow forecasting and data analysis.

The IWD also funds water quality operations in the regions (Vancouver, Regina, Moncton). These centres produce data on the quality of water systems through the collection and analysis of water samples for organic and inorganic materials. As an example of the additional duties of one of the units, the Water Planning and Management Branch of the IWD in Regina is involved in studies of the diversion and supply effects of modifying such water systems as the Mackenzie-Athabasca and the Saskatchewan-Nelson.

The last part of the Environmental Management Services is the Canadian Wildlife Service (CWS), which has extensive regional operations; it is primarily concerned with administering the

Migratory Birds Convention Act and the Canada Wildlife Act, and conducts research in the areas covered by these acts. There are small CWS stations in Aurora and Midland, Ontario; Cap Tourmente and Ste. Foy, Quebec; Vancouver, BC; Edmonton, Alberta; Last Mountain Lake, Saskatchewan; Winnipeg, Manitoba; Halifax, Nova Scotia; Fredericton and Sackville, NB; St. John's, Newfoundland; and Inuvik, Whitehorse and Fort Smith in the Territories.

Another part of the Environmental Services Program is the Environmental Protection Service (EPS). As noted earlier, the EPS is generally responsible for dealing with problem areas and policies concerning the protection of the Canadian environment through environmental regulation. The EPS is responsible for the collation of data concerning Canadian air, land and water pollution, the development of policies to protect the natural environment and the implementation of those policies.

The EPS operates regional environmental protection services in Montreal, Vancouver, Edmonton, Winnipeg and Dartmouth (Nova Scotia). At the Quebec Region facility, for example, the main activity is the testing of waste treatment facilities and effluents of industries to ensure compliance with Water and Clean Air Acts. The service acts as consultant to industry, which loans use of its test laboratories as do universities.

To complete this review of the research activities of DOE, we must examine an entirely different section of the department, the Fisheries and Marine Service and particularly the Research Development Directorate.

This directorate is a headquarters unit providing the focal point for planning, coordination and evaluation of all fisheries research and development programmes sponsoredby the federal government to meet national and international needs.

While actual fisheries research and development is carried out at 12 regional research establishments across Canada and through grants to individuals and institutions, the directorate in Ottawa is responsible for the coordination and in-

tegration of the various programmes and for responses to the recommendations of the Fisheries Research Board of Canada. The directorate is staffed by a small group of scientific experts in the fields of fisheries resources, environmental quality, products and processing and aquaculture.[24]

The following chart shows the various expenditures of the Fisheries and Marine Service in the regions and indicates the range of activity characteristic of F & MS:

Province	Agency	1973 Expenditure ($000's)[25]
British Columbia	Marine Sciences, Pacific Regional Office, Victoria	6 280
	Fisheries Service, Nanaimo	4 358
	Fisheries Service, Vancouver	2 463
Manitoba	Fisheries Service Winnipeg	4 739
Ontario	Fisheries Service (Biology, Limnology Div.) and the Marine Science, Central Region	4 011
Quebec	Fisheries Management and Research, Arctic Laboratory, Ste. Anne de Bellevue	1 033
New Brunswick	Biological Station, St. Andrew's	2 354
Nova Scotia	Marine Sciences, Atlantic Region, Dartmouth	13 766
	Fisheries Service, Halifax	3 937
Newfoundland	Fisheries Service, Biological Station, St. John's	2 854

The Fisheries and Marine Research Directorate encompasses institutions devoted to the investigation of such areas as fisheries development, fisheries operations, oceanography and hydrography. These institutions fall into two categories - the Marine Sciences Institutes (Pacific, Atlantic and Central Region) and the Fisheries Research Services. A brief description of an example from each category would best serve to indicate the missions of these services. At the Marine Sciences Atlantic Region Laboratory a large part of recent activities

has been devoted to HUDSON -70, an oceanographic expedition around North and South America undertaken to contribute to the International Oceanographic Decade's exploration of the oceans, and to continue the exploration of the Canadian Continental Shelf. Interpretation of results will continue for some time to come. The Marine Sciences Division also undertook extensive research as a result of the sinking of the Liberian Tanker Arrow. Other research areas include organic geochemistry, inorganic geochemistry, physical geology, regional geology, micropaleontology and geophysics.

The Fisheries Service's Biological Station at Nanaimo is concerned with commercial and recreation fisheries, and with environmental quality programs. Work is concentrated in several areas, including the biology of aquatic resources, the productivity of the aquatic environment, increasing the productive capacity of the environment, augmenting the supply of resources, and improving the farming methods of sablefish and oysters.

As with the other departments and agencies examined, the DOE research efforts are sometimes regionally oriented, in the sense of benefitting the region, sometimes not. What is noteworthy about DOE is the comprehensiveness of its regional program and the sheer magnitude of its regional expenditures. Another important aspect of the regional research effort is the emphasis on an interdisciplinary approach to regional and environmental problems, as exemplified by the Canada Centre for Inland Water's and IWD's determined onslaught on the Great Lakes project. This mixture of function and expertise arises, in part, from the wide mandate which DOE has, but it might be useful for certain other departments to review well-coordinated regional and environmental programs developed by DOE as an example for their own future development.

Another department which has historically had a large role to play in the regions of Canada, particularly in the West, is the Department of Agriculture. As can be seen from a quick comparison of the departmental expenditure graphs in the Appendix to this report, AGR has the most widely and evenly distributed regional research program of all federal departments, although there is a dis-

tinct tendency to concentrate research activities in provinces west of Ottawa.

The scientific research of AGR is conducted in four main subdivisions of the department, the Research Branch, the Health of Animals Branch, the Canadian Grain Commission and the Financial and Administration Branch.* Of these divisions the Research Branch is by far the largest and, together with the Health of Animals Branch, accounts for the vast majority of the federal in-house research effort in agriculture.

We shall deal first with a sampling of the activities of the Research Branch which is the main agricultural research organization for Canada. The headquarters for the Research Branch is the Central Experimental Farm in Ottawa. As noted earlier, a number of research institutes dealing with various scientific areas are located at the Ottawa Research Branch Headquarters. Outside the NCR the Research Branch operates 34 stations, substations and experimental farms which conduct research associated with the particular soil, climate and vegetation conditions of the Canadian regions. The Research Branch is subdivided into four divisions, each under the control of an Assistant Director General: Eastern, Western, Institutes and Administration. We need not be concerned here with the Administration Branch, but the Eastern and Western research subdivisions are crucial, and the Institutes division is important to the extent that it operates a Research Institute in Belleville, Ontario, and another in London, Ontario.

Again the simplest way of conveying a feeling for the work of these divisions is to briefly describe the activities of the several types of regional research establishments which AGR has evolved. For instance, the experimental farms at Thunder Bay, Kapuskasing and Smithfield are typical of many other experimental farms in their regional orientation and mandate. All three farms are directed from the research station in Ottawa. Thunder Bay activities are primarily related to the adapt-

* Through a network of approximately twenty regional research libraries the Financial and Administrative Branch services the needs of the agricultural research community.

ation and management of field crops in northwestern Ontario. The farm at Kapuskasing is concerned with crop management in northeastern Ontario and northwestern Quebec, and with the nutritional requirements and overwintering of beef cattle. The Smithfield farm is devoted to trees and small fruits and vegetables, particularly canning crops - their management, breeding, physiology and processing. The research station at Saint-Jean in Quebec is also fairly typical. This station serves as the horticultural research centre for Quebec. Breeding and management of horticultural plant nutrition and physiology, control of insects and diseases, soil fertility and the management of organic soils are the main lines of study. The station also directs work at La Pocatiere and Normandin experimental farms where coordinated research on soils crops and animals is carried out.

Returning for a moment to Ontario we should mention the only two regional research institutes of the Research Branch of AGR; the research institute in London, Ontario, which is primarily involved in fungicide, herbicide and insecticide research; and the institute in Belleville, Ontario, which searches for non-chemical ways to reduce weed or pest damage through studies of pest ecology.

It should be mentioned that about 60 per cent of the operating research budget of AGR goes to the regions - about 10 per cent to the Atlantic provinces, 30 per cent to the Prairies, 5 per cent to BC and 15 per cent to Ontario and Quebec. The relatively small budget allotted to Eastern Canada in comparison with Western Canada probably reflects the value of the agricultural output of the two areas.

The second large research program associated with AGR is that operated by the Health of Animals Branch. This branch is the veterinary agency of the department and operates throughout Canada. It carries out animal disease control and eradication measures. Branch inspectors at meat packing and other food processing plants ensure that hygenic and wholesomeness standards are met. Its laboratories conduct research and provide diagnostic services. Three divisions make up the branch.[26] These are the Contagious Diseases Division, the Animal Pathology Division and the Meat Inspection Division.

The Health of Animals Branch has research institutes located in Guelph, Ontario; Hull, Quebec; St. Anne de Bellevue, Quebec; Vancouver, BC; Lethbridge, Alberta; Saskatoon, Saskatchewan; Winnipeg, Manitoba; Sackville, New Brunswick. The majority of these research institutes operate in a service capacity and the work is almost entirely devoted to the testing and diagnosis of local animals for the department.

The last branch of research importance at AGR is the Canadian Grain Commission which provides supervision for grain handling in Canada. The CGC has a fairly large grain research laboratory in Winnipeg. The laboratory activities include research on hard-red spring wheat, Hamber-Durham wheat and barley, and on the protein content in wheat and cereal grains, as well as providing statistical data and analysis on grain research.

It is obvious from the foregoing descriptions that AGR is one of the most regionally oriented of the federal research departments. Many of its institutes benefit the local economies in the regions in which they are located.

AGR, like DOE, is concerned with primary industry and attendant processing industries. These two departments assist and enhance agriculture, forestry and fishing, all renewable resources. When the OECD published its Reviews of National Science Policy, Canada in 1969 it distinguished among the various research institutions of Canada.[27] The authors of the OECD document defined a category called NRC and the MRC, and a category, 'Institutions concerned with research on renewable resources', in which they included AGR and the now defunct Fisheries and Forestry Department.* Another category grouped 'Institutions conducting research on collective needs' such as DND, MOT, NHW, DOC and DREE. Finally, the OECD authors defined a category called 'Institutions concerned with research on non-renewable resources' which embraced EMR, AECL and AECB.

This distinction among research per se, research concerned with renewable resources and

* 'Fisheries' has now been given departmental status under the recent cabinet changes following the 1974 federal election (Mr. LeBlanc, Minister).

research concerned with non-renewable resources is a useful one. Policy decisions of the respective departments will be conditioned by the nature of the physical resources under consideration. Those departments concerned with non-renewable resources must employ a different time horizon with greater constraints than those concerned with renewable resources. This distinction also serves as an introduction to the regional activities of the last regionally oriented department, EMR. Just as those departments concerned with widely distributed renewable resources perceived an obligation to locate some of their research facilities in the regions, so the major department concerned with widely distributed non-renewable resources felt a similar obligation (although the extent of its regional commitment is much less).*

As we saw in an earlier section, EMR possesses two research arms - the Mines Branch and the Geological Survey of Canada. Both branches of the department have regional agencies. The Mines Branch unit at Elliot Lake, Ontario is devoted to mining problems, particularly at great depths underground; the unit at Quebec City commenced operating in 1971, and specializes in rock fracture and drilling problems. The Mines Research Centre in Calgary is concerned with coal mining problems, and the Fuels Research branch at Edmonton evaluates the coking potential of coals.

The Geological Survey unit at Dartmouth, Nova Scotia (Atlantic Geoscience Centre) conducts investigations into marine geoscience. The unit at Calgary, Alberta (Institute of Sedimentary and Petroleum Geology) contributes to the Geological Survey's responsibility of providing a national and regional inventory of the formation of rocks and surficial materials, their structures, minerals, land forms, and stability along with back-up studies in order to evaluate the potential of relatively unknown areas. Finally, the Polar Continental Shelf Project at Tuktoyaktuk and Resolute Bay in NWT should be mentioned. The project is designed

* It is interesting to note that only DND of all the departments concerned with the OECD's 'collective needs' felt an obligation to invest intensively in the regions. And even DND's regional commitment results largely from strategic considerations.

to study the continental shelf north of the Canadian mainland and north and west of the Arctic Archipelago. Work is conducted in geophysical fields, but investigations have also been launched to study the fragile ecological systems of the Canadian north.

The brief review of the regional activities of EMR concludes this presentation of the regional activities of the federal research departments and agencies. It is obvious that the picture is extremely variegated, even more so perhaps than that of the NCR research community. For a complete analysis of the regional research effort, one would have to know how the laboratories manage to function effectively in regional isolation (even though their functions are often not related to the region) when the general pattern of research deployment of the departments is locational concentration, particularly in the National Capital Region. Possibly the regional research nodes described above play some intermediate role in enhancing communication and a sense of research community. Without more information in this area, a complete evaluation of the distributional characteristics of the federal research community is impossible.

5. The Issue of Regional Discrepancy: An Analysis

In section 2 of this Chapter the aggregate figures describing the research effort of the federal government in the provinces were briefly reviewed. An examination of the bar graphs (Appendix Figures A.2 to A.16) illustrating the regional breakdown of departmental research budgets for the four regionally-oriented departments shows that the distribution of federal research resources is by no means equitable. AGR concentrates its activities in the western provinces; EMR favours Alberta and Nova Scotia over the rest of Canada; DOE spends an extraordinary amount of money in Ontario with varying amounts going to other provinces; and DND displays a wide expenditure range in the regions, reflecting the various sizes of its DRB establishments. If the grand totals for manpower and monetary resources allocated to each region are reviewed (Table II.19 and 20), it is apparent that certain provinces are receiving substantially more than others. Ontario with 21.5 per cent of the total federal regional research budget in 1973-74 appears to dwarf all

Table II.19 - Federal Scientific Establishments, Natural Sciences, 1972-73
Regional Breakdown

Province or Region	Manpower				Expenditures ($000s)[1]			
	Sci. & Prof.	Others	Total	Percentage of Grand Total	Current	Capital	Total	Percentage of Grand Total
British Columbia	471.5	1 311.4	1 782.9	6.8	33 792	3 738	37 530	6.1
Prairie Provinces	909.3	2 978.4	3 887.7	14.8	78 248	8 656	86 904	14.2
Alberta	377.0	1 574.0	1 951.0	7.5	36 412	3 983	40 395	6.6
Saskatchewan	161.2	403.7	564.9	2.2	9 154	679	9 833	1.6
Manitoba	371.1	1 000.7	1 371.8	5.2	32 682	3 994	36 676	6.0
NWT & Yukon	10.0	40.0	50.0	0.2	1 766	257	2 023	0.3
Ontario (excluding Ottawa)	1 265.6	3 578.5	4 844.1	18.5	114 764	12 354	127 118	20.8
National Capital Region	3 084.5	7 555.5	10 640.0	40.6	216 205	40 875	257 080	42.0
Quebec (excluding Hull)	337.4	1 863.5	2 200.9	8.4	34 775	2 093	36 868	6.0
Atlantic Provinces	579.5	1 912.7	2 492.2	9.5	44 341	4 705	49 046	8.0
New Brunswick	177.0	569.0	746.0	2.8	9 989	728	10 717	1.8
Nova Scotia	326.5	1 103.7	1 430.2	5.5	28 326	3 589	31 915	5.2
P.E.I.	18.0	76.0	94.0	0.4	1 224	36	1 260	0.2
Newfoundland	58.0	164.0	222.0	0.8	4 802	352	5 154	0.8
Unallocated	102.2	182.0	284.0	1.1	9 931	5 510	15 441	2.5
Grand Total	6 579.8	19 422.0	26 181.8	100.0	533 822	78 188	612 010	100.0

[1] Figures represent intramural costs plus the costs of administering extramural programs.

Source: Ministry of State for Science and Technology, Scientific and Technological Resources Division, 1972-73 Survey of the Federal Government Research Effort (figures supplied to MOSST by the Science Statistics Section of Statistics Canada) 1974.

Table II.20 - Federal Scientific Establishments, Natural Sciences, 1973-74
Regional Breakdown

Province or Region	Manpower				Expenditures ($000s)[1]			
	Sci. & Prof.	Others	Total	Percentage of Grand Total	Current	Capital	Total	Percentage of Grand Total
British Columbia	474.5	1 391.0	1 865.5	7.0	33 655	3 655	37 310	6.2
Prairie Provinces	926.8	3 234.6	4 161.4	15.7	80 268	6 134	86 402	14.3
Alberta	337	1 631.6	2 008.6	7.5	37 621	2 800	40 421	6.7
Saskatchewan	158.5	433.5	592	2.2	7 795	512	8 307	1.4
Manitoba	391.3	1 169.5	1 560.8	5.8	34 852	2 822	37 674	6.2
NWT & Yukon	30	80	110	0.4	1 478	874	2 352	0.4
Ontario (excluding Ottawa)	1 339.5	3 750.1	5 089.6	19.0	117 446	12 141	129 587	21.5
NCR	3 245.2	7 874.2	11 119.4	41.6	227 904	36 954	264 858	43.9
Quebec (excluding Hull)	312.8	1 598.6	1 911.4	7.1	35 115	2 198	37 313	6.2
Atlantic Provinces	603.7	1 889.0	2 492.7	9.3	42 170	3 286	45 456	7.5
Grand Total	7 859.3	23 052.1	26 750.0	100	618 304	71 376	603 278	100

[1]Figures represent intramural costs plus the costs of administering extramural programs.
Source: Produced by Statistics Canada, Science Statistics Section, (1973-74 Survey of Federal Government Departments and Agencies).

other provinces. Quebec and British Columbia are low in comparison, with about 6.0 per cent of the total each.

These inter-regional disparities are not corrected, although they are somewhat changed, when the expenditure figures for the regions are placed on a per capita basis (Tables II.21 and II.22). The third column of Table II.22 shows that in 1973-74 Alberta, Manitoba and the Atlantic Provinces taken together had the highest levels of per capita expenditure on federal research. The 1972-73 figures in Table II.21 present a disaggregated pattern for the Atlantic region; it is clear from these figures that it is the high per capita expenditures in Nova Scotia ($40.5 in 1972-73) that accounts for the leading position of the Atlantic region taken as a whole in the 1973-74 set of figures. Turning back to the 1973-74 table, Ontario and British Columbia are seen to be on an approximate par in per capita terms ($17.5 per capita in Ontario, $17.1 in BC). But what is really remarkable in this set of figures is the very low level of per capita expenditure in Quebec. This results from the low absolute expenditure of federal research funds in Quebec (only $37.3 million in 1973-74 or 6.2 per cent of the grand total) and the fact that more than a quarter of the Canadian population resides in Quebec. It was a comparison of this type which initially sparked the provincial reaction to federal research efforts at the regional level in Quebec.[28]

It is also interesting to note the last column of tables which presents regional per capita expenditure on federal scientific activities as a percentage of regional average income. The wide distribution of percentages indicates clearly that no policy of regional adjustment through research allocation is being followed. Again Quebec is at the bottom of the scale, Ontario and BC are on a par and Alberta, Manitoba and the Atlantic Provinces (or rather Nova Scotia as indicated by the 1972-73 figures) are high. Saskatchewan is just above Quebec in this comparison.

Federal research expenditures in the regions are not keyed to population size or economic prosperity. Indeed, in light of the review of the detailed functions of federal research establish-

Table II.21 - Regional Comparisons: Federal Scientific Expenditures in 1972-73

Region	Total Federal Expenditures on Scientific Activities in the Region[1] ($ millions)	Total Population of the Region, 1971 census (millions)	Regional per capita Expenditures on Scientific Activities by the Federal Government ($)	Average Individual Income for the Region[2] ($) (1967)	Regional per capita Expenditure on Federal Scientific Activities as a percentage of Regional Average Income (x10)
Ontario (excluding Ottawa)	127.1	7.40	17.2	4 674	3.7
Alberta	40.4	1.63	24.7	4 092	6.0
British Columbia	37.5	2.18	17.2	4 372	3.9
Quebec (excluding Hull)	36.9	5.97	6.2	4 105	1.5
Manitoba	36.7	0.99	37.1	3 709	10.0
Nova Scotia	31.9	0.79	40.5	3 218	12.6
New Brunswick	10.7	0.64	16.9	3 323	5.1
Saskatchewan	9.8	0.92	10.6	3 871	2.7
Newfoundland	5.2	0.52	9.9	2 912	3.4
Yukon & NWT	2.0	0.05	38.1	-	-
PEI	1.3	0.10	11.4	2 323	4.9
Grand Total	339.5	21.19			

[1] Figures include the costs of administering extramural programs.

[2] Source: Dominion Bureau of Statistics, Income Distribution by Size in Canada for 1967, Queen's Printer, Ottawa, December 1970, Cat. no. 13-534, Table 34.

Table II.22 - Regional Comparisons: Federal Scientific Expenditures in 1973-74

Region	Total Federal Expenditures on Scientific Activities in the Region[1] ($ millions)	Total Population of the Region, 1971 census (millions)	Regional per capita Expenditures on Scientific Activities by the Federal Government ($)	Average Individual Income for the Region[2]	Regional per capita Expenditures on Federal Scientific Activities as percentage of Regional Average Income (x10)
Ontario (excluding Ottawa)	129.6	7.40	17.5	4 674	3.7
Alberta	40.4	1.63	24.8	4 092	6.1
BC	37.3	2.18	17.1	4 372	3.9
Quebec (excluding Hull)	37.3	5.97	6.2	4 105	1.5
Manitoba	37.7	0.99	38.1	3 709	10.3
Atlantic Provinces	45.5	2.05	22.2	2 944	7.5
Saskatchewan	8.3	0.92	9.0	3 871	2.3
Yukon & NWT	2.4	0.05	48.0		
Total	338.5	21.19			

[1] Figures include the costs of administering extramural programs.

[2] Source: Dominion Bureau of Statistics, Income Distribution by Size in Canada for 1967, Queen's Printer, Ottawa, December 1970, Cat. no. 13-534, Table 34.

ments presented earlier there appears to be no intuitive or necessary reason for a policy of this type. 'Variety' and 'diversity' are the key words characterizing the entire federal research in terms of effort, function, goals, needs, expenditures and manpower; 'coordination', 'order' and 'planning' are generally foreign concepts in terms of the 'outside' needs which these labs might fulfil. Coordination and planning have only been important at the internal level where scientific priorities, and occasionally economic priorities, are important. The region sometimes impinges upon the work of a regional laboratory, but often it does not. Given these facts one would not expect the aggregate regional figures to reflect a policy of equalization or regional economic promotion.

These factors were not considered in the analysis of the functions of government labs when the debate over the 'inequity' of the distribution of federal research resources opened in Quebec in 1968. As has been noted, the aggregate figures for federal research distribution indicate that Quebec lags behind the rest of the country. Similar figures became the focus of an academic and governmental debate in Quebec in the early seventies on Quebec's place in the scientific community and her capacity to develop scientifically under the alleged restrictionsimposed by federal research policy. Scientists and administrators were not only concerned about the inequity of the federal in-house research distribution, but were also frustrated by the 'individual merit and excellence' criterion which federal funding agencies such as NRC and the various departments applied to university research support programs. Since Quebec historically has not been a region characterized by a high level of scientific activity, policy makers in the province were concerned that federal policies closed a vicious circle in which 'mediocre' science received little funding and therefore remained 'mediocre'. Programs developed at the federal level to remedy this problem (such as NRC's Negotiated Developments Grants Program) were welcomed in the province; but the Quebec scientific community felt that such efforts were not sufficient to 'launch' the province scientifically.[29]

It is not the purpose of this paper to review the institutional and policy developments which

arose from the dissatisfaction with federal scientific policies. Suffice it to say that the 'scientific' debate was underlaid with an 'economic' assumption - that increased scientific research (both pure and applied) was absolutely necessary to solve Quebec's economic problems. The governmental and scientific communities became convinced that what Quebec needed was a set of governmentally and industrially funded institutions to conduct research into the special industrial problems of Quebec and to aid Quebec industries through scientific consultation. Action was taken in the late sixties and early seventies to fulfil these requirements. The National Institute of Scientific Research (INRS) was created in 1969 with a mandate: "to conduct interdisciplinary mission-oriented research in areas which have special relevance for the development of Quebec and which are in accordance with the economic goals of the province."[30]

The INRS is an arm of the University of Quebec; under the aegis of the university it has created two types of institutions: autonomous centres which are managed by INRS (Le Centre Québécois des sciences de l'eau, le Centre de recherches urbaines et régionales, le Centre de recherche en sciences de la santé) and associated research centres (le Centre de recherches en ingénerie des télécommunications, le Centre de recherche de l'énergie).[31]

Two other institutions of major import in the sciences have been created: the first of these is the Industrial Research Centre of Quebec (CRIQ) with the objectives of

(a) applied research in its own laboratories and other research centres;
(b) the development of products, processes and industrial or scientific apparatus and
(c) the collection and dissemination of technological and industrial information.[32]

CRIQ's goals are much more firmly tied to economic development and growth than are those of INRS. Finally, the Hydro-Quebec Institute of Research (IREQ), created in 1967 by the Hydro-Electric Commission, has been very influential as an example of what concentrated research on a large scale can accomplish in one particular field. In 1970 IREQ concluded an agreement with INRS at the University

of Quebec - specifically with le Centre de recherche de l'energie - which allows IREQ to maintain its university contacts and participate in teaching programs, and on the other hand gives the Energy Research Centre access to IREQ's facilities.

Having created these institutions, the governmental and scientific communities in Quebec soon perceived a vital need for an organization or set of organizations to coordinate the efforts of the scientific institutions described above. Dr. Maurice l'Abbe, Vice Rector of the University of Montreal, highlighted the need for such coordination in an article entitled "Les Elements d'un Politique Scientifique pour le Quebec" in Le Devoir in 1970:

> The responsible authorities should immediately study these measures: establishment of a council for scientific and technological research with advisory power to the government on scientific policy; to support research and at times, undertake research; and finally a minister should be designated to deal with scientific and technological affairs: the secretariat would be responsible to him.[33]

L'Abbe's recommendations were at least partially realized in 1971 with the creation of a Ministerial Science Policy Committee, a Science Policy Secretariat and a Science Policy Council within the Quebec government. Without going into detail about the functions of these bodies, it may be noted that the Ministerial Committee is responsible for the formulation of science policy; the Secretariat[34] acts as the administrative arm of the Committee and the Science Policy Council[35] acts as an advisory body to the government.

The entire machinery which has been established in Quebec has in part been a response to a perceived neglect on the part of the federal government. However, several questions should be asked before the attacks on the federal government over research allocations in Quebec can be taken too seriously. Referring specifically to federal in-house activities in Quebec, and keeping in mind the division established earlier between the regional and non-regional functions of federal government

laboratories, can Quebec (or any other province) really assent that it has been discriminated against?

To answer this question adequately, an assessment must be made of the impact of federal in-house research institutions on the regions in which they are located. In a previous section, it was suggested that such a multi-million dollar facility as the Chalk River Nuclear Laboratories has very little impact on the local economy, yet it accounts for practically a third ($41.6 million in 1973) of the federal in-house research expenditure in Ontario, the province which is said to have benefitted most from federal research expenditures. The same could be said of the Valcartier Defence Research Establishment in Quebec and the DND research centre in Toronto. In contrast to these establishments many research units - particularly those of DOE and AGR - are of direct benefit to the region and the local economy. A careful analysis of the regional impact of institutions located in Quebec and elsewhere is required before a complete evaluation of Quebec's complaints can be made. It may be that Ontario, for instance, has a surfeit of institutions with a non-regional impact and that this accounts for its dominance in the comparative expenditure charts. Alternatively, Quebec may be characterized by a wide range of institutions which directly benefit its economy.

A second question of continuing importance in the evaluation of provincial scientific and technological development concerns the degree to which provincial agencies undertaking scientific activities are federally funded. At present, comprehensive statistics are not available that describe the flow of federal funds to the regions in forms other than direct in-house expenditure. Such statistics would indicate, for example, how much money has been made available to INRS since 1969 through federal university support funds, how much IREQ has received from federal grants or loans to start up and expand its facilities[36] and finally, how much CRIQ, which corresponds closely to the industrially-oriented Research Councils in other provinces, has received through IRDIA, PAIT, DIP, DIR and IRAP programs or from departmental contracts resulting from "Make or Buy".[37]

Whatever the outcome of such investigations might be and whether Quebec has a legitimate complaint or not, Quebec's scientific organization has burgeoned beyond that of any other province in Canada. The present provincial government has made a commitment to the development of a comprehensive policy on science and technology. In the sense that the events of the last few years have strengthened the scientific community in Quebec, these provincial initiatives should be welcomed, even if they were undertaken for the wrong reasons.

In the process of transforming its own internal research structure, however, Quebec has adopted a policy orientation that is largely foreign to the federal research structure: it consists of an explicit commitment on the part of scientific institutions to aid industrial growth and economic development. The importance of stimulating economic growth in Quebec is reiterated in every report of the Ministerial Committee, and INRS, CRIQ and IREQ are seen as the institutional means to stimulate that growth.

No such commitment to the Canadian economy or industrial development is written into the mandate of most federal research establishments. Only NRC, among them all, has a specific mandate to foster the development of industrial R & D capabilities. AGR and EMR have strong ties with the primary industries concerned with agriculture, mining and fossil fuels, but these are not generally considered to be high-growth industries. DOT, DOC, DND and EMR all maintain contacts with high-growth, employment-creating secondary industries; but again these contacts are seen primarily as benefitting the internal functions of the department, and only secondarily as helping the industry. 'Make or Buy' has emerged as a first step toward the re-direction of the functions of government laboratories away from exclusively internal concerns toward the management of R & D which is of direct benefit to the industrial sector and will ultimately benefit the economy as a whole. In many ways, however, the success of 'Make or Buy' is still in doubt since, for example, it is viewed in scientific sectors as an imposed policy.

The question remains whether federal government research establishments should be totally or

partially directed toward industrial sponsorship and R & D management. The experience of the 'Make or Buy' policy should reveal at least some of the problems involved. It is obvious that at present federal institutions are not prepared either geographically or functionally for a major shift in this direction. It becomes debatable whether the federal laboratories should even have such a policy imposed upon them. It may be that Quebec has embarked on a sensible experiment in developing laboratories of its own to promote economic and industrial development. The key to the future may lie with the Research Councils in other provinces which are also industrially oriented. A shared cost federal-provincial program to expand and develop these institutions might be more productive than diverting resources from federal laboratories which are performing other functions. Of course, looming in the background of all these discussions is the debate over the exact relationship between science, technology and growth. (See Chapter I, where the issue is explored in greater detail.)

III. Structure and Functioning of R & D Establishments

Chapter III. Structure and Functioning of R & D Establishments

1. Role of Government Research and Development Establishments

The first chapter of this report gave some of the more basic economic and social reasons why governments establish and maintain R & D facilities. Before we can seriously consider the question of technology transfer from government R & D establishments, we must understand why we have these establishments, how they function and how they are structured.* All R & D undertaken on behalf of the government, whether in a government establishment, a university or in private industry, relates to the same common need and desire - the maintenance or augmentation of the general well-being of the Canadian people. Notwithstanding the impossibility of achieving a university accepted definition of "general well-being", this still stands as the only universal justification for government R & D.

Justification for government R & D is not justification for government R & D establishments. Why should any government funded R & D be undertaken in a government establishment rather than in a private one? The question is not easily answered. All government establishments are the products of decisions made under circumstances existing at a particular time. A truly thorough examination of their roles, therefore, would require the examination of each establishment and of the historical context in which it was created.** This approach, however, would transcend the scope of this study. As an alternative we shall examine the roles of government establishments from a generic standpoint.

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* In this chapter the term R & D refers to all scientific activities of government establishments, i.e., research and development and related scientific activities.

** In The Organization of Research Establishments, edited by Sir John Cockcroft, Cambridge University Press, 1965, the point is made that to fully understand and evaluate the performance of any particular R & D establishment one must see it in its historical setting - when and why created - and one should further conduct a behavioural study of the directors and senior scientists of the establishment over time.

A useful point of departure for the examination of the roles is provided by the criteria for in-house research and development now being used by government R & D establishments in applying the "Make or Buy" policy introduced by the Minister of State for Science and Technology in 1972. We shall consider each criterion in turn.

Government R & D should be performed in-house:

(1) "where questions of security prohibit industrial involvement (this would apply to a very small fraction of classified projects);"

This criterion largely speaks for itself and requires no clarification. It provides one reason, although by no means the only one, for the establishment and continued existence of the research establishments of DND.

The second criterion is vague and open to wide interpretation, yet it probably defines the most important role of government R & D establishments.

Government R & D should be performed in-house:

(2) "where the R & D requirement needed to perform the mission of the department is inappropriate to industry, or where no suitable industrial capability exists and it would not be of benefit to Canada to create one."

Considered from an historical viewpoint, this is the single most important criterion in the creation of a governmental research establishment. Whether or not it applies to each of the numerous establishments is, of course, an entirely different matter, and a question of vital concern for Canadian science policy. Later in this report, the question is considered in more detail.

This criterion is not easily applied. It is no simple matter, for example, to say unequivocally that an R & D requirement is inappropriate to industry. It may be that the only satisfactory way of establishing an industrial R & D capability is first to establish an in-house government capability. For example, one of the major goals of Canada's atomic energy R & D program was and is the creation of an atomic energy industry with its own R & D capability.

The clearest application of the criterion is the establishments created to perform roles in the area of natural resources and related activities. There exists little private industrial capability for R & D in agriculture, forestry, oceans, inland water and wildlife, and it is doubtful if Canada would benefit by creating private R & D capabilities in these areas. Much of the government's "inventory research" on such things as Canada's geology, weather, climate, soils, etc. is also covered by this criterion.

Government scientists themselves seem to perceive this as the most important role of their establishments. Almost every establishment director who was interviewed made a statement similar to one of the four quoted below.

One role of government R & D establishments is:

"To produce things which people want, but which no one else is prepared to produce."

"To do work in areas where commercial activity would not be viable."

"To do work which needs to be done for the common good, but which industry is not prepared to take on."

"To do research which nobody else could do or would do, but which is required as a public good."

The third criterion is less complex and less important because it does not define a role applicable to all establishments. It is, nevertheless, an important role of many establishments.

Government R & D should be performed in-house:

(3) "where the R & D requirement is essential to provide direct support to a regulatory function and associated planning activities, and where no private establishment independent of the firms being regulated can be found or created, e.g., certain aspects of research associated with food quality, narcotics control, transportation safety regulations and communications."

This criterion largely speaks for itself and justifies much of the in-house R & D of NHW, DOC and MOT. However, there is a small regulatory component in the work of many government establishments attached to departments other than those mentioned above. The fourth criterion reads as follows.

Government R & D should be performed in-house:

(4) "where the R & D requirement is essential to the development and maintenance of a set of national primary standards and in some cases, secondary and consumer standards, including their relationship to international standards."

This is not commonly the prime or only function of an establishment (although it may be the sole function of a laboratory within an establishment), or a major reason for the creation of a particular establishment. Nevertheless, it defines the major role of several government establishments and a minor role in many of them. For example, this criterion covers an important part of the work of the Division of Building Research of NRC. This division's "activities include technical support to the Central Mortgage and Housing Corporation, technical and secretarial assistance to the NRC Associate Committee which has responsibility for the production of the National Building Code for Canada, and serivce on a large number of standards and technical committees, both national and international..."[1] It is similarly an important role in the Division of Physics of NRC, which is responsible for the "maintenance of basic physical standards and calibration of measuring instruments for industries, governments and universities."[2] The Research Station at Winnipeg of AGR, like many other government R & D establishments, has an important if small-scale involvement in setting standards. The Cereal Quality Section of this establishment is "responsible for quality screening of hybrid material from Canadian cereal breeding programs."[3]

The Forest Products Laboratory (Vancouver) of DOE does R & D related to the standards and grades of wood products. This work feeds into the National Building Code. Plywoods produced in Canada have to be certified by CMHC before they can be sold and used, and the establishment carries out the tests required for certification.

The fifth criterion defines an extremely important role which, to a greater or lesser extent, underlies the creation and continued existence of all R & D establishments attached to operating

departments. It is a role fraught with questions and is central to the arguments concerning the nature and future of government R & D in Canada.

Government R & D should be performed in-house:

(5) "where the conduct of research and development is essential to establish and maintain a limited in-house competence sufficient to assess the opportunities represented by the current state-of-the-art, to enable the operating department to perform its mission and manage its contract research in industry."

Although this criterion is specifically related to the establishments of operating departments, it can be considered as defining the role of other establishments unconnected with line departments. One can certainly argue that although NRC or AECL may not be involved in maintaining a competence necessary to a department they are maintaining a competence necessary to the nation as a whole.

It is obvious that this is a criterion which, although necessary, is contentious. How much in-house R & D is <u>essential</u> to establish and maintain an in-house competence? How are we to define what is essential? What is a limited in-house competence? It is unlikely that any two authorities would agree on the answers to these and other questions. It should also be recognized that there may be a considerable difference between establishing a competence and maintaining one. Government scientists themselves consider this to be a vital role and, to a man, those interviewed were of the opinion that once established the necessary competence can only be maintained by a constant involvement of scientific personnel in formulating and undertaking R & D. Their views are well represented by the following two statements:

> "Government must have the expertise to give advice on those activities in which government is involved. But expertise must be cultivated and maintained. Scientific skills can only be maintained if the scientists do science and the engineers do engineering."

> "It is only people who are themselves actively engaged in research and development who can help guide and advise industrial companies who are engaged in active research and development for the government."

Although it is not explicitly covered by this criterion, there is a need to provide the public at large with a body of skills which can be applied objectively. Discussion with government officials both in and out of government R & D establishments revealed perceptions of a role whose value is hard to dispute. One laboratory director expressed it very succinctly:

> "A role of government R & D establishments is to represent a pool of informed but unbiased opinion."

Another director said:

> "You cannot rely on getting the best answer for society from people whose skills are vested in special interests. This is less likely in government R & D establishments."

A scientist expressed a similar view almost with vehemence:

> "It is essential that the government possesses groups of expertise for the purpose of judging that the government is not being snowed, sold, cheated or given bad goods by the private sector."

This role is common to all parts of the government's science complex but probably reaches its greatest significance and value in those establishments unattached to operating departments. In particular, NRC emerges as able and willing to play the role of honest broker in matters of vital importance to the public and for which an informed and objective opinion is required. A very good example of the necessity for objectivity combined with expertise is in the determination of the causes of air crashes.

To some extent the final criterion and the role it defines is a consequence of four of the five criteria discussed above.

Government R & D should be performed in-house:

(6) "where the conduct of research and development is necessary to the effective support and operation of in-house capital facilities which provide central testing and research services which are agreed after appropriate consultation to be necessary to Canadian Industry."

Once again, this defines a role which although not common to all establishments is very important

to several of them. The types of capital facilities referred to in the criterion tend to be very costly and beyond the resources of all or most firms. At the same time, such facilities may be of vital importance to the continued viability of certain industries, enabling firms to undertake the type of research needed to stay abreast of technological changes and needs. Accordingly, it is assumed to be in the public interest for the government to own and operate specialized facilities in order to ensure that all interested parties have equal access. The classic example of such a facility is the wind-tunnel of the National Aeronautical Establishment of NRC. Of a similar nature are the various large hydraulic facilities of the Canada Centre for Inland Waters at Burlington and many of the large and unique facilities at the research establishments of AECL.

The six criteria, in large measure, define the accepted roles of government R & D establishments. However, these six roles apply mainly to the establishments of operating departments (AGR, DOC, DOE, etc.) but rather less specifically to other government R & D establishments, some of which have very particular roles and reasons for existence. Moreover, the six criteria define only the more apparent roles. They do not include roles which have been given, evolved, or in some cases assumed, by R & D establishments. Thus, the roles of the establishments include both those set down in official government statements and those that have slowly evolved in an unplanned and incremental manner. Although these latter roles may not have been officially sanctioned,they appear to be of value; they may in fact be indispensable. Some of these roles have been identified during our interviews with those who direct or work in government R & D establishments.

One additional role is well described in the words of a laboratory director: "An important role of Government R & D establishments is to enable Canada to procure information, research results and technology from other countries which engage in research and development." It should be kept in mind that Canada undertakes only a tiny proportion of the world's R & D. Of the world's ten leading technologically advanced countries, Canada has

about 2.1 per cent of the total qualified scientists and engineers devoted to R & D.[4] Obviously, therefore, Canada's share of total world science and technology is even smaller, and this means that by far the greater part of our science and technology will continue to be imported, as it has been in the past. Government R & D establishments play a role in much of this necessary importation, even though Canadian needs to a considerable extent may be satisfied by the process of free interchange among scientists and engineers around the world, the purchasing of technology from abroad, the technology transfer mechanisms of international firms, and other means. However, in the acquisition of certain kinds of science and technology for Canada, the role of government is indispensable. For example, certain types of R & D tend to be the preserve of governments, e.g., military and related matters and atomic energy. There exists a sizeable interchange of information among the establishments of different countries, but unless a country has something to contribute to the common pool of new knowledge and technology, it is denied access. Hence, for certain types of R & D, government establishments, while doing useful work on their own part, act as collectors and funnels of information from sources larger than themselves.

This role extends beyond the narrow confines of classified R & D. It is characteristic of R & D establishments in most countries to publish some of their work in in-house journals of limited circulation, often intended for restricted audiences. They are used because they are a rapid way of publishing results and information and because not all information is suitable for the learned journals. NASA in the United States produces a very large number of in-house publications and is very generous in distributing them to foreign establishments which have scientific respectability, a moderate research output, and thus something to offer NASA in return. When these conditions are not met, this fruitful interchange may not occur.

This type of interchange applies on a wider scale. For example, the existence of NRC and the reciprocal relationships which it is able to set up with scientific organizations around the world permits Canada to draw on an exceedingly large source of scientific information. This source might not be

readily available to Canada unless NRC itself[5] were contributing to the world stock of knowledge.

There is another perceived role to consider, actually a series of roles that are so closely interrelated as to become a composite. The multi-faceted nature of this role is clearly brought out in various statements made by laboratory directors during our interviews:

One role of government labs is to:

"...Do work where continuity is needed."

"...Do high risk work."

"...Do high risk projects which in the long run may be of great value to science and the community."

"...Do fundamental research in areas where nobody else can go."

Others said:

"There should be one institution where research is unfettered by controls, by immediacy, by specific goals, by time constraints, by shortages of equipment."

"There should be one place where work is allowed to continue even if it does not appear that direct benefits may accrue to the public, to industry, etc."

These related views can be summarized as follows: no matter how energetically or effectively universities and industry carry out R & D, and regardless of whether or not universities and industry have a greater share of total Canadian R & D than at present, there will always exist a certain type of R & D which does not give direct and immediate benefits, but which is nevertheless very important to society, and which can only be undertaken by government if it is to be undertaken at all.

Clearly, there are limitations on the types of work which can be undertaken by both the universities and industry. Industry, unlike government, cannot be relied on to maintain a steadiness in the application of resources to R & D, its expenditures on R & D tend to rise and fall according to economic conditions and the fluctuating fortunes of individual companies. On the other hand, government establishments tend to maintain a sustained level of activity in R & D year after year (an attribute which some would fault). As a result, expertise is always available when needed. There are also limit-

ations on the type of research which can be done in universities. Some relate to facilities and manpower, others to national security. Another limitation is quite simply that of time; university research is not usually undertaken unless results can be published within three to five years.

Thus some government laboratory directors believe that in every major field there should be at least one government establishment involved in long-term, highly speculative work. Untouched by the ups and downs and the limitations affecting R & D in other institutions, and in constant interaction with the universities and industrial laboratories, such establishments would ensure a central Canadian focus in each area. At present NRC comes closest to playing this role. An excellent example of how this role can be interpreted is found at the Prairie Regional Laboratory of NRC. Here, scientists are involved in several on-going related programs whose long-term objective is the production of new plant species. With an apparently growing world shortage of food, the implications of such work could be critical: the production of high protein plants to fill the protein gap, the production of faster growing trees to replenish forests and the production of new plants that will enable society to take advantage of the newest development in agronomy and agricultural technology.

2. Functions, Objectives and Activities of Government Research and Development Establishments

The roles described above define the relationships between R & D establishments and society. They tell us little, however, about what goes on inside these establishments and the factors controlling their intramural activity. For this, we must examine the functions, objectives and activities of the establishment.

The functions of a single establishment are usually subdivisions of the general function of the larger institution or departmental research arm of which it is a part. The research activities of DND, for example, embrace several establishments. Each of these performs some functions within the framework of the program objective which is: "To maintain and advance Canadian scientific and technological knowledge and analytical capability for defence."[6] The Defence Research Establishment

Valcartier (DREV) conducts "research in the fields of armament, surveillance, technology, propellants and explosives, aerospace lasers and weapons sytems analysis."[7] In order to performs its functions, DREV, like all government establishments, establishes short- or long-term objectives and these determine the R & D activities at any particular time. Objectives may be met or abandoned, and therefore particular R & D activities wax and wane. Functions are more permanent in nature and are usually changed only after prolonged deliberation.

Government R & D establishments perform an enormous number of functions. The activities generated by these functions encompass most areas of scientific inquiry and reach into every corner of the nation. Some establishments are oriented toward large scale natural phenomena such as the atmosphere, the ocean, the forests or inland waters. Others are directly concerned with specific bundles of economic activities, such as fishing, mining or transportation. They are remarkably diverse in size, character, and orientation. A tour of all government establishments would exhaust the energy and powers of memory of the most tireless and thorough investigator. He or she would encounter an establishment concerned with mechanical engineering problems, another concerned with environmental medicine, many establishments concerned with agricultural problems, an establishment concerned with fundamental research in chemistry. He or she would find establishments concerned with regional problems and others with broad problem areas of national significance. Virtually every scientific and engineering discipline is represented. A structure as complex as this must be conceptually simplified in order to be understood.

In seeking to analyse the structure of Federal Government scientific activities the OECD Report on Science Policy in Canada[8] used a very simple classification. Federal Departments and agencies with agencies with scientific activities were organized into four main categories according to their individual purposes. These were (1) those concerned with renewable resources; (2) those concerned with non-renewable resources; (3) those concerned with collective needs; and (4) those concerned with research in general.

In the first category belong the scientific establishments of the Departments of Agriculture and Environment. The scientific arms of these departments are large, contain numerous establishments and embrace a wide variety of scientific activities. Individual establishments are typically oriented toward narrow parts of the spectrum of problems relating to renewable resources.

Each of the research stations and experimental farms of the Department of Agriculture concentrates on only a few of the many applied research problems faced by the Research Branch of the Department in meeting its mandate to increase the productivity of Canadian agriculture. Research stations carry out applied research aimed at solving concrete regional problems. Their locations give evidence of this preoccupation: they are determined by the climate, soil and other environmental factors appropriate to the study of specific regional problems. For example, the Research Station at Fredericton is the principal site in Canada for research on the potato crop with emphasis on breeding and genetics, pest and disease management, agricultural engineering and soil and crop management. The Research Station at Delhi, Ontario, is responsible for research on flue-cured tobacco in Ontario, while the Research Station at Winnipeg is oriented toward the development of high-yielding disease resistant varieties of wheat, barley and oats.

In addition, the Department of Agriculture has research institutes which are organized by scientific disciplines. They study general questions of more universal scientific significance, although consideration of ultimate application is inherent in their work. Their location is not dependent on environmental or economic conditions but rather on the existence of an intellectual climate favourable to research. One such institute is the Entomology Research Institute. Its main function is "to provide the National Identification Service for Canada on insects, arachnids and nematodes. To meet this responsibility, the Institute carries out extensive research in taxonomy, biosystematics, and faunistics. The Institute is also responsible for developing and curating the Canadian National Collection of Insects, Arachnids and Nematodes."[9] Other Institutes include those for research on food, soil and animals.

As we have seen in Chapter II, the Department of the Environment possesses the largest scientific arm in the Federal Government. Each of its many research establishments tend to be oriented toward a specific resource; and laboratory locations reflect the distribution of resources. One large section of this complex is devoted to Canada's forest resources, and has functions related to their exploitation, utilization and protection.It consists of regional forest research establishments, responsible for surveys, research and development, together with liaison services responsible for implementing programs at the regional level; research institutes, such as the Forest Fire Research Institute and the Chemical Control Research Institute; and also, two forest products laboratories. Thus, as in the Department of Agriculture, there is "a regional research structure directed toward local problems of immediate interest, and a horizontal structure by disciplines and specific research functions directed toward longer-term fundamental and applied research."[10]

Resources are usually worked on from a variety of perspectives and by the practitioners of numerous disciplines. As a consequence some establishments are large and have complex structures. A case in point is the Canada Centre for Inland Waters at Burlington, Ontario, which contains components of three services of Environment all of which have a direct or indirect interest in Canada's inland waters. Work is undertaken on chemical, geographical, and physical limnology, biolimnology, hydraulics, waste water and water treatment, analytical and microbiological methods, social sciences and water instrumentation. Burlington is also the home of the Inland Waters Directorate, Ontario Regional Headquarters, and as such, has regional programs involving the operation of federal hydrometric and water quality data collection networks, and water planning and management programs. In addition, it is a base for hydrographic charting and the collection and analysis of associated data in navigable waters for a large part of Central Canada. In short, the Centre's responsibility for inland water is both complex and comprehensive.

The second category in the OECD report consists of departments and agencies concerned with

non-renewable resources. For the most part, establishments concerned with non-renewable resources fall under the aegis of either the Department of Energy, Mines and Resources (EMR), or Atomic Energy of Canada Limited.

AECL is responsible for research and development on peaceful uses of atomic energy, in particular, the development of nuclear power systems to meet Canadian needs, and improved applications of radioisotopes and radiation. In performing this function AECL operates research establishments for basic and applied research and engineering development. These are large and complex establishments. Chalk River (CRNL) has a staff of approximately 2400, and undertakes basic research in nuclear and solid-state physics, nuclear and radiation chemistry, materials science and radiation biology, and applied research bearing on reactor physics, fuel development, moderator and coolant chemistry, corrosion and radiation effects on reactor materials, electronics and simulation, and computer studies of costs. Another nuclear research establishment operated in Manitoba has basic and applied research functions. These two establishments represent a considerable investment in equipment, such as nuclear reactors, reactor loops, accelerators, facilities for work on highly radioactive materials, high-speed computers and a very wide range of engineering equipment. There are two other R & D establishments. The first is attached to AECL's Power Projects Group which, among other things, is responsible for nuclear power system design, nuclear consulting services and the development and testing of major equipment items for nuclear power plants. The second is part of AECL's Commercial Products group which processes and markets radioisotopes and designs, manufactures and sells related equipment and services.

The Science and Technology Sector of EMR is another large Federal Government R & D arm with quite distinctive functions. It is subdivided into a number of branches, centres or divisions. Some of these are heavily involved in R & D, such as the Mines Branch, while others devote most of their manpower and resources to the collection and synthesis of particular kinds of data, e.g., Surveys and Mapping and the Geological Survey of Canada. However, nearly all groups have at least a minor

involvement in R & D. Its functions comprise the identification of mineral desposits of economic interest; the production of raw materials by developing new mining technology; the processing and conversion of minerals, metals and fuels by improving methods for recovery and use; and the improvement of the environment by preventing or abating pollution arising from mining, metallurgical and energy producing operations. These functions are subdivided and translated into objectives and activities in the Branch's research centres (R & D establishments). These are mineral processing, extraction metallurgy, mineral sciences, fuels research, mining research, metals reduction and energy and physical metallurgy. In some cases these centres consist of one establishment and in other cases of several. The Mining Research Centre consists of five laboratories. These are Canadian Explosives Research Laboratory (CERL) and Rock Mechanics Laboratory, both in Ottawa, the Elliot Lake Laboratory, the Western Office at Calgary, and the Rock Breakage Group at Quebec City.

In the third OECD category are the establishments concerned with collective needs. Here are found the R & D establishments of DND, MOT, NHW, and DOC. While linked by the common contribution which they make to society, the establishments of the departments differ enormously in their R & D functions, objectives and activities.

The R & D of DOC is highly concentrated in the Communications Research Centre at Shirley's Bay, Ontario, and is concerned with communication systems, the information sciences, satellite communications and radio research. The function of the Health Protection Branch of NHW is to undertake the research and other investigations necessary to protect consumers against health hazards and fraud associated with drugs, cosmetics and medical supplies, and against health hazards associated with foods. Agood deal of research activity is necessary to perform this function, and the branch has a number of laboratories located in Ottawa and other parts of the country. DND also has R & D establishments in various parts of the country, and their functional diversity is wide. One establishment is concerned with fundamental and applied research in improved methods of detecting submerged submarines; another devotes its energies to the study of human

factors and the capacities and limitations of human endurance in different fighting conditions, while yet another is involved in fundamental and applied research on defence against biological, chemical and nuclear warfare.

The fourth and final category described by the OECD report consists of those departments and agencies concerned with research in general. This is a residual category, and as far as R & D establishments are concerned, is almost completely dominated by the National Research Council (NRC). While NRC is concerned with research in general, its various research establishments have specific functions to perform, which could easily be fitted into the other three OECD categories. For example, it can be argued that all NRC functions are concerned with collective needs: some in a very direct way and others in a rather indirect way. The Division of Building Research, for example, carries out a comprehensive research program devised to meet the more pressing needs of the country for science-based information and knowledge in support of the construction industry; in so doing it makes a rather direct contribution to collective Canadian needs. On the other hand, the Division of Chemistry, which devotes much of its energies to fundamental research, is, in contrast, more removed from the ultimate objective of meeting collective needs. Despite their many differences both divisions fall clearly within NRC's broad mandate, "To promote, assist and perform research for the creation of new scientific knowledge and for the application of science; and to promote effective use of national and technological resources for the social and economic advancement of Canada."[11]

NRC has seven research divisions and two regional laboratories. The former consist of scientific divisions and engineering divisions. The Scientific Divisions are Biological Sciences, Chemistry and Physics; while the Engineering Divisions are the National Aeronautical Establishment, Mechanical, Building Research and Radio and Electrical Engineering. The diversity in the functions of these divisions is self-evident from their titles. The two regional laboratories are the Atlantic Regional Laboratory which is mainly involved in biological and chemical research and the Prairie Regional Laboratory which concentrates

on the biochemistry of plants, micro-organisms and proteins.

3. Roles and Function Combined -- An Overall View
By now it should be obvious that the large Federal Government R & D complex is highly diverse. It is not a coherent, monolithic entity. It has no administrative or organizational coherence, lacking as it does a central controlling authority and common policies and objectives other than the most abstract and general. This raises a question about the problem of technology transfer. Without a structural coherence, general descriptive statements cannot be made about the scientific activities of government; how, therefore, can one make general and meaningful statements about technology transfer from the many scientific establishments operated by the government?

A corollary to the above is that there is no such thing as the typical government R & D establishment. This will become even more obvious when the structures, operations and relationships of R & D establishments are explored later in this chapter.

We have described the various roles carried out by research establishments; that is, we have given reasons to explain why there are government R & D establishments. No single set of reasons adequately covers all establishments. Some are centrally involved in this or that role, but not at all in others. Some establishments exist for several reasons, the existence of others can only be explained in terms of one role. Those who search for uniformity will be disappointed. The differences among government R & D establishments deriving from differences among roles cannot and must not be waved away as insigificant. They are crucial and must be recognized as such. Critical analysis of the performance of establishments in research, development and technology transfer, if it is to be of any value, must recognize the different foundations on which the establishments have been built. This rather obvious and fundamental consideration has received scant attention in most studies of government R & D or of policies for it.

We have illustrated through example the great variation in the functions of establishments.

Functions are roles translated into on-going programs of R & D activities to fulfil specific objectives. Roles are several in number and vary in their relative importance from one establishment to another; functions, however, are numerous and serve to differentiate each establishment. In functions each establishment is unique; there is no other establishment quite like the Atlantic Geoscience Centre, or the Chalk River Nuclear Laboratories. In recent years there has arisen a strong tendency to ignore or forget the reasons why particular establishments were founded and this has led to a general criticism of government establishments. If they are meeting the wrong needs they should be re-equipped or closed down. But they should not be criticized for failing to do what they are not instructed to do, or not equipped to do. There may be many grounds on which these establishments can be criticized: some may have the wrong roles; others the wrong functions; still others the right roles and wrong functions or vice versa. As a number of writers have pointed out, government institutions are characterized by inertia and hence by the slow way they react to new concerns and conditions. There must exist establishments whose roles and functions should be changed to meet current issues.

It may be that even when establishments have appropriate roles and functions, they do an ineffective job. The scope for criticism is almost boundless. Some establishments may be misinterpreting or even subverting their roles and mandates. Others may perform poorly in carrying out their functions. And finally, there may be grounds for criticism in the ways in which the fruits of government research are put to use. This last consideration raises the question of technology and is dealt with in Chapter IV of this report.

4. The Application of Government R & D

We have outlined the major reasons why government R & D is undertaken in government establishments rather than in the private sector, and have described the functions and activities of establishments; we now turn to the question of the use which is made of the work done in them. In the manufacture of commodities, three distinct stages can be recog-

nized: first, the procurement of materials and parts; second, processing, production and/or assembly; and third, sale and distribution of finished goods to the consumer. The first two activities are pointless unless followed by the third. By analogy, there is the identification of problems appropriate to the establishments' roles and functions; second, there is the processing and production, namely the R & D and the finished results or information they create, and third, there is the delivery of the results to the consumer.*

In the case of government research (regardless of where it is done), who is the consumer? In a sense, this question has already been answered when we define the general purpose of government R & D, namely to increase the general well-being of the Canadian people. Hence, we are all of us the market for the output or finished product of government science. However, this finished product may go through various stages of consumption, and indeed modification, before it ultimately benefits the public at large.

This short section describes consumers of government R & D, but for the moment we shall refrain from examining the mechanisms which connect the users to the government science complex.

The first major category of user or consumer is the government itself. All governments require information and not just opinion to carry out their function of legislating and managing. Many kinds of information are needed, but certainly the kind generated by scientific R & D is at least as important as other categories of information in facilitating the government's work. Governments are large hierarchical structures; the ultimate government consumers are the legislators, but information usually percolates upwards to them through the various levels of the hierarchy. In relation to DOE one writer has noted, "The major audience to which much of our research is addressed is the departmental policy makers, the Deputy Minister, the Minister, etc... Much of our research is directed towards

* The reader is reminded that the term R & D in this chapter is employed in a general sense and refers to all scientific activities of government establishments.

improving the quality and timeliness of policy decisions on a wide range of water management issues, and supports intelligent decision-making on water management policies and water pollution control programmes, many of which require decisions on federal funding support."[12]

It is also quite common for part of the government scientific complex itself to be the immediate user of scientific and technical information generated in government R & D establishments. In our examination of roles it was observed that government departments have service and regulatory functions and also responsibilities for the development and maintenance of a set of national primary standards. The agencies responsible for such roles and functions quite properly attempt to increase the standard and quality of their work, an endeavour which involves them in R & D. A good example of this is the Atmospheric Environment Service. A major proportion of the activities in AES is not concerned with research per se, but rather with the provision of meteorological and ice services which are essential or important to many activities. Most AES scientists may be described as operational scientists. Nevertheless, because it is constantly trying to improve its weather or ice forecast capabilities, AES does have a research component. Thus the immediate user of the information is the operational part of the very service which has generated the information.

There are many other ways in which the government is the customer for its own information. Its research complex provides information needed for legislation, policy, planning, regulation (and regulation enforcement), the setting of standards, and the operation of services that are usually the preserve of government. The capacity of government to consume its own information is generally underestimated, even by government scientists themselves. As far as we know, measurements of the relative strengths of the different categories of consumption have not been made. They may be unmeasurable. However, we suspect that government itself may be the most important immediate consumer of the scientific and technological information which it itself generates.

Industry is another major consumer. The term

"industry" refers to all economic activity and should not be interpreted as meaning "manufacturing industry" which is but one, and by no means the largest, industrial sector. Hence, we are talking about agriculture, forestry, fishing, primary manufacturing, secondary manufacturing and various exchange and service industries such as communications, transportation, etc. The linkages from the federal government to some industries are not direct, but are through the provincial governments which act as intermediaries. The origin of this relationship is found in the British North America Act which gives the provinces a large measure of control over the natural resources lying within their boundaries. For example, much of the information which reaches the agricultural sector flows first to the provincial governments and their agencies and thence to the farmers.

Many of the major industrial sectors have very little Canadian R & D capability of their own although many firms have access to R & D conducted by a foreign parent organization. The agricultural and fishery sectors have very few sources of scientific and technical information other than the federal government. Firms or agencies engaged in mining, forestry and energy conduct some R & D of their own in Canada but the federal government remains an important source of information. Manufacturing industry probably undertakes a greater proportion of its own R & D than any private industrial sector in Canada. However, as already discussed, its R & D involvement is proportionately much smaller than that of manufacturing in other industrialized countries, and it continues to be an important consumer of the federal government's R & D. Despite this, of all sectors manufacturing has been most critical of the activities of federal R & D establishments, charging that much work is irrelevant to their needs and interests, and calling for better communications between manufacturers' and government scientists, and a greater share of federal spending on R & D. These matters are considered at length later in this report. It is worth noting, in passing, that comparatively few government establishments are directly oriented towards the type of R & D of greatest interest to manufacturing. The clearest cases of direct links are provided by the engineering divisions of NRC. Other establishments, of course, do work which can and

does have important spin-offs for manufacturing. But the tendency to equate industry with manufacturing industry has to some extent obscured this fact.

The third major consumer is the research community itself both at home and abroad. Most scientific progress is achieved by small forward steps, an incremental accumulation of knowledge. Knowledge is circulated around the scientific community by a variety of mechanisms, enabling researchers to build on the achievements or failures of their colleagues. Consequently, the circulation of research findings is essential to the health of the scientific community and to scientific progress, and R & D workers are major consumers of their own product.

It is worth noting that some of the outputs from government R & D are employed to produce goods and services for the ultimate consumer. These products and services may take an infinite variety of forms. We may mention improved air traffic control systems, environmental protection measures that help produce a cleaner and safer environment, new manufacturing processes and products, new jobs, new species of crops and more efficient agriculture, nuclear power stations, new surgical techniques, safer vehicles and so on. In short, all output, at least in theory, leads by a variety of routes, some short and some tortuous, to an improvement of the general well-being.

Finally, some of the output from federal scientific activities goes directly, or nearly so, to the general public. Among other things we may mention weather forecasts, standards, codes and various health protection measures. Such matters are too self-evident to need further explication.

These, then, are the broad categories of consumers of the scientific activities of government establishments. Perhaps these consumers are not always provided with or offered useful or appropriate products; perhaps the mechanisms which link the government establishments to them have flaws; perhaps the needs of consumers are not always sufficiently considered or heeded by the government. It is to these and related issues which later parts of this report are addressed.

5. Internal Characteristics of Government R & D Establishments: Their Physical Nature

The reader may be puzzled, indeed annoyed, at the persistent use in this study of the clumsy phrase "government R & D establishment". After all, there is the much simpler and more commonplace term, "laboratory". Unfortunately, "laboratory" is not a suitable substitute for "R & D establishment"; the two are rarely synonymous. The customary definition of a laboratory is "a room or building equipped with apparatus and set apart for experimental work in the sciences." By that definition the government owns and operates literally thousands of laboratories. These, however, are usually much smaller than the administrative entities which we have recognized as R & D establishments.

An establishment of the most basic sort consists of a complex of laboratories, large or small. Some establishments have only a handful, others have dozens. Many R & D establishments assume other characteristics, and encompass activities, capital plant and equipment which are scarcely compatible with the common definition of a laboratory. Tractors, nuclear reactors, herds of cattle, pig-sties, machine shops, orchards, aircraft, sea-going ships, food-processing equipment and saw-mills are not the expected contents of laboratories. In the mind of the layman, R & D is generally equated with research in the pure sciences, and that research is done in laboratories. But such activity constitutes only a part of the work of government scientists and engineers. It should be obvious from our discussion of roles and functions that government R & D is of such a nature that much of its activity cannot be confined to laboratories *per se*.

The pursuit of R & D requires more than laboratories. The nature and scale of the additional facilities depend on the roles and functions of departments and agencies and their establishments. Establishments vary greatly in complexity, size and equipment. At one end of the scale we have the single small laboratory and at the other we have huge complexes such as Chalk River Nuclear Laboratories, with their several reactors, many laboratories, test facilities, engineering shops and all the infrastructure and facilities necessary to operate a large establishment. The typical agricultural research station has experimental agricultural land,

perhaps some livestock, greenhouses and agricultural implements, as well as laboratories and other facilities. Other establishments require wharves and ships and the facilities related to these. In a few cases the R & D facilities of different departments are placed in the same establishment because of a common R & D orientation and the need for similar types of equipment and facilities. The Bedford Institute of Oceanography, for example, contains elements of both DOE and EMR; EMR has the Atlantic Geoscience Centre, and DOE has the Atlantic Oceanography Laboratory and the Marine Ecology Laboratory. Each of these is in reality a cluster of laboratories concerned with different aspects of the oceans, and they are tied together in a mutually convenient use of a fleet of ships, wharves, engineering facilities, computer facilities, library, and maintenance and administrative services. To describe the Bedford Institute of Oceanography as a laboratory would thus be a quite unjustifiable representation of its true nature. To describe it as a typical government R & D establishment would be to ignore the multi-faceted nature of the government's R & D complex.

6. The Employees of Government R & D Establishments

The core of every research establishment is composed of professional scientists and engineers. These employees have the minimum of a Bachelor's degree (or its equivalent) in either science or engineering; but a high proportion has more advanced degrees. It is unlikely that any scientific or engineering discipline is lacking representation in the government scientific complex as a whole. Hydrologists, glaciologists, virologists, chemical engineers, metallurgists, physicists, mathematicians, zoologists, oceanographers, etc., are to be found in one or more establishments. Naturally enough, the number of skills present in any particular establishment is more restricted; yet even in the smaller ones a wide range of expertise is frequently found.

As one would expect, certain skills are relatively more important in some establishments than in others. The broadest distinction one can recognize is that between scientists and engineers: in some establishments the former predominate, in

others it is the latter. Whichever group is predominant there is nevertheless nearly always a wide representation of interests and backgrounds. For example, the Prairie Regional Laboratory of NRC with only 27 professionals employs such specialists as chemical engineers, biochemists, bacteriologists, chemists and microbiologists. The Defence Research Establishment Atlantic draws on such fields as chemistry, metallurgy, aerodynamics, mechanical engineering, electrical engineering and mathematics. Similarly, the Chemistry Division of NRC contains almost every conceivable type of chemist as well as physicists, chemical, electrical and metallurgical engineers, mathematicians and others. The bigger the establishment the greater becomes the range of skills it contains, so that a huge establishment like Chalk River Nuclear Laboratories provides employment for a very wide variety of specialists.

Nearly all establishments are multi-disciplinary. The range and type of problems tackled in any establishment demands this approach. The individual scientist or engineer working on his own special isolated problem is becoming rare; more and more the problems tackled by R & D professionals are too complex for solution by the practitioners of any single discipline. The ease with which inter-disciplinary work can be arranged and carried through gives the establishments a flexibility which is frequently lacking in Canadian universities.

In most cases, the professional scientists and engineers are outnumbered by non-professional employees who are described as technical, administrative, hourly rate and service personnel, depending on the department, or the establishment. In keeping with the distinctiveness of establishments, the ratio of professional to non-professional staff varies among (and within) establishments in accordance with such things as their size, functions, capital equipment needs and their activities, as well as with the budgetary constraints imposed by the departments or Crown corporations to which they belong. The following tables show employment categories in a number of varied R & D establishments and the non-professional to professional ratios in these and two other establishments.

Table III.1 - Full-time continuing employees at Chalk River Nuclear Laboratories and Whiteshell Nuclear Research Establishment on 31 March 1973

	Prof.	Tech.	Admin.	Hourly Rate	Total
CRNL	482	550	395	906	2333
WNRE	171	210	177	227	787

Source: Atomic Energy of Canada Ltd., Annual Report 1972-73, Information Canada, Ottawa, 1973, p.32.

Table III.2 - The Disposition of the staff at the Division of Mechanical Engineering, NRC, March 1973

Professionals	61	
Technical	215	(includes 75 shop staff)
Service	40	(includes stationary engineers, programmers, stores, clerical, secretaries)

Source: Information provided by the Division of Mechanical Engineering, NRC, Ottawa.

Table III.3 - Summary of Mines Branch Staff as of 31 December 1971

Division	Professional	Non-Professional	Total
Administration	10	23	33
Mineral Processing	36	49	85
Extraction Metallurgy	39	50	89
Mineral Sciences	45	39	84
Fuels Research Centre	31	32	63
Mining Research Centre	27	26	53
Metals Reduction and Energy Centre	20	19	39
Physical Metallurgy	59	80	139
Technical Services	3	70	73
Total	270	388	658

Source: Department of Energy, Mines and Resources, Mines Memo - 1972, Annual Review of Research Investigations of the Mines Branch, Mines Branch Admin. Report, ADM72-1, Ottawa, 1972, Appendix A, p.9.

Table III.4 - Non-Professional per Professional in Various R & D Establishments

Establishment	Non-Profs. per Prof.
Chalk River Nuclear Laboratories	3.8
Whiteshell Nuclear Research Establishment	3.6
Division of Mechanical Engineering	4.1
Mines Branch, EMR	1.4
Defence Research Establishment Valcartier	5.4
Defence and Civil Institute of Environmental Medicine	3.5

Sources: Derived from Organisation for Economic Cooperation and Development, Reviews of National Science Policy: Canada, Paris, 1969; Canada, Treasury Board, Estimates for the Fiscal Year Ending 31 March 1974, Information Canada, Ottawa, 1973; Defence Research Board, Defence Science in Canada: A Brief Prepared for the Management Review Group, Plans Report 71-4, Department of National Defence, Ottawa, 1971.

Table III.5 - Division of Building Research, NRC, Research Staff Time Record for 1972

Activity	Percentage of Total Staff Time
Research	64
Education	17
Administration	7
Standards	5
Codes	6
Testing	1
Total	100

Source: Information provided by the Division of Building Research, NRC.

The number of occupations embraced by the term non-professional is large. Some of the occupations may seem surprising. They include typists, laboratory technicians and assistants, clerks, skilled tradesmen of all sorts, truck drivers, labourers, computer technicians, cooks and waitresses, and others such as byremen, seamen, and ships' capitains. The Atlantic Oceanographic Laboratory, which provides the ship services for itself and all other R & D activities at the Bedford Insitute of Oceanography, uses 241 work-years (man-years) per annum for its ship alone.

The point should be clear. The government's R & D establishments consist of much more than laboratories as these are conventionally understood, and the government's professional scientists and engineers, while they constitute the indispensable core, are outnumbered by different types of non-professional employees without whom the establishments could not function.

As with most other characteristics of R & D establishments we cannot say there are typical patterns of activity among professional scientists and engineers. Few establishments were able to provide us with breakdowns of staff time allocation, as shown in Table III.5 for the staff of the Division of Building Research, NRC. The figures should be taken as illustrative rather than as representative. They show some of the variety that exists in the work of the R & D staff. In this particular case research per se is the dominant activity. However, its dominance extends to just under two-thirds of the total activity. It should be remembered that 'research' includes everything from doing experiments to writing reports. A sizeable proportion of time is given over to "education". This covers such activities as answering inquiries, giving advice on problems posed by outside individuals, committee meetings, professional meetings, talks, lectures, seminars and workshops. Then there is administration and other activities relating to codes and standards. A certain amount of time may be spent outside the establishment in helping industrial firms with development or other problems. On occasion, a government engineer may be loaned to a firm for several months to assist it, for example, in its work for a fully funded development contract.

As will be discussed in more detail elsewhere in this report, the committee system is an important device for the transmission of information and knowledge from establishments to other parts of the government and to bodies outside the government. In 1971, for example, the 270 professionals of the Mines Branch of EMR held positions in over 350 committees. These included technical committees of international organizations, such as the International Copper Research Association, and the International Organization for Standardization, United States and Commonwealth organization, numerous committees of the federal government, departmental and interdepartmental, as well as the committees of various private or semi-public organizations in Canada. Most other establishments participate in committees to a commensurate degree.

The intramural activity of government establishments is therefore more varied than one might expect. Of course, R & D occupy most of the professionals' working hours, and that seems entirely appropriate in view of the broad purpose of these establishments.

7. The Place of R & D Establishments Within Government Departments

Since most establishments are part of operating departments, it is reasonable to expect that relationships with departments have an important bearing on the programs and activities of establishments. However, before examining how these relationships affect R & D programs, there is a need to understand the place of R & D establishments within departmental structures. This sets the scene for more detailed consideration of establishment-department relationships, and serves to correct a number of widely held misconceptions.

First, however, we deal with the exceptions. Neither NRC nor AECL constitutes the research arm of a department. Each is unique. Both institutions enjoy a high degree of autonomy, and their R & D establishments have no direct formal connections with any operating department.

NRC was established as a Crown corporation under the authority of the Research Council Act. It enjoys considerable autonomy, both in its administrative management and in its scientific activities. The Council reports to Parliament through a designated Minister. The Minister now responsible for NRC is also Minister of Public Works and Minister of State for Science and Technology. These are formal, extramural ties, linking NRC to the upper governmental decision-making groups, and have virtually no influence on the intramural activity of NRC.

There are some strong similarities between NRC and AECL. The latter is also a Crown corporation, reporting to the Minister designated for the purposes of the Atomic Energy Control Act - at present the Minister of Energy, Mines and Resources. In a sense AECL now represents a very special offshoot of EMR, although in fact it grew out of NRC. EMR has the federal responsibility for energy; AECL has an R & D responsibility for a very specialized and highly complex type of energy generation, namely, nuclear energy. Therefore, AECL takes care of part of the wider mandate of a department, and in so doing differs from NRC. To all intents and purposes AECL is its own master, and not subject to influences and directives from EMR. It has great autonomy and exercises very strong control over the formulation of its R & D programs. However, nuclear research is very expensive and new ventures require vast expenditures of public money. The truly major decisions, e.g., whether or not to develop a new type of reactor, cannot be made by AECL itself; their magnitude and their political and economic implications require a decision by Cabinet.

Typically, an R & D establishment is a component of a research arm which in turn is part of an operating department. Specifically, the departments which concern us here are Agriculture; Energy, Mines and Resources; Environment; Communications; National Defence; Transport; and Health and Welfare.

In the formative stages of the study, we conceived of R & D establishments as occupying a position analogous to the R & D arm of a corporate entity. Logically, in the context of technology transfer to the "outside world", this led us to

believe that we should concern ourselves with two separate sets of interactions. First, we assumed there was interaction (including technology transfer) between establishments and the operating departments to which they belong. We supposed R & D establishments to be controlled by departments, yet removed from the main stream of activities of their departments. Put another way, we expected these establishments to be rather separate and distinctive parts of their departments, working in response to directives and problems posed by the "operational" parts of their departments. Our conception is crudely represented in Figure III.1. Orders, commands, requests, flow from a department to an R & D establishment, and information and knowledge flow back in response. At the same time the establishment receives information from its area of concern in the private sector (or more generally, the outside world) and responds with a counter flow of information, knowledge and technology.

In accordance with this concept we designed two questionnaires to further our investigations of technology transfer. The first was intended for what we described as the 'operating source' of a department, and the second for the R & D establishments assumed to be working for the operating service. It did not require many interviews to reveal the inappropriateness of our assumptions. Respondents were rather baffled by the distinction we had assumed to exist. In general, there is no clear separation between R & D establishments and the rest of their departments. An R & D establishment is part of a department's research or scientific arm, which is a fully integrated part of a department just like most other parts. A diagrammatic representation of AGR (Figure III.2) serves to illustrate this and to demonstrate the wrongness of our assumptions. This should not be regarded as a general model of the structure of government departments. Each is unique and has its own structural peculiarities. Nevertheless, the model brings out elements which are common to all departments with research arms.

There are four major components in this particular department as shown in Figure III.2. First, there is a component, common to all departments, concerned with the overall internal administration. It handles such things as property and buildings

Figure III.1 - Assumed Departmental Structure

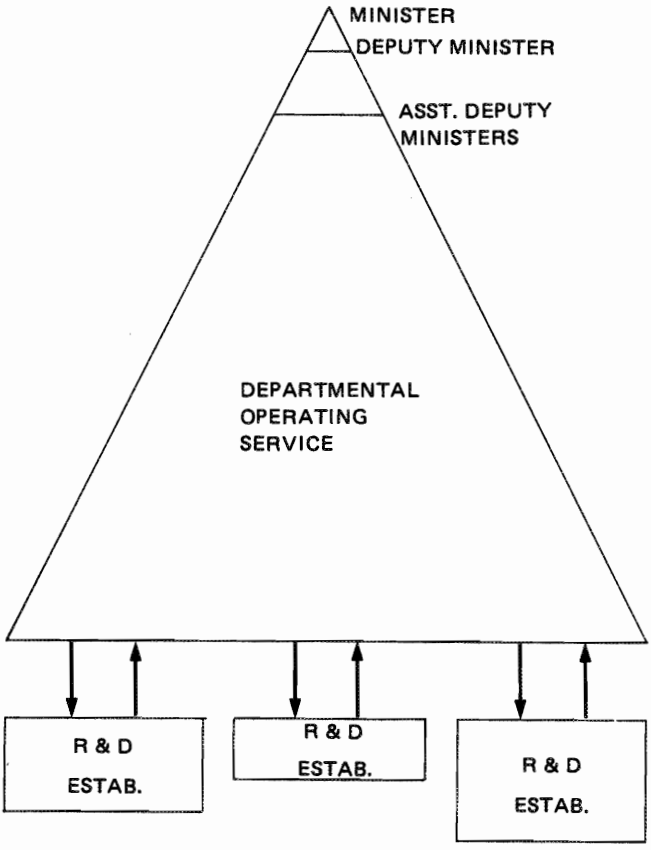
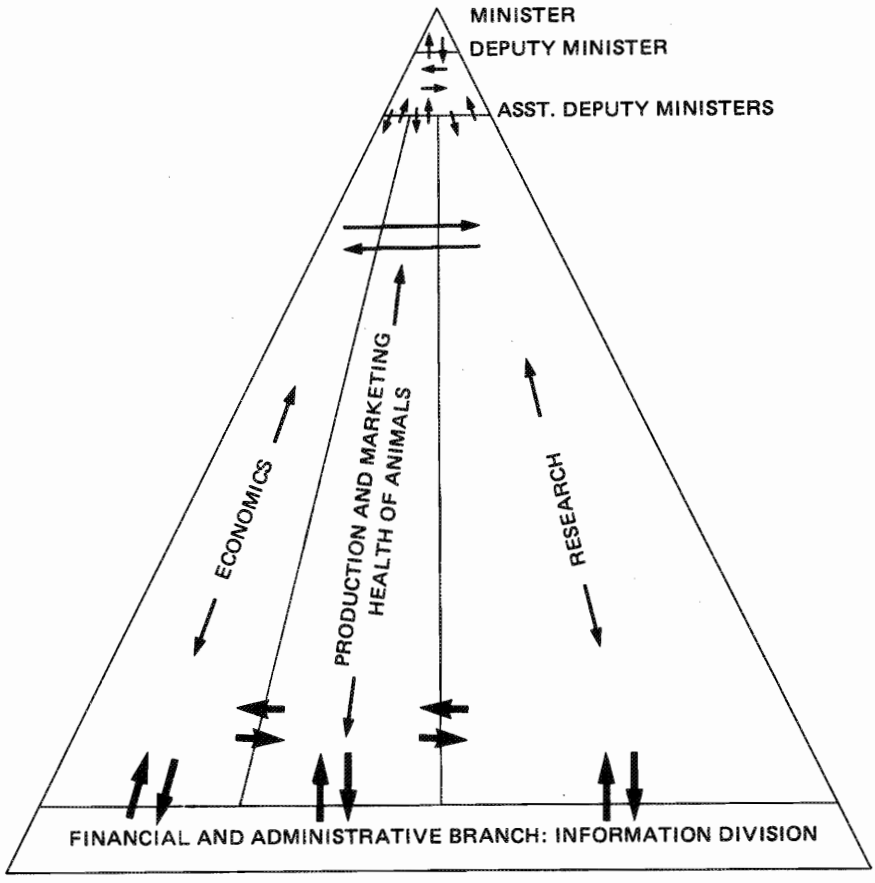


Figure III.2 - General Model of the Department of Agriculture



management, libraries, financial and personnel administration, etc. Services are provided for the whole department so we have placed this component at the base of the structure. Included in this base is the department's Information Division which provides services needed to facilitate communications with the outside world.

The rest of the structure consists of the operational part of AGR. This is by far the greatest portion of the department and is where the department's mandate is carried out. Obviously, its structure will vary enormously from one department to another. In this case there are three components, of which one is research. For the moment, its internal structure is of no concern: what does matter is the fact that the research component is neither organizationally separate from, nor subservient to, the rest of the department. It is an integral part of AGR and, indeed, is its largest single component.

Like the other two components, research reports to an Assistant Deputy Minister, who in turn reports to the Deputy Minister. Research, therefore, sits parallel to the other major parts of AGR, and like them contributes directly to the department's aims, objectives and functions. Because the research arm is an integral and very large component of the operational part of the department, there is much less need for the transfer of technology within the department than was implied in our initial model. The research arm is 'of the department' rather than merely linked to it, and naturally need not transfer technology to itself.

The establishments, found in greater or lesser numbers within departmental scientific research arms, are subject to considerable control from the upper administrative echelons of the arm, but the research arm as a whole enjoys a high degree of autonomy, just as do the other components of a department. Each assumes part of the total responsibility or mandate of the department. Each has an internal structure appropriate to the departmental functions assigned to it, and each is responsible for interaction with the outside world in fulfilment of those functions with which it has been charged.

However, the research arm does not exist in complete isolation from the rest of the department, despite its considerable autonomy. Diagram III.2 shows, in a broad way, the three types of major intradepartmental connections; horizontal, vertical and composite, or those which have both vertical and horizontal components.

a. Horizontal. On both a regular and sporadic basis requests and information flow backwards and forwards between units of the research arm and units of the other major operational components of the department. For example, an R & D unit may continuously devote part of its energies to the generation of knowledge required by a regulatory unit in another part of the department. Other interactions are sporadic and tend to occur at all levels of the departmental structure. For example, the section head of an R & D establishment may provide information to someone with a problem in the economics component. There is a lot of informal interaction in all departments, horizontal or approximately so in direction, which puts little demand on the resources of the units involved in it.

Under horizontal interaction we should note again the existence of committees. All departments contain many intradepartmental committees. These bring together members of diverse units, and facilitate information exchange, coordination and cooperation among different parts of a department. They are an important vehicle for facilitating interaction and preventing isolation in the departmental components.

b. Vertical. This is quickly dealt with. Here we are referring to the connections upwards to the assistant deputy minister and downwards from him linking the component's various chains of command. These connections are important for policy formulation.

c. Composite. Where one component has a problem which can only be solved with extensive aid from the R & D component, the interactions, at least initially, are less likely to occur in a simple horizontal fashion. Interaction is more likely to move upwards to the top of the structure of the initiating component, lead to discussions among the ADM's of the components concerned, and then proceed

downwards through the structure of the research component to the specific R & D establishment where the research will be performed. However, once everything is arranged, there may be horizontal interaction between the R & D establishment and the unit which initiated the request for the work.

Examination of other operating departments reveals some variety in their structures, but the positions of their research arms are similar to that of the AGR. Each department has its own peculiarities, and each research arm relates to its department in its own special way. Nevertheless, the common elements outnumber the unique.

For example, DOC has the following broad objective:

> "To foster the orderly development and operation of communications for Canada in the domestic and international spheres."

This is divided into the following sub-objectives:

> "To foster, develop and introduce new communications sytems, facilities and resources.
>
> "To foster, develop and extend telecommunications services to obtain optimum benefits for Canada in the short and long run.
>
> "To protect and sustain Canadian interests in international telecommunications systems, services and undertakings.
>
> "To improve and extend the utilization of the radio frequency spectrum to permit the development and growth of radio communications."[13]

Clearly, R & D is built into the mission of the department and is not merely an adjunct to that mission. The sub-objectives described above are shared among three components. These are, the operations component, which is dominated by regulatory functions, the planning component and the research component. As in AGR research is not subservient to the other components; it is separate yet works in conjunction with them. Each component reports to an Assistant Deputy Minister, and the R & D compon-

ent interacts both horizontally and vertically within the department. Both types of interaction are equally important. A major function of the research component is to provide the advice needed for the development of policy and plans. This entails both a vertical connection with the ADM (Research), and beyond to the Deputy Minister, as well as horizontal connections with various units or personnel of the planning component. Such connections also act in the other direction, for the planning component may make specific requests to the research component for research to be undertaken on a particular problem. Similarly there is reciprocity between the regulatory and the research components. Although well integrated into the total departmental structure, the research component maintains a high degree of independence. Naturally, all its work must respond and be relevant to the national policy for communications developed by the department, but much of the initiative in interpreting that policy is the research component's responsibility. For example, some of the functions of the research component include:

> To demonstrate or verify the potential of new communications systems and systems concepts in meeting changing national needs; to examine and promote the use of new methods for systems analysis and systems synthesis in a complex communications environment, to develop and maintain technological competence in the industry so it can better respond to national and international requirements for cost-effective systems, sub-systems and components.[14]

In these functions the research component is very much its own master and in fulfilment of them interacts directly with industry, universities, other government departments and various other bodies. Put another way, the research branch is an integral part of the department, and exercises the department's responsibilities inter- and intramurally as far as research is concerned.

To close this section we must consider the special case of DRB. Since April 1974 the research establishments of DRB are operated directly by DND, although DRB continues to function in an advisory and review capacity. The Board is under the aegis of DND but its relationship to that department is

unique within the federal government structure. Like the research components of other operating departments, DRB enjoys considerable autonomy. It differs markedly, however, in its self-containment. DRB is more or less an organizational entity and strictly speaking cannot be regarded as a mere component of a department. It is essentially a civilian agency, both in staff and management. "In form, its management is rather like a board of directors. It is headed by a Chairman and Vice-Chairman. Several members are appointed ex-officio; they represent the armed forces, the Deputy Minister of National Defence and the National Research Council. The other members are appointed for three-year terms. Eight members of the Board represent the administration and eight come from the Universities."[15] In liaison with the department, DRB provides advice to the Minister, conducts technological assessments of defence science capabilities and monitors the programs of the R & D establishments of DND. Its upper administrative echelons interlock in a number of ways with DND. Some of these interlocking devices are summarized in the same report.

> The Chairman of the Defence Research Board has a seat on the Defence Council with the heads of the General Staff, the Deputy Minister and the Minister of Defence himself. In this capacity and through these channels, he is able to make known the views of the Defence Research Board at the highest decision making level.
>
> Furthermore, a number of scientists in the Defence Research Board belong to the technical services organization of the Department of Defence, responsible for planning and coordinating development programmes.

In the performance of its practical day-to-day work, DRB makes use of a variety of liaison systems at lower levels in its hierarchical structure. Two senior scientists are on full-time duty as Scientific Assistants to the Vice Chief Defence Staff and Chief of Personnel. They also provide a Scientific Adviser to the Commander, Northern Region H.Q., to the Commander, Mobile Command, and to the RCMP. Additional scientists are posted to other Canadian military headquarters throughout Canada and abroad.

The R & D establishments are not the responsibility of DRB but are controlled in the upper echelons of DND. The Operational Research and Analysis Establishment provides a good example of how the establishments cooperate in DND. ORAE conducts operations research, war games and systems analysis on behalf of NDHQ and the various Command Headquarters; strategic arms limitation analysis on behalf of DND and EA; manpower, logistics and statistical analysis on behalf of the Defence Council and other senior decision-making groups. By nature, therefore, ORAE is an interface institution, connecting the scientific arm, the armed services and DND. Its role is reflected in the composition of its professional staff: military officers (30 per cent) and scientific officers (70 per cent). The connection between the scientific arm and the armed forces is two-way; scientists are posted to armed forces establishments and armed forces personnel are posted to R & D establishments, most of which have several attached military officers.

8. R & D Establishments and Program Formation

The work undertaken in any R & D establishment relates first to the mandate and objectives of the department or agency of which it is a part, and second, to the specific departmental or agency sub-objectives assigned to it. Major objectives and sub-objectives are usually pursued for prolonged periods of time, hence the broad outlines of R & D programs are pre-determined for equally long periods of time. Of course, there is always scope for different types of work within the framework of objectives so that programs can and do change in character from year to year. Continuity is especially evident in establishments with a surveying or monitoring function. Normally an establishment's objectives and functions are divided into a number of sub-objectives and sub-functions. These, too, may have considerable durability which is frequently expressed in the physical and administrative organization of the establishment. An establishment is often composed of a number of laboratories each of which corresponds to one of its objectives and functions. In some other establishments the major subdivisions corresponding to sub-objectives may be called divisions, or branches, or even sections.

The Mines Branch of the Department of Energy, Mines and Resources is composed of a number of activity centres or divisions which have both administrative and physical expression. These are: mineral processing, extraction metallurgy, mineral sources, fuels research, mining research, metals reduction and energy, physical metallurgy and technical services. Each of these reports to a division chief, head of centre of resident manager and each represents a broad and long term set of functions.

Each activity centre or division is composed of a number of groups or sections, whose titles identify their major preoccupation. For example, the Physical Metallurgy Division is composed of the following groups or sections: Corrosion, Engineering Physics, Ferrous Metals, Foundry, Mechanical Testing, Metal Physics, Nondestructive Testing, Nonferrous Metals, Nuclear and Powder Metallurgy, Refractory Metals, and Welding. It should be noted that some of these exist chiefly to provide Technical Services to other section of the division or to other divisions of the Mines Branch. Although these groups or sections are comparatively lasting, at this primary level of subdivision of the work program there is a likelihood of structural rearrangement from time to time, caused by the adoption, completion or abandonment of projects. At this level decisions on the program are usually made on an annual basis.

The Mines Branch is a rather large scientific organization, but even so, the structure of its work program bears a strong similarity to that of other R & D establishments both large and small. The Agricultural Research Station at Summerland, BC is small as establishments go, yet like the Mines Branch, it is subdivided into sections with a fairly high degree of permanence. These sections are agricultural, engineering, animal science, entomology, food processing, plant pathology, pomology, and soil science. The sections reflect the objectives and functions of the Station and until such time as these are changed, they will continue to exist. However, they may vary in size and importance from one year to another depending on fluctuations in research priorities. Within the sections, there is quite frequent change in research activities as projects are adopted or terminated.

Within the research program of DND, the terms "technical program", "project" and "task" describe the major units into which R & D activities are divided for purposes of resource allocation and management.

A technical program is a group of related projects, and is the primary unit considered in allocating resources of manpower and money. The Defence Research Program is divided into twenty technical programs which cover various fields of science and technology. A technical program is normally limited to one laboratory and usually has a life of several years.

A DND laboratory usually has several technical programs. For example, in 1972-73 the Defence Research Establishment Valcartier had the following programs: ordnance research; advancement of laser technology; optical and acoustic sensing technology; rocket technology; special laboratory support services to Canadian Forces; acquisition, development and improvement of major research facilities.

Technical programs are normally subdivided into projects, which are the basic units considered and managed at the establishment level for the Research Program. A task is a specific piece of research or analysis, usually of short duration, which is part of the work of a project. It is used by the project scientist or division manager for organizing and managing the work program below the project level.

This subdivision of the (DND) program into technical programs, projects and tasks enables managers at each level to examine a limited number of subdivisions of effort about which they can be well informed concerning the current priorities, progress and potential.[16]

There appears, therefore, to be a definite pattern in work organization in government establishments. There are several levels of organization which are differentiated according to the breadth of their definitions and their degree of permanence. The broadest level need not be considered in this section for it relates to the objectives and functions discussed earlier in this chapter. Fur-

thermore, decisions regarding changes in the broad objectives and functions of establishments are not made wholly within the establishment or indeed the research arms themselves. These are unique and very occasional decisions made at high levels within the government. The remaining activities are decided within the research establishments themselves and it is these to which we turn our attention.

9. The Inputs to Program Formation

The proposals which may ultimately be incorporated into work programs originate from many sources, and are developed by means of a variety of mechanisms. The effectiveness of technology transfer is directly tied to the work which an establishment performs. Work must be relevant to needs, whether these be private, public, industrial, agricultural, governmental or other. In the sense in which it is used here, relevance ultimately depends on the quality and quantity of information on needs and problems which reaches the establishment and which is appreciated and assimilated by its professional staff. In short, technology transfer is related to the informational inputs flowing into the establishment, even though the process of technology transfer involves the outflow of information from the establishment.

The question of inputs to the establishment is highly complex and before deriving any general statements, it is useful to illustrate how one establishment obtains information on needs and problems relating to its area of responsibility. This example serves to illustrate the intricacy of the mechanisms employed by establishments in keeping informed on the many problems to which their scarce resources may be allocated.

The example chosen is the Division of Building Research (DBR) of NRC. The Division can be described as an information agency; in broad terms it exists to provide information to the building industry and to consumers of the building industry's products. To do this DBR carries out research for the purpose of meeting informational needs that cannot be met elsewhere in the country.

The Division's research program is determined through a process of interaction between the di-

rector and his staff, and between the staff and industry, other government establishments, construction associations, etc. All interactions, whether they are initated within the establishment or outside contribute to the continuous flow of information which is so essential to the formation of a relevant work program.

An important source of information on needs is provided by the many inquiries addressed to the Division. In a normal month DBR handles approximately 1000 inquiries. They come from a variety of sources and take many forms. Most frequently they originate and end with a single phone call or letter. But many of them can lead to meetings or provide the starting point of a research project or even a program. Inquiries are classified into three types. These are technical inquiries, which account for 63 per cent of the total; inquiries relating to the National Building Code (19 per cent); and inquiries about building research in general (18 per cent). The division also categorizes the inquiries as follows: private individuals, 25 per cent; government agencies including federal, provincial and municipal, 21 per cent; manufacturers and suppliers, 15 per cent; consulting engineering, 11 per cent; architects and designers, 9 per cent; research agencies including universities, 7 per cent; contractors' representatives, 5 per cent; general business representatives, 3 per cent; and other, including school teachers, 4 per cent.[17] Through these inquiries the division receives an enormous amount of information on problems and needs.

Inquiries flow into DBR at all levels. Some enter at the top, others at all levels down to the bench scientist. If inflowing information generates a proposal for research among scientists in the lower levels, the proposal will be processed upwards through the Division's organizational structure. Alterntively, ideas, inquiries or information coming to the director, say, from another government agency, may be channelled down to the bench scientists for consideration as possible sources of research projects.

These information inputs are only one means whereby DBR obtains an indication of what research might usefully be undertaken. The Division has actively developed a host of interaction mechan-

isms. Many of them have the transmission of information as their primary objective but at the same time they provide feed-back that gives insights into where problems lie and what type of research is needed.

The Division sends out numerous publications that provide information on a variety of problems and subjects and the demand for this literature gives some idea of information needs. In addition, a series of two-day Building Science Seminars is presented by the staff every year to about 600 persons in Ottawa and Calgary. Since 1964 twelve seminars have been presented, and have resulted in an increased demand for printed and taped materials, and in requests from a variety of institutions and agencies for the participation of staff in educational programs.

Formal means of communication have been developed to increase the knowledge of different occupational categories within the building and associated trades. These include workshops for on-site contractors, two-week courses for teachers from schools of architecture and institutes of technology, and seminar programs for architects and engineers in the federal civil service. Less formal activities are carried out on an even wider scale, with professional staff delivering lectures and participating in discussion groups in many different organizations. The Division is also involved in seminars and workshops for construction supervisors, in courses, lectures and talks to students, and in upgrading courses for plumbers, pipefitters, bricklayers, etc. Information is also exchanged through participation in national and international trade and professional associations and societies, and in regional associations and committees. Committees are regarded as very important vehicles for interaction and in 1972 the staff of the Division held 488 positions on committees, of which 292 were in codes and standards.

With so many interactions creating such a continuous influx of information, the major problem faced by DBR is not one of finding useful projects to undertake but of deciding the priorities among the many urgent problems requiring investigation.

The Division of Building Research is of course only one out of hundreds of R & D establishments maintained by the government. In its roles and functions, in the orientation of its interactions, and in the information it gathers and surveys for the purposes of achieving relevance in its work program, it is unique. Similar descriptions could be given for other establishments. Suffice it to say here that each establishment orients its interactions in directions appropriate to its roles and functions. However, the nature and type of inputs vary tremendously from one establishment to another. Except for establishments attached to the same operating department, or the same agency, it is not easy to discern any pattern or derive any valid general statements on the nature of the inputs to program formation or on the way in which such inputs are procured.

External inputs may be categorized in the following manner. First there are inputs from other parts of the same department or agency. They include both formal and informal, regular and sporadic communication between professionals of the same or different rank in different parts of the same research arm. Such inputs may flow vertically and/or horizontally within research arms and establishments. Intra-departmental committees frequently play an important role in moving information between different parts of the same department.

The second major set of inputs consists of the flows between different departments and agencies within the federal government and between units of the federal and provincial governments. These flows may be chanelled, or they may be highly personal sporadic communications between individuals and groups both within and without R & D establishments. Departments communicate their needs to each other, and take advantage of each others' special skills and equipment. At one time or another most establishments undertake projects for other parts of the government structure.

The third category consists of information flows between R & D establishments and private bodies and organizations. This refers to interactions with industry, professional associations, nonprofit organizations, consultants, etc. Communication channels of this type take a variety of forms. Objectives and functions dictate the type of com-

munication. Hence an agricultural research station in BC will have completely different communication channels and inputs sources compared with a nuclear research station in Manitoba, or a fisheries research station in New Brunswick. Each establishment reaches towards that sector of the economy, or interest group, or problem area designated as its responsibility.

It is important to observe that comparatively few establishments are directly oriented towards secondary manufacturing industry, and hence only a small minority attempts to develop strong flows of input from that sector. However, in the course of doing work in relation to health, forestry, fishing, or water quality, there is often indirect communication with secondary manufacturing. In our opinion, most establishments, regardless of their prime focus of interest, can benefit to some degree by learning from, working with, contracting to, and simply talking with secondary industries.

The general and specialized information which reaches government scientists and engineers also constitutes input to the establishment. Like all of us, they are bombarded with information and knowledge from day to day and of course are constantly seeking and receiving information associated with their professional training and interests. Every scientist and engineer is tuned in to some extent to the developments and trends in his own specialized field. These professional inputs originate in the journals, discussion papers, conferences, seminars and other mechanisms employed to convey information throughout the scientific and engineering communities. One should also note that there is a certain amount of interchange of staff between universities and R & D establishments, and a number of establishments have post-doctoral fellows. University staff may be permitted to use government research facilities and some government employees hold teaching positions in universities.

The exigencies of policy constitute another major determinant of program formation. The presence or absence of this kind of input frequently serves to establish the form of work program undertaken by an establishment. For example, where the work program is powerfully influenced by new or ongoing policy objectives, there is likely to be

strong mission orientation and possibly no resources available for basic research. An establishment unaffected by policy considerations, however, can be more involved in basic research and is likely to enjoy a high degree of freedom in the formulation of its program. Most establishments, as far as it is within their power, try to maintain a balance between mission-oriented, or applied, research and basic research, believing that the latter is essential if they are to be able to tackle future problems of application.

In one sense, many inputs occur spontaneously within the establishments from the minds of their scientists and engineers. But in another sense all inputs have their origin in the coalescence of internal and external inputs. New information from a multitude of sources is continually being received, sorted, and related to older information. It is impossible, therefore, to say what proportion of a program is internally generated (i.e. within the establishment itself) and what proportion is externally generated. Ideas, proposal, projects and programs rarely develop out of a single isolated conception. They develop through the conjunction of many different types of information and suggestions with the professional expertise of scientists and engineers.

10. Decision-Making Mechanisms and Program Formation

In this section we attempt to describe how decisions on the deployment of human and material resources of government R & D establishments are made from one year to another. Our interviews revealed a wide variety of ways in which establishments formulate their work programs. In order to demonstrate the differences in approach, some specific cases are discussed in detail.

Within establishments the level at which decisions are made often depends on the amount of money or labour a proposed project or study would consume. In some cases a staff member acting entirely on his own initiative may conduct a small study if it stays within certain financial and temporal limitations. Should the study appear likely to lead to large or long projects, the scientist or engineer may (in some establishments)

on his own initiative proceed with a small pilot project or feasibility study. If this small study shows promising results, then the larger study which it suggests will be decided on at higher levels.*

Regardless of the variations between establishments, the bench scientist or his equivalent is the first level of decision making. At this level there are usually no formal procedures.

The next level of decision making is the section head or his equivalent. Finally, there is the director of the establishment. As a general observation, it appears that strongly mission-oriented establishments do not allow lower level staff to undertake small projects on their own initiative, whereas establishments with a large basic research component accord their scientists a moderate degree of freedom to inaugurate small studies or pilot projects. The following paraphrased statements drawn from interviews at various establishments give some idea of the differences in approach.

Establishment 1. If the implementation of a new idea does not cost much, the scientist may go ahead on his own initiative. Usually he can do a small feasibility study without consulting his superiors. However, an idea involving a major change in program would have to be discussed with the section head, or possibly with the director.

Scientists have quite a lot of "discretionary time". For example, development work may take only 50 per cent of a plant pathologist's time; the other 50 per cent is largely discretionary during which the plant pathologist may pursue projects of

* Cockcroft, op. cit., pp. 39-40, notes that there are often distortions in the nature of the messages which go up from the bench scientist to the director. For various reasons the distortions are generally in the direction of "over-optimistification." These distortions have their origins in the human element of "selling and accepting" the project as it moves up the chain of command to the director. To minimize this problem, the director must attempt to mingle with and know the bench scientists and section heads so that he can more accurately gauge the capabilities and capacities of the staff.

his own personal choice. Such work, while usually basic, is invariably important to his development work.

Establishment 2. Once the work program has been laid down, there is little time left for scientists to pursue additional work or to pursue special interests of their own.

Establishment 3. An idea has to be oriented towards the objectives of the establishment. The idea or proposal is evaluated at various levels. If a proposal looks promising, it will go the establishment's management group. If the proposal is accepted and involves less than half a man-year, then the Director will authorize the project. To some extent the cut-off depends on whether or not the idea or the project fits into the on-going program.

Establishment 4. If a new idea requires only a slight change in the program, it will probably be approved by the section head, who has a limited discretion in the allocation of funds. A major idea requiring a larger change would have to be inserted in the new budget and approval sought in Ottawa.

Establishment 5. The program is so mission oriented that there is little scope for the development of ideas and projects by the professional staff. Indeed, there is no need for the development of new ideas by the staff.

Establishment 6. Every project, large or small, goes through the hierarchical chain of evaluation.

Above the individual scientist, and the section head or division chief, the next level of decision making is the director of the establishment. It is rare, however, that a director is free to make decisions about the work program totally unaided. Usually there is an advisory group drawn from within or without the establishment, or some type of management group headed or controlled by the director.

At the director's level, major differences emerge between establishments; differences in the degree of independence in formulating programs, and

in the type of decision-making mechanisms employed.*

Establishments also vary in the degree to which they can allocate their funds without the consultation or approval of authorities located outside and above the establishment. The range is from virtual autonomy to a rigid accounting of amounts spent. In one establishment we learned that the Director, in theory, has the sole responsibility for the allocation of the $4 million annual budget. In practice, he consults on a continuous and informal basis with his senior professional staff. At the same time, however, other more formal mechanisms require that annually every section head has to defend his part of the budget on the basis of previously declared objectives. In addition, the Director is aided in his evaluation on on-going and proposed work by an advisory board composed of experts from within and without the government.

The director of another establishment which is very independent in program formation argued that it is possible to establish rigid procedures for program formation, the program evolves through discussion, and decisions reflect a slowly reached consensus. His remarks are interesting and worth noting:

> People who say that there are rigid procedures for handling requests, and for turning requests and ideas into projects, are probably rationalizing what are really vague and irregular processes. A $10,000 job doesn't jump out of the woodwork overnight. In the establishment everyone is very much involved in group activity, with the result that there is not much probability of an individual suddenly springing a project on his colleagues. Ideas and projects don't arise in

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* Cockcroft, op. cit., p.5, notes that "The most important problem of a director is to decide, amongst many competing ideas coming from below, which projects to work on, to decide the scale of support and to decide when to drop unfruitful lines. The last decision is the hardest of all, for those working on projects usually believe in them and are nearly always loathe to see them dropped."

a vacuum. In general, ideas are being bounced around all th etime between the bench scientists and the section chiefs, and between the section chiefs and the director.

There has usually been a lot of talking and thinking before we are dealing with something which could be called a new idea. The director is in constant touch with his staff. He talks with his section chiefs every day and therefore always has a good feel for what is happening, what is evolving and what sort of ideas are being developed. The establishment usually starts off with a broad problem or project which may have arisen either in the establishment or outside it. Ideas relating to the broad problem are then bounced around both indside and outside the director's office and slowly the program is evolved through a process of consensus. By the time the program starts to assume a finer form, there are few members of the staff who have not been consulted and had a say in shaping it. (emphasis added)

Another establishment in a different department explained that is experiences very little direct control from Ottawa headquarters over its program. For program formulation it relies on advisory committees, two of which are national and advise other establishments also, and three of which are local and advise only this establishment.[18] To a great extent these committees determine the establishment's program. They meet several times a year to discuss the relevance and significance of

problems which are or could be tackled by the establishment. All told there are 81 people on these committees, and they are drawn from industry, provincial governments, universities and the federal government. Each committee is chaired by someone from industry selected by the director. The program is formulated from two main sources of ideas and information: ideas emanating both from the committees themselves and from the laboratory personnel. At least 50 per cent of the projects originate from the ideas of the professional staff but, like all ideas and proposals, they are processed and considered by the committees, each of which is respon-

sible for one of the establishment's major problem areas. Once all programs and projects are approved by the committees, the scientists' time is rigidly scheduled. Nevertheless the director has some discretionary power. Most professionals have their time specified to within approximately one fifth of a man-year. The remaining fifth, which has not been approved by the committee, can be used for crises and professional consulting. In fact, most of the work which has not had prior approval from the advisory committee is of a "fire-fighting" nature.

A hierarchical decision-making system ascending beyond the individual establishment was employed by the DRB. In order to demonstrate the potential complexity of program formation, the procedures of DRB are described in detail. It is assumed that even though control of the research establishments has passed to DND, the program formation mechanisms employed by the DRB continue in large measure unchanged.

The headquarters staff of DND exercises an overall control of the programs and projects of all the establishments, but the Director-General and Directors, in consultation with headquarters staff, have an important say in the details of the intramural activities of their respective establishments. At the highest levels of decision making, the "headquarters judgement is oriented to the subdivision of resources between groups of projects designated as programs to a general assessment of the value of the overall program and how it might be improved, to assessment of the balance between the long and short term objectives of the program, to assessment and improvement of the efficiency of management and to other policy level assessments."[19]

An important element in DRB's (now DND's) program formulation is planning studies. These

> are coordinated and written by the planning staff of D.R.B. with active participation of laboratory scientists, on subjects either initiated by senior management or by the planning staff. The studies provide the basis for decisions relating to policies or the allocation of resources to the scientific projects in the area of study. They may cover broad areas such as maritime research...or

narrow areas, such as...sonar research. In each study, military requirements for systems or equipments which depend on the research are reviewed. A general policy which should govern participation in that research activity is outlined, and a shopping list of research alterntives is prepared. The alterntaives are evaluated in terms of their potential to meet long term objectives such as maintaining of expertise, short term objectives, such as the solution of existing military problems, or the potential for innovation leading to needed principles of equipment.

Since planning studies cannot be undertaken on all activities at the same time, and the planning staff and senior management must develop an overall five year program forecast on an annual basis, the planning staff prepares an informal annual overview study which utilizes all the information about known military needs, planning studies and progress reports on existing programs which is available at the time. This overview analysis is used to formulate a proposed resource allocation between the existing technical programs and a series of guidelines to research establishments which, after review and modification by the Program Review Group is communicated to research establishments outlining central management's decisions on priorities and levels of resource allocation.[20]

The five year program forecast is central to the allocation sources within and between establishments:

As a first step in the development of a program forecast, meetings are scheduled between the Program Review Group and research establishments represented by the director-general and his senior staff. In each case the headquarters planning staff proposes to the Program Review Group, program subjects and any particular points of concern which are to be the subject of briefings and review at the meeting. These special subjects may arise in cases where the planning process has revealed a change in priorities requiring initiation of a new technical program, or expansion or

> reduction of an existing program, or where major facility expenditures are anticipated ...During these program review meetings, establishments also propose and discuss new work which may be accepted subject to a later presentation of a formal proposal.[21]

It is important to observe that the headquarters staff is not responsible for assessing the priorities or determining the allocation of resources between the various projects which make up a program. This is the responsibility of the Director-General of the establishment. It is part of his job to satisfy headquarters that the allocation of resources among the projects within a technical program is satisfactory. New projects and revisions of existing projects which exceed the Director General's resource commitment authority must be submitted to the Program Review Group for approval. The submission must contain an explanation of the availability of resources from within the overall allocation of resources to the establishment.

> Following the review of establishment programs, the planning staff draws up a draft program forecast with allocation of man-years and funds to individual technical programs. This information along with general guidelines of priority is sent to research establishments with a request to complete the Management Information System annual return providing the details of how the establishment would allocate these resources to projects. The Management Information System return presents resource allocations by project for each technical program for the current year, and the first program forecast year, and is used by the planning staff to build the five year program forecast document, which includes justification of the program and outlines how the objectives are to be met. The program forecast document then goes to the Defence Council and Treasury Board, and after approval, the estimates for the next fiscal year are structured by the Comptroller and research establishments are informed of the specific allocation of funds.[22]

It should be clear from this rather long description that at least in one group of establish-

ments, program formation is a well-planned process. The degree and type of planning varies among departments and there is much variation between establishments in terms of the degree of freedom allowed them to establish their own work programs, and of the formality and rigour of the procedures employed to decide how resources should be used.

11. Program Formation - The Framework of Constraints and Conditions

It is, by now, quite clear that research arms and Crown corporations and/or their establishments can form and change their work programs only within certain recognized frameworks. That is, outer boundaries are set concerning the type of work which may be undertaken. Each establishment has objectives or sub-objectives which are fixed for long periods of time; all elements of the work program must be directly relevant to these objectives.

For some establishments, or laboratories or divisions within them, the question of program formation is of minor concern. These are the establishments or laboratories with an inventory or surveying function. Their objectives and functions are highly specific and the same activities are repeated year after year. Hydrographic surveying, which falls under the aegis of DOE is a good case in point. A large proportion of Canadian territorial water has never been charted, and many areas which have been charted must be re-surveyed from time to time. As one official put it, "the hydrographic surveying is on-going and never-ending work." In the case of this service, as with others with an inventory function, such as the Canada Soil Survey and the Geological Survey, the most important question to be faced is not what work shall be done, but where shall it be done?

In a somewhat similar manner, establishments or laboratories concerned with standards, testing, coding and quality control experience little significant change in their work programs from year to year, and there is generally no need for elaborate decision-making mechanisms.

Another inflexible constraint or condition can be spatial or geographical. For example, in AGR

the research stations and experimental farms, as distinct from the research institutes, are given objectives relating to regional soil, climate and other environmental conditions. A regional constraint is prevalent among establishments concerned with renewable resources (soil, water, forests, fisheries, etc.) but also emerges in connection with such matters as health, defence, basic science and several others.

A quite different set of constraints on program formation is rooted in the professional composition of establishments and in the nature of the research facilities available to the professionals. We have talked of outer boundaries that define the maximum possible range of work in which an establishment can become involved. For many establishments these outer boundaries encompass a far greater range of work possibilities than could possibly be undertaken with their present buildings, equipment and personnel. They must be selective, establish priorities and concentrate on only a few of the alternatives available to them. We may say that there is a set of inner boundaries describing the type of work which can be undertaken by establishments. Over quite long periods of time these inner boundaries are just as real, and perhaps more significant to the establishment than the outer boundaries described by its official objectives. Such inner boundaries, or in more commonplace terms the short-term R & D options of the establishment, are a function of past decisions which have led to the present structure of the establishment: the professional specializations and skills and the types of research facilities.

Over a period of time an establishment can change the position of its inner boundaries. There may be a series of increments to staff, research equipment, or buildings. Often all three are expanded at once. Between each expansion or shift, the establishment settles down to work within its new inner boundaries.

At any particular time, however, the establishment's work program is limited by the staff's professional expertise and by the equipment at its disposal; the inner boundaries. The observations of some directors are of interest in this regard:

Director 1. "Our resources are very limited, and in this situation, it is essential that we choose our problems very carefully and use the equipment at hand. There are so many problems to which we could turn our attention. Our real difficulty is deciding which problems we should tackle. For the most part our research program is pre-determined, a reflection of the fact that from the beginning we selected large broad questions. We are doing on-going things, partly because we get stuck with our technology and partly because our questions are very large. We try to do the best we can with the experimental equipment available to us."

Director 2. "To some extent our program and our work is long-term and partly determined because of the people we have hired and because of our past capital and equipment purchases. Twenty years ago we had hardly any equipment. Now we have approximately $400,000 worth of it. A mass spectrometer costs $75,000. Once you have such an expensive piece of equipment, it's important to get a good man to use it.

"Our programs change slowly and most continue over many years. Our sections have a long life although the particular activities appropriate to any section may have a more short-lived existence. On the whole things are quite fixed."

Director 3. "Once you have acquired a facility such as this there is an obligation to use it. Our work program possesses a solid continuing core. There are many things which you either do continuously or which you strike out completely. Core activity takes up about 90 per cent of the total man-hours of this establishment."

A shift in the inner boundaries allows for a new venture by the establishment; it does not necessarily imply, however, that at the same time old undertakings will be abandoned. There has been a marked tendency for the distance between the inner boundaries to widen through time, that is, a boundary shift is frequently associated with growth in the size of the establishment and new programs are added but old ones are not terminated. This process may be termed incrementalism. This apparent inability to be selective may be one of the major contemporary weaknesses of government R & D establishments.

Incrementalism occurs for a number of reasons and has implications for work programs and their formulation. One reason for incrementalism appears to be the tenure enjoyed by scientists and engineers after only a few years employment with the government. They appear to enjoy a degree of security in their jobs which cannot be paralleled even by university professors. Every director we interviewed explained how extremely difficult and tiresome it is to try to terminate the employment of a professional staff member (and to some extent technical support staff as well). This circumstance can have a profound effect on the work program.

All professional staff members are specialists of one sort or another, and can only be employed on certain types of projects and certain kinds of work. However, although the skills and capabilities of the professionals are fairly fixed (especially as they grow older and their length of service increases), the inputs of skills and professional expertise required change as the establishment identifies new problems. If such inputs cannot be furnished from the establishment's existing labour force, new personnel must be hired. There is a persistent danger, therefore, that long-serving professionals may become of less and less value to the establishment. But since they cannot be dismissed and often cannot be redeployed into new programs, there may be a tendency to maintain old programs (if at a reduced intensity) of diminishing utility. This means that the establishment's flexibility to change its work program is greatly reduced, and that a considerable proportion of its resources may be committed to programs yielding progressively diminishing returns.

If growth of the establishment becomes a prerequisite for the creation of new programs, there is a likelihood of the overall establishment work program becoming stable -- even stagnant -- between major growth periods. The same skills employing the same equipment are applied to variations of an ongoing program. With each year, because of the inflexibility, the value of the work as well as the enthusiasm and inventiveness of the staff may decline.

As is the case with a number of establishments visited by the writers, the periods between the development of new programs may be periods of nearly or totally frozen budgets. If this situation occurs for a long period, and given the great difficulty of dismissing staff, the implications for the work program and the establishment can be serious. With frozen budgets there is a tendency for salaries to consume a growing proportion of the establishment's total budget. The greater this proportion the more difficult it becomes for the establishment to make anything other than minor changes in its work program. The activities or projects change but the same old programs are maintained. The writers visited some establishments where salaries were 80 to 85 per cent of the total budget. With such a high percentage, and with operating and maintenance costs consuming much of the rest of the budget, such establishments have little opportunity for buying new research equipment. This may have a damaging effect on an establishment's ability to operate a viable program.

The attempt to control expenditures on government R & D by freezing budgets is therefore likely to have a dysfunctional effect on the output of establishments. The work becomes more labour-intensive and less capital-intensive, bright new staff cannot be recuited and the work atmosphere tends to become less stimulating. Creative conditions are difficult to achieve and seem to be even more difficult to sustain. Creativity within a lab appears to involve a great deal of intuitive judgement on the part of the director plus equal amounts of serendipity and synergy. Cockcroft notes that one can evaluate the creative climate within a laboratory rather easily:

> Although it may be difficult to assess the achievement of a laboratory in terms of the worthwhileness of its contribution in relation to the money and resources it uses, it is not difficult to get an impression of whether it is a 'good' laboratory or a mediocre one. It is possible to walk round a laboratory, talk to the men working in it and come away with a rather definite impression of the quality of the work. One can often do this even if one knows very little of the subject under investigation or of the past achievements of the

> laboratory. Such judgements are based, I believe, on a recognition of an attitude of mind of the staff to the work and to the establishment. This suggests that the first consideration in the organization of a research establishment is the fostering of the right climate of opinion. This consideration is, perhaps, more important even than the intellectual quality of the staff.[23]

This climate in a lab is often a function of bright enthusiastic colleagues and its slide into mediocrity may result from the disappearance of one or a few enthusiastic people.

To continue to work, in a creative way, within fixed inner boundaries is difficult. The structural rigidity imposed by government rules and regulations on staff dismissal and/or rotation promotes periods of stagnation. The problem of stopping work that is no longer fruitful becomes paramount. Since staff cannot be hired to work on new projects, the work must be adapted - and often diluted - to meet the competence and interests of the existing staff.

Optimum program formation and the dynamics of a creative laboratory cannot be simply stated in an organizational manual. A high degree of intuitive insight is necessary, and looking at the problem as an exercise in accounting or economics can lead to controlled expenditures but non-creative research. It is interesting to note Gerhard Herzberg's comments on this topic:

> The Glassco Commission was really not interested in good science. It was intersted in good accounting. There is, of course, nothing wrong with good accounting, except that it does not necessarily lead to good science. The Glassco Commission considered the NRC in the same way as the Post Office or the Justice Department. Of course, these are important government departments, but their way of working is quite different from that of a research organization. What the Glassco Commission should have done was to enquire what particular organizational features were the reason for the high international standing of the National Research Council and how this standing could be further improved. Instead,

> the Commission recommended reorganization aimed at making the set-up tidier and more amenable to accounting.[24]

We must appreciate that program choice and the establishment and maintenance of a creative atmosphere is, ironically, more of an art than a science. What projects should be encouraged and what should be left undone? How to re-orient the interests of the existing staff and still maintain their original enthusiasm? How to maintain their elan when the inner boundary conditions remain unchanged for some time?

Of course there are no neat answers. The director must be inspired and must somehow pass his inspiration on to his staff. Some work will prove to be of short- or long-term value, other work will prove to have been useless. The allocation of scarce resources among competing uses so as to meet objectives is a continuing problem that the decision-maker must face. How to decide? Cockcroft notes the depth of the problem of program choice and turns to Goethe for an answer: "In deciding what to leave undone it must be remembered that the value of a project depends on the chance of achieving useful results as well as on the importance of the results if achieved, 'das schonste Gluck des denkenden Menschen ist, das Erforschliche erforscht zu haben und das Unerforschliche ruhig zu verehren.'"*

12. Summary and Conclusions

In this chapter we have examined, in some detail, the roles of government research and development establishments. The functions and work activities of the establishments are formulated and continuously up-dated so as to meet the broad objectives of the department of which, we have seen, it is an integral part. It should be emphasized that historical circumstance has conditioned the roles of government R & D establishments; evolutionary changes, slowly adopted and accepted through the

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* Cockcroft, op. cit., p. 268. Taken from Goethe, W.V. Aphorismen uber die Natur. It translates approximately as follows: The thinker's good fortune is to be able to investigate investigatable things, and to let alone things that cannot be investigated.

passage of time tempt the investigator to say that each R & D establishment is unique and that each deserves to be examined as a separate case.

On analysis, and after careful thought, the establishment appears to take on an organic structure. Historical circumstance, roles, personalities of directors, creativeness of scientists, etc., all tend to leave the impression that we are not dealing with a mechanical entity that can be speeded up, slowed down, or redirected at will.

We agree with the conclusions of earlier investigations of government laboratories - notably Glassco - but hope that this chapter has pointed out the inappropriateness of applying a universal solution or formula to the problem of analysing the government R & D establishment.

IV. Technology Transfer from Government R & D Establishments

Chapter IV. Technology Transfer from Government R & D Establishments

1. The Nature of Technology Transfer: What is it? An acceptable definition

It has to be made clear from the outset that technology transfer means different things to different people, and that not even the most general definition can encompass all the notions concerning it. One of the broadest and probably the least contentious definition of technology transfer is provided by Chakrabarti. "Technology transfer can be viewed as the generalized process of information transfer between science, technology and actual utilization of scientific ideas."[1] Chakrabarti quotes Brooks who likewise provides a definition which most would find acceptable. "Wherever systematic rational knowledge developed by one group or institution is embodied in a way of doing things by other institutions or groups, we have technology transfer."[2] This latter definition has been chosen as the most suitable working definition for the discussion which follows and for this study in general. Although it does not embrace all understandings of technology transfer, it is sufficiently broad to contain most of the more limited definitions in the literature. It also covers the many types of technology transfer in government R & D establishments. The definition does not cover ordinary scientific information transfer since such transfer does not embody information in an actual operation of some kind.

A review of the literature on technology transfer reveals a confusing picture. To some extent this reflects a lack of research on the subject. But the real difficulty lies in the comprehensiveness of the general concept of technology transfer, and in the lack of general agreement about its constituents. For the most part, individual researchers have examined only one or a few case studies of technology transfer, and have tended to define it in a way that reflects their own particular research experience. Since the cases they examine are so different, their definitions of technology transfer also differ, and the result is a literature filled with contradictions and semantic chaos. As one writer on the subject puts it:

> "Technology transfer comes in all shapes and sizes. ...but some of the less complicated definitions are: the multilateral flow of information and techniques across the boundaries of science; technology and the practical world; transferring research results to operations; accelerating the application of research and exploratory development results to industrial application; science and technology transfer to the would-be user at the earliest practicable date and in a language he can understand; the process of matching solutions in the form of existing science and engineering knowledge to problems in commerce or public programmes. ...It is also getting knowledge out of the academic area and into the hands of those who apply it, (and is) ... the process by which a technology is applied to a purpose other than the one for which it was originally intended."[3]

The literature is filled with other definitions and it may be useful to note a few of them. For example, some writers associate technology transfer only with new knowledge or technology; that is, technology transfer occurs only when new knowledge is created and moved from one group or organization to another where the knowledge is applied for the first time. Others would say that newness of the knowledge being transferred is not an essential feature; what counts is its newness to the recipient. Hence, a manufacturing process widely used in the industrialized nations may be adopted in a third-world country for the first time. This has been cited as an example of the international transfer of technology. Others, however, would refer to it as an example of the diffusion of innovation or the diffusion of technology.* This reflects the notion that the transfer of any particular technology can occur only once, and that subsequent adoption of the technology represents

* An innovation diffuses in two dimensions, the spatial and the social. Some disciplines emphasize the former and others the latter. Geographers, for example, examine diffusion from a spatial point of view, placing their emphasis on situation factors in explaining differences in adoption times from place to place. Sociologists and anthropologists emphasize adoption with a minimal consideration of locationally derived factors.

diffusion. According to the definition we have adopted, both cases represent examples of technology transfer.*

Another source of the confusion surrounding technology transfer derives from the nature of the investigations made of it. Köhler, Rubenstein and Douds[4] have comprehensively summarized the various approaches to the investigation of technology transfer as revealed by the literature, and this chapter draws heavily on their findings. It should be noted that many of their statements rest on an earlier seminal paper by Douds.[5]

There appear to be three general types of literature describing the phenomenon of technology transfer. The first and most common may be described as the "wisdom" literature. Typically, it is written by people who have been directly involved in a particular case of transfer or who have been observers of it. Most frequently, lessons are drawn from the experience and are intended as advice for whoever may be involved in technology transfer in the future. Many of the contributors are clearly enthusiastic amateurs lacking any knowledge or appreciation of the complexity of the subject to which they believe they are making a contribution. This type is of little use, "due to the variety of definitions and terms employed, and the abundance of inconsistencies and contradictions this segment of the literature does not provide an organized useful body of knowledge."[6]

The second type consists of case studies describing the chain of events between and within organizations in particular instances of technology transfer. There is no way of knowing how typical or how unique the cases are. They have not been

* Another way of looking at the process is: "Technology transfers or moves when it is applied somewhere else than where it is originated. A technology transfer program is a purposive, conscious effort to move technical devices, materials, methods and/or information from the point of discovery or development to new users." Charlton R. Price, "The Environment and the Action in Technology Transfer 1970-1980," Report of a Conference Sponsored by the Denver Research Institute, University of Denver, Snowmass-at-Aspen, Colorado, September 1969.

done to facilitate comparisons but they do offer some scope for the building of general models.

The third type is also composed of case studies but they are structured in such a way as to "permit generalizations beyond the immediate circumstances studied. Ideally, data is obtained from a representative sample of particular situations in such a manner that inferences drawn from the sample observed can be extrapolated to general classes of situations".[7] But even these more rigorous studies have their deficiencies; insufficient attention is paid to the organizational structures of the firms or institutions involved, or to the behavioural aspects of the transfer process. Köhler, Rubenstein and Douds advocate studies which will examine "the dynamics of the process at a detailed behavioural level"[8] and conclude: "It also seems that the time is ripe to carry out prestructured case studies and experiments. At this point, further purely theoretical speculation about the process of technology transfer without more systematically gathered empirical data, is likely only to increase the confusion association with the subject."[9]

There is not, and perhaps there never will be, a universally acceptable definition. At present, technology transfer is apparently whatever one wants it to be; thus we find the following discussion in a recent Background Study of the Science Council.

> "When discussing technology transfer, it is important that we distinguish the form in which it is transferred, as this will have important consequences on the benefits that can be derived from it. Many forms of transfer are possible. The simplest, and often least beneficial method is to transfer it in its fully embodied form; this is what happens, for example, when we import an entirely new machine that makes for more efficient production or when we import a new plastic for a given application."[10]

If we accept the above examples of technology transfer, then we should also have to accept that a consumer purchasing a new advanced razor is likewise involved in the process of technology transfer. Provided this is consistent with one's definition, then it is a legitimate example.

To sum up, the process of technology transfer has been employed to describe a wide variety of situations. Upon reflection however, it appears that most of the processes which are described as technology transfer have a number of characteristics in common. Thus despite the many different definitions of technology transfer that exist, most of them turn out to be variants of a broadly defined set of processes and factors which are coming to be regarded as essential ingredients of technology transfer. We feel that Brooks' definition contains these ingredients, and that any definition which does not accord with Brooks' definition is not referring to technology transfer as it is currently understood by serious investigators of the process.

2. Technology Transfer - Types and Characteristics

> "Wherever systematic rational knowledge developed by one group or institution is embodied in a way of doing things by other institutions or groups, we have technology transfer."[1]

When the layman thinks of technology, he generally has in mind hardware in the form of productive apparatus and machines in general - blast furnaces, computers, locomotives, cranes, machine tools, television, etc. In a sense he is not wrong in thinking this way; machines are examples of technology which have been given tangible form. They represent the translation of organized knowledge into physical form and/or observable processes.

Technology really refers to a way of doing things and can exist in the abstract. A machine is technology applied, but the technology can exist without the machine. If all our machines and man-made products were destroyed today, but we retained the capability to reproduce them, it could not be said that we had lost our technology. Technology is organized knowledge relating to processes, techniques and products. The man who can design and produce a table or a chair is in possession of a certain body of knowledge which can be regarded as a technology, or even better, a technological capability. The latter term signifies that technology is more than just abstract knowledge,

but also includes specific pieces of information and manual dexterity or "know-how" which can only be acquired through experience. In the normal case, however, especially when we are dealing with what is loosely described as "high technology", a technological capability incorporates so much abstract knowledge as well as knowledge in the form of skill, expertise and experience that it cannot be possessed by a single man. In this context we may think of the gargantuan bundles of knowledge essential to the production of a jet aircraft, a nuclear-fueled electricity generating station, or, for that matter, the ubiquitous automobile.

The knowledge which is technology may exist solely in mens' minds and during most of mankind's history this was exactly the case. Just as language, religion, values, etc. were passed from one generation to another, undergoing slow modification in the process, so technology was handed down through time. More recently we have been able to reduce our reliance on man's ability to store information in his mind and have developed other means of storage, which at the same time have facilitated the movement of knowledge among men. Today we are able to encapsulate much of the knowledge that is technology (but never all of it) in the form of books, papers, reports, drawings, plans, specifications, etc. But it must be remembered that these are but representations of the knowledge.

Technology transfer refers to the movement of knowledge among men, among groups, among institutions. Movement is used in the sociological rather than in the geographical sense of the word. Movement through space is not a criterion of technology transfer even though it occurs in most cases.

Transfer and movement are words implying the existence of a source of knowledge and a recipient of knowledge. However, transfer does not occur unless the recipient puts the knowledge to use in one way or another. Without use or application there has been no transfer. Hence, the movement of knowledge is not synonymous with technology transfer: the recipient may reject the knowledge as of no value, so that transfer fails to occur.

We should recognize the distinction between the international and the intranational transfer of technology. Usually, international transfer is the product of a deliberate act: "the creation of a capability in the recipient country to reproduce profitably or otherwise usefully replicate a technical performance previously or concurrently being achieved in another country."[12] However, it is the intricacies of intranational transfer which concern us in this report. The central distinction in this type is between inter-sectoral and intra-sectoral transfer. The particularconcern of this report is the specific inter-sectoral transfer between the government on the one hand and private manufacturing industry on the other.

Technology transfer is a process; it consists of a series of steps between the generation of a piece of technology and the actual implementation of that technology. Where technology transfer relates to new knowledge we may equate it with the process of innovation, which some would define as the process of bringing invention to use. Innovation or technology transfer as a series of time related events is well described by Globe, Levy and Schwartz. Innovation

> "is a complex series of activities, beginning at 'first conception' when the original idea is conceived; proceeding through a succession of interwoven steps of research, development, engineering, design, market analysis, management, decision making, etc., and ending at 'first realization' when an individually successful 'product' which may actually be a thing, a technique, or a process, is accepted in the market place."[13]

The highly variable character of technology transfer implies that the sequence of steps from the origination of knowledge to its application will take many forms. In a later section, we discuss the impediments to transfer which can occur at various points in the transfer.

3. Transformation and the Impulse to Transfer

We have characterized technology transfer as the process (describable as a set of steps or stages) connecting a source of technology to a recipient who puts it to use. This is a skeletal outline,

which neglects certain important attributes of technology transfer.

It appears that technology transfer nearly always involves transformation or modification of technology. This is especially so where the source of the technology is an R & D facility, and establishing feasibility may be the most important motivating factor. Thereafter, as the technology is moved to design, production and possibly marketing groups, it is subjected to quite different criteria, and is likely to undergo considerable adaptation before the transfer process is complete. Adaptation is probably least likely when a fully developed technology is transferred, e.g. by a multinational corporation, from one country to another. But even here, especially in the case of transfer to a developing country from a developed country, modification may be necessary to take account of local production skills, local needs, size of market and so on. This suggests that the question of adaptation is at the core of the difference between transfer and diffusion. Transfer, if it involves adaptation, implies the existence or the acquisition of a technological capability on the part of the recipient in order that the technology can be adapted and hence applied. If no adaptation is required, as for example when a Canadian firm buys a new type of machine tool from a US firm, there need be no technological capability on the part of the recipient in order to put the technology to use. We may argue that the transfer process ended when the American firm produced a marketable machine tool. Thereafter the technology was diffused.

Implicit in our definition of technology transfer is the assumption of an impulse or reason which causes the transfer, or the attempt to make the transfer, to be made in the first place. Although the transfer process can occur accidentally or at random, in the sense that no initial direction is given to the transfer process, most transfer is directed from the outset and the direction can be related to two major categories of impulse. The impulse to transfer can emanate from either the source or the recipient of the transfer process. The implications for technology transfer are very different depending on which provides the initial impulse.

Impulse from the recipient most often occurs when the recipient perceives a need to be satisfied, e.g., the marketing people of an organization perceive an unfulfilled need, and give the problem to the organization's R & D group. Under these conditions we may anticipate a fairly high degree of success in technology transfer. We may characterize this situation as a need in search of a technological solution. The other side of this situation is when the impulse to transfer comes from the source, and we have a situation of technology in search of a need. This does not mean that technology is developed for no reason. In many cases technology may initially have been developed for a very specific purpose, but subsequently its developers see that it could be used (usually in a modified form) to meet needs beyond those for which it was first developed. Impulse from the source of technology can frequently be equated with what is sometimes referred to as "technology-stimulated" innovation. Transfer is likely to be more difficult than in the case of "need-stimulated" innovation, although in the long run technology-stimulated innovations may be more significant. "Such a technology is more likely to spark off secondary innovations than an idea developed as a result of a recognized need."[14] According to Kenward, about a third of all innovations find their basic stimulus in the technological ability to do something, while the remaining two thirds are initiated because someone wants something to do a particular job.[15]

4. Technology Transfer: With and Without Source Direction

Most writers on the subject consider technology transfer to be a directed process in the sense that there is an element of purposeful direction or control of the movement of technology from the source to the recipient. Chakrabarti speaks of "the purposiveness manifested by conscious, predetermined effort and commitment of resources to transplant technology from one setting to another."[16] Although the first steps in the transfer process can occur in a random manner, perhaps as a result of a chance meeting or casual perusal of a research paper, purposiveness and direction must exist at some stage, otherwise the transfer will not be effected. Also in every case of transfer there must

ultimately be purposiveness and conscious effort on the part of the recipient of the technology. After all, it is the recipient who must want to apply or to use the technology, and it is the recipient who will gain the immediate benefits from its application.

Although the recipient must sooner or later make a conscious effort in regard to the transfer process, a parallel effort by the source is not essential. We may find many cases of transfer in which effort and direction issued from the source as well as from the recipient, but others, in which they issued only from the recipient, occur most frequently in inter-sectoral transfers, the major concern of this report.

We may therefore recognize a distinction between technology transfer with source direction and without source direction. Because of this study's focus on government R & D establishments this distinction is a significant one. Government R & D establishments are the sources of technology and the manufacturing firms are the recipients. Hence, the transfer, if there is any, is predominantly in one direction. However, the degree to which transfer is encouraged and facilitated by establishments varies greatly from one case to another and can range from direct concerted action to effect transfer to a position of utter passivity. In both theory and practice transfer can occur regardless of the establishment's attitude. Not surprisingly, the more an establishment has made a concerted effort to bring technology transfer about, the greater the chance of success.

An example of transfer with source direction from an establishment could be as follows. The establishment develops a device intended to meet its own research requirements. It is felt that the device has a potential for wider application and considerable commercial possibilities. With this belief, the establishment actively searches out commercial firms which may be interested in developing, manufacturing and marketing the device. If a firm willing to participate is found, the establishment makes a concerted effort to transfer by such means as providing specifications, technical advice, staff time, etc. In short, the establishment regards transfer as desirable and takes active

steps to secure it. Of course, even here certain factors could prevent the transfer from taking place; for example, no firm evinces interest, or production problems prove to be insurmountable and the firm abandons the device.

The commonest example of transfer occurring without source direction is transfer initiated as a result of the transmission of information. For reasons which are considered later in this chapter, establishments are frequently content to transmit information in the form of papers, reports, bulletins, etc. This makes the inception of the transfer process a random event. Transmission of information is a passive activity which may or may not be the first step in technology transfer depending on receipt of the information and reaction to it. Transmission does not ensure the presence of receivers, and there is no certainty that potential receivers will understand and/or act on information received.

Nevertheless transmission can constitute the first of the several possible steps in the process of technology transfer. A bulletin may arouse the curiosity of a reader; it may cause him to make a mental connection, and lead him to make enquiries and perhaps to visit the laboratory which published the bulletin. He may ultimately adopt, perhaps adapt and apply the piece of technology.

From a research point of view one of the greatest difficulties in dealing with technology transfer lacking source direction is knowing whether or not technology transfer has occurred. The problem is especially severe when trying to assess government involvement and effectiveness in technology transfer. Government R & D establishments pour out information; every year they transmit in printed form millions of words about scientific and technological matters. They answer tens of thousands of enquiries. Their scientists and engineers have countless discussions with people from business, government and the universities. Information, facts, ideas and concepts flow in and out of the establishments and among the establishments. Unfortunately, there is no way of measuring the impact of all this, of knowing how much knowledge is taken up and put to some use. Hence the amount of technology transfer cannot be estimated or evaluated. Because government R & D

establishments tend to employ transmission more than transfer, and because a great deal of information is exchanged in person-to-person contacts, the effects of which cannot be assessed, the overall effectiveness of government R & D is quite difficult to measure.

5. Technology Transfer and the Roles of Government R & D Establishments

It is apparent from the roles of R & D establishments, described in Chapter III that some form of technology transfer (with or without source direction) is either essential to role fulfilment or greatly facilitates it. Sometimes technology transfer is the last step which an establishment takes in meeting its responsibilities. For example, much of the work of the R & D establishments of the Department of Agriculture would be futile unless the knowledge gained eventually finds its way to the farmer. When technology transfer is the last step of an establishment's mission it could be said that the prime reason for the establishment's existence is to confer benefits on some particular social or economic group. This is implicit in one of the roles previously described: "Government R & D should be performed in-house where the R & D requirement needed to perform the mission of the department is inappropriate to industry, or where no suitable industrial capability exists and it would not be of benefit to Canada to create one."

Technology transfer is often only an intermediate step employed by an establishment as it moves towards specific objectives conforming with its role and functions. For example, an establishment designs an instrument required for its research work; contracts the production to an industrial firm and in so doing has to transfer a technology. The firm develops a capability to produce a satisfactory instrument. Instruments are delivered to the establishment which uses them to further its research, e.g., effects of pollution of lakes on aquatic vegetation. In this case, technology transfer per se is not used as a means of conferring benefit on an economic sector or an organization, even though benefits may result. It is the establishment that wishes to meet a need; benefits to the recipient are incidental and not the primary motivating reason for the transfer.

There are many other reasons why technology transfer may occur either with or without source direction. However, these will be considered when technology transfer to manufacturing industry is examined in detail.

6. Technology Transfer: Its Relation to the Functions of R & D Establishments

Scarcely any R & D agency or departmental R & D arm has a mandate which reads to the effect that "you shall transfer technology to this or that sector, or to the operating arm of this or that department." To a great extent the lack of direct reference to technology transfer reflects the breadth and generality of functions assigned to R & D arms and their establishments. Functions relate to broad goals, but the means of reaching these goals are not usually specified. Technology transfer may or may not be a means, depending on the goals, and on what alternative means are available. This point can be elaborated in terms of specific examples.

The Mines Branch of EMR has its mission in three of the objectives of the Mineral and Energy Resources Program of the Department.

> "(1) To ascertain the mineral and energy resources potential available in Canada.
> (2) To improve the means of discovering, mining, processing, transportation, and use of the mineral and energy resources available in Canada.
> (3) To reduce the social and environmental problems arising from the development and use of Canada's mineral and energy resources."[17]

With such a mission the Mines Branch tends to be involved in R & D on technological matters and our research has shown that it is concerned to see its findings used in both the private and public sectors. Technology transfer is essential in order to meet part of this mission. For example, if the Branch wants to improve the means of processing mineral and energy resources, its ideas (if they are worthwhile) must be adopted by the organizations actually involved in processing.

In a very small number of cases, technology transfer is explicit in the missions of R & D establishments. For example, to fulfil its obligations, AECL, among other things,

> "Offers to supply nuclear power stations on the domestic and international markets
> ...designs and builds prototype nuclear power stations in cooperation with electric utilities and private industry
> ...makes available its special facilities and expertise to
> (a) assist industry in developing manufacturing capability to nuclear quality specifications
> (b) assist utilities in putting nuclear energy to practical use."[18]

Technology transfer as such is not mentioned in the above quotation, but obviously it is central to at least part of AECL's mission.

The same applies to the Research Branch of the Department of Communications, one of whose functions is research and development for new communications systems:

> "To demonstrate or verify the potential of new communications systems and systems concepts in meeting changing national needs; to examine and promote the use of new methods for systems analysis and systems synthesis in a complex communications environment; to develop and maintain technological competence in the industry so it can better respond to national and international requirements for cost-effective systems, subsystems and components."[19]

However in several other departments, the functions of their R & D arms do not imply a need for technology transfer. For example, according to the 1973-74 Estimates, the objective of the Environmental Services Program of DOE is:

> "To promote and undertake programs to protect and enhance the quality of the environment, and programs designed to improve the management and sustained economic utilization of the forest wildlife and inland water resources of the nation."

The Sub-objectives are:

> "To promote the quality, management and use of inland water resources.
> To develop preventive, and other control measures directed to air and water pollution.
> To provide meteorological and ice information services and encourage and promote the application and development of meteorological science.
> To assist in the improvement of the quality, management and use of land.
> To promote effective and economic management and use of the forest resources of the nation.
> To conserve and manage wildlife resources including migratory birds and their habitat in Canada."[20]

Admittedly, these objectives do not totally preclude the possibility of some involvement in technology transfer, but clearly, it would be very limited.

Although many more descriptions of functions could be provided, the few quoted above are sufficient to show that the use of some form of technology transfer as a means to fulfilling functions will greatly depend upon the nature of these functions.

In seeking to find some order in the relationships between technology transfer and the functions or missions of R & D establishments, we have identified three broad categories which seem to include most situations.

Category 1 A function includes the improvement or the introduction of technological capability into the private or public sectors. Hence technology transfer is central and unavoidable in the fulfilment of at least some of the establishment's functions. Examples: establishments of AGR and AECL.

Category 2 Functions may require some form of technology transfer for their fulfilment, but if technology transfer is employed, it is as an intermediate step towards goals which lie beyond the improvement or introduction of technological capability into the private or public sectors. Examples: establishments of DND.

Category 3 Functions do not usually require technology transfer for their fulfilment. Examples: many establishments of DOE, NRC, EMR, and virtually all of the R & D of National Health and Welfare.

Since nearly all establishments are multifunctional, a single establishment may find itself in all three categories. For example, one section in an establishment may devote all its time to inventory work and hence have no need for technology transfer, while other sections engage in activities whose results have no value unless transferred, e.g., improved agricultural techniques. Also, it should be noted that many establishment activities are responsive to several functions at the same time. For example, establishments of line departments are usually collectively assigned the responsibility of providing expert advice for the departmental policy makers. Fulfilment of this function overlaps others, so that even when an establishment appears to have a strong commitment to technology transfer, the production of transferable technology is possibly only one of several reasons for undertaking certain activities.

Regardless of which category an establishment, or part of an establishment, falls into, the likelihood of technology transfer must never be totally discounted. But likelihood is much less in category 3 than in the other two. With no mandate to transfer, and finding little need to transfer, establishments in category 3 transmit information, rather than transfer technology. Their strong reliance on transmission reflects their mandate which in turn controls the nature of the information generated by them, and causes them to engage in work generating results of a low transfer potential. This is a very important point requiring separate consideration.

7. The Transfer Potential of Government R & D

Most government R & D establishments have little or no direct concern with the development of technology, and usually this is clearly set out in their mandates. Technology is organized knowledge relating to processes, techniques and products, i.e., knowledge relating to ways of doing things. Technological knowledge is inextricably related to scientific knowledge, yet the two are still quite

distinct. A very large number of government R & D establishments are not in the business of producing technological knowledge per se, rather they are empowered to engage in basic (e.g., pure chemistry) or applied (e.g., effects of DDT on the reproduction of wildlife) scientific research. Such work may, and occasionally does have important implications for technology. The information generated by scientific research may come to be incorporated into technology, or raise the demand for new technology, e.g., basic and applied scientific research gave us synthetic fibres, but in turn a technology had to be developed to produce them. Normally, scientific research does not immediately create processes or techniques which can be transferred and put to use. Scientific knowledge generally has a long road to travel before it becomes incorporated in technology. The potential for direct transfer to the private sector is low.

There is often little evidence of the transfer potential of scientific research. A prime example is scientific inventory activity, e.g., the collection and classifiction of data on physical and biotic phenomena, such as weather, soils, rocks, water, insects, forests, animals. Such inventory work (designated as related scientific activities in Chapter II) consumes a large proportion of the government science budget. The technology transfer potential of this work is minimal. Opportunities for new technologies may arise to the extent that methodologies, tools or equipment are developed to facilitate scientific data collection and processing. Finally we should note the significant portion of government effort devoted to the establishment of codes and standards and to providing the information needed to set regulations. This tends to have only minor implications for technology transfer.

Although there are a few establishments largely given over to basic scientific research, normally there is a strong emphasis on applied scientific research. In principle, most establishments concerned with scientific problems engage in basic research only insofar as applied scientific research problems demand basic research results for their solution, e.g., an applied problem may be the elimination of root rot in carrots, but the solution requires fundamental research into micro-biology. Much of the basic research, therefore, is

of the type described by Kruus as "oriented basic research" - "basic research undertaken because of apparent lack of basic knowledge in some fields, which is holding up, or may hold up, the pursuit of some mission".[21]

Much applied scientific research is directed towards problems which are non-technological in nature, and which do not require technological solutions to be brought under control. The application of the research results frequently lies in controls, regulations, policies, prohibitions, the setting of acceptable standards and so on. Very often the production of scientific information for its own sake meets governmental needs; there is no need for technology transfer to achieve fulfilment of mission, e.g., warning messages on cigarette packets.

An excellent example of an organization with a minimal involvement in technology transfer is the Health Protection Branch of NHW. The function of the several laboratories of this branch is to provide expert advice on all matters pertaining to public health protection, and it is carried out through the generation of scientific information which enables the making of informed public health decisions. The output of the labs has little transfer potential; it can only be transmitted to, and taken into account by, departmental policy makers and the public.

What we have said about the Health Protection Branch applies equally to many establishments or sections within establishments of several other departments. Indeed, except for the R & D facilities of agencies such as NRC, it is generally true to say that there is a sizeable component in every R & D establishment where the production of scientific information with no foreseeable implication for technology is the culmination of its work. Significant proportions of the R & D budgets of AGR, DOE, and EMR are allocated to the generation of scientific information that is non-technological in nature. Both AGR and EMR contain large scientific data collection components and thus a lot of activity is directed towards the production of scientific information essential to the formulation of controls and regulations. DOE undertakes a great deal of applied scientific research, with some

containing an important inventory component. Much of this research has limited implications for technology and its transfer.

Although most basic scientific research is oriented basic research, free basic research is occasionally undertaken, possibly in accordance with an establishment's mandate. Kruus defines this as "basic research undertaken without relationship to a practical mission or problem".[22] He also notes that 19 per cent of the R & D effort in government was devoted to basic research in 1968. However, this includes both free basic research and oriented basic research. Although one can theoretically distinguish between the two, in practice it is almost impossible to separate them.

Basic research, both free and oriented, can be the source of significant innovation. Kruus believes that: "The results of basic research may lead to new innovations of great benefit to society, including some which clean up problems caused by unwise use of technology in the past; they may also prevent the introduction of innovations which may eventually be harmful to society."[23] Kruus is referring to the big "break-throughs" stemming from basic scientific research, but these are rare, and it is impossible to predict when and where they will emerge. Most basic research simply falls in existing gaps and carries few implications for technology.[24] There is a strong random element in the entire process connecting discovery in basic science to the emergence of innovation, and the process tends to be lengthy. "The long time span between the action and the eventual consequences is especially extended in the case of basic research - a generation is often quoted as being the average delay".[25]

Although many establishments have little direct concern for technology or its development, a significant number do have just such an involvement. These are establishments attached to DND, NRC, AECL, DOC, MOT, EMR; and provided we give a broad connotation to technology, we should also include establishments of AGR. None of these is exclusively concerned with technologically oriented research: the links between science and technology are so close and interwoven as to almost necessitate scientific research even when the prime inter-

est is technology. All the same, their functions often cause them to place greater emphasis on research in technology than on scientific research either basic or applied, and their potential to produce transferable technology is high.

But, and this is a crucially important point, an establishment's potential to transfer technology and an establishment's actual involvement in technology transfer are two entirely different things. Despite possession of a potential, an establishment may not have, or may not believe it has, a mandate involving technology transfer. The implications of this will be discussed when dealing with the particulars of technology transfer to manufacturing industry.

8. Technology Transfer to Manufacturing Industry: The General Situation

No R & D establishments exist solely for the purposes of conferring benefits on manufacturing industry. No establishment has a relationship with and a commitment to the manufacturing sector that parallels the relationship and commitment of establishments of the Department of Agriculture to the agricultural sector. The objective of the research program of the Department of Agriculture is to increase the efficiency and productivity of Canadian agriculture. This objective represents a response to a sector of national importance which is incapable of undertaking its own R & D. The government has not assumed a similar responsibility towards manufacturing.

The relationships of government R & D establishments with manufacturing vary greatly. The majority of establishments are not charged with any responsibility toward the manufacturing sector. A minority of establishments are concerned with the manufacturing sector, but it is important to note two major points:

a) The responsibility is always one of several other responsibilities.
b) The responsibility is never solely for the purpose of conferring a benefit on manufacturing, but relates to other goals which are reached partly through interaction (including technology transfer) with manufacturing.

More often than not, the transfer of technology to manufacturing is not an end in itself but a necessary step towards the achievement of goals other than promoting the interests of manufacturing. For example, the concern of the Department of Communications is not with manufacturing industry per se, but with the communications sector.

It must be emphasized that we are referring to the broadly defined missions and functions of establishments. In practice, many establishments do give direct assistance to manufacturing firms irrespective of the relationship this activity has to the primary functions of the establishment. In addition, establishments with no responsibilities towards manufacturing on occasion attempt to pass on incidental benefits from their work to manufacturing industry.

There is a general misconception in the public mind, and more particularly in certain quarters of manufacturing, that government R & D establishments have greater responsibilities towards manufacturing than is actually the case. To some extent the misconception is a result of wishful thinking. It is sufficiently deep-rooted to justify a department by department examination of relationships with manufacturing, before we examine more closely the particulars of technology transfer and the problems associated with it.

Department of Agriculture

The sizeable R & D arm of this department has no direct responsibilities towards manufacturing industry, but in attending to the welfare of agriculture it interacts with manufacturing and does transfer some technology to it. A sub-objective of the research program is "to develop new and improved methods for preparation, preservation and packaging of food products." Of course, work in this area benefits agriculture by widening the markets and uses of its products, but at the same time manufacturing stands to benefit from the new processes and products. Work on food products is, however, a very minor part of the total activity, and interaction with the food processing industry is very limited. There is a certain amount of interaction with the producers of fertilizers and pesticides. But this has to do with control, use

and effects and rarely involves technology transfer to manufacturing.

Department of Communications

The Department of Communications' research arm is one of the best examples of an organization which employs technology transfer to manufacturing as an intermediate step in the completion of its missions and therefore a fulfilment of its functions. Manufacturing benefits from its considerable interactions with the research branch, but the benefits are incidental, and not a primary objective of the research branch. DOC exists "to foster the orderly development and operation of communications for Canada in the domestic and international spheres". Two sub-objectives are "to foster, develop and introduce new communications systems, facilities and resoures" and "to foster, develop and extend telecommunications services to obtain benefits for Canada in the short and long term".[26] The existence of the research branch is partly a response to these two sub-objectives, as is much of the activity and interaction with manufacturing. The development and introduction of new communications and telecommunications systems requires modification and development of the relevant technology and its ultimate production in fully embodied form. Technology transfer to manufacturing and other forms of interaction are therefore necessary if Canada is to acquire the hardware for new systems.

Department of Energy, Mines and Resources

The Science and Technology Sector is the largest component of the Department of Energy, Mines and Resources. It is composed of Surveys and Mapping, Mines, Geological Survey of Canda, Earth Physics, Canada Centre for Remote Sensing, and the Polar Continental Shelf Project. Only the Mines Branch has a responsibility towards manufacturing. The Mines Branch accounts for only about 21 per cent of the labour of the Science and Technology Sector. As already noted, one of the objectives of the Mines Branch is "to improve the means of discovery, mining, processing, transportation, and use of the ation, and use of the mineral and energy resources available in Canada". This implies a need for technology transfer to manufacturing industry. However, much of the activity of the Branch is directed towards the primary extraction sector and to the energy sector. All in all, therefore, probably

only about 10 per cent of the total resources of the Science and Technology Sector are devoted to questions of direct interest to manufacturing industry, e.g., minerals processing and extraction metallurgy.

Department of the Environment

"When Environment Canada was created, the Minister gave six goals for the new department:

1. To carry on established resource programs and services.
2. To clean up and control pollution.
3. To assess and minimize the environmental impact of major development.
4. To initiate long-term environmental programs.
5. To promote and support international and environmental initiatives.
6. To develop an environmental information and education program."[27]

The last five of these goals demonstrate another example of a research arm with no direct responsibilities towards manufacturing industry, one likely to have only incidental interactions with manufacturing. However, consideration of the first goal changes the picture somewhat. The research arm of the department, one of the largest in the federal government, is a coalescence of research arms and establishments formerly attached to a number of departments and agencies. In all of these, there was a certain element of concern for conservation and environmental protection, but also for bringing economic benefits to the fishing and forest-based industries. Despite the new goals declared at the formation of DOE, the department continues with aspects of the inherited functions and these are incorporated in goal No. 1 above. As far as our interest in technology transfer to manufacturing industry is concerned, only two establishments (both carrying on established resource programs and services) have direct responsibilities towards manufacturing industry. These are the Forest Products Laboratories, one in Vancouver, the other in Ottawa. The objective of their research is "to develop, collect and disseminate information on the properties, behaviour and use of wood which will lead to increased efficiency in the harvesting and processing of the forest resource, and to maximize utilization."[28]

Throughout the rest of this very large R & D complex there is practically no interaction with manufacturing. The orientation is very much towards science problems, and final output takes the form of scientific data. Interaction with manufacturing, where it occurs, relates to instruments required for data collection, processing and display.

Department of Health and Welfare

Most of the R & D of this department is performed in the Health Protection Branch. This important organization has no direct mandate to benefit manufacturing and, as noted earlier, the output of its laboratories is of little direct economic value to manufacturing or to any other economic sector. There is no mandate to transfer, and consequently there exists little interest in the transfer of products to manufacturing. The one important exception is vaccines, which at times are transferred to manufacturing and subsequently put into production. There does nevertheless occur a transfer of techniques (e.g., quality control techniques) and ideas and scientific information which are of value to manufacturing. Also, in pursuit of its objectives, the Branch often produces results which have important economic implications for manufacturing, for example, if the Branch should find a drug to be unsafe.

Department of National Defence (formerly the Research Establishment of the Defence Research Board)

The relationship of the DND research establishments to manufacturing industry is somewhat similar to that of the research arm of the Department of Communications. There is no direct responsibility towards Canadian manufacturing. However, in fulfilling its functions DND interacts on a very considerable scale with manufacturing, and in the course of the interaction technology transfer quite frequently occurs.

DND establishments are very much concerned with engineering problems, and more often than not the outcome of their research is defence-related equipment of one form or another (a submarine detection device, a new weapon, a vehicle, etc.) the technology for which, if it is to be employed to meet Canadian defence needs, must ultimately be transferred to manufacturing industry for product-

ion. The emphasis is on research as opposed to development (as is the case in most government R & D organizations), so that work usually proceeds no further than the establishment of the feasibility of a technique or piece of equipment. Initial development is usually contracted out to manufacturing industry. The research establishments are often involved right up to the final stages of the development undertaken in industry. There is thus a considerable involvement in technology transfer to manufacturing, even though transfer is not a goal in itself but only a means to an end, for which manufacturing assistance and participation are essential.

In any detailed examination of successful government involvement in technology transfer to manufacturing industry careful attention should be paid to the procedure developed by the Defence Research Board.*

Atomic Energy of Canada Limited

If any government R & D organization matches the past performance of the Defence Research Board in the extent and frequency of its technology transfer to manufacturing industry, it is Atomic Energy of Canada Limited. Once again, this is an organization which has no responsibilities towards manufacturing and which was not established for the purposes of bringing benefits to manufacturing. "AECL is responsible for research into and development of nuclear power systems to meet Canadian needs and improved application of radioisotope and radiation".[29] As in the case of DOC and DND, AECL's responsibilities cannot be met without a certain degree of interaction with manufacturing industry. This involves the transfer of technology to manufacturing and the subsequent conferral of sizeable benefits on manufacturing. The development and production of nuclear power systems requires the manufacture of a very wide range of complex and sophisticated equipment. Cooperation between AECL and manufacturing is absolutely essential. Although in theory the

* The outstanding role played by DRB in effecting technology transfer deserves special attention. It is hoped that the transfer of the research establishment to DND will not adversely affect this activity.

tangible products of AECL's research could be manufactured by a production arm of AECL, it is more practical, and worthwhile, to add to the expertise, capability and opportunities of manufacturing industry at the same time as realizing AECL's objectives. Cooperation with manufacturing is therefore considerable and takes place in relation to the following objectives (which of course are subsidiary to AECL's central objectives).

> "1. To apply AECL's research findings.
> 2. To improve the technological base of industry.
> 3. To promote the manufacture of nuclear products in Canada.
> 4. To improve the quality and reliability of of existing nuclear products.
> 5. To promote within industry an improved design capability.
> 6. To stimulate a capability for research and development within industry.
> 7. To expand AECL's problem solving capability."[30]

There is no question that this organization frequently makes attempts to transfer technology and that its success rate is high.

National Research Council

Of all the departmental R & D arms and separate R & D agencies or Crown corporations, NRC is the only one charged with a direct responsibility towards manufacturing industry.

> "Under the National Research Council Act, the Council has been assigned a broad responsibility to undertake, assist or promote scientific and industrial research, and has charge of all matters affecting scientific and industrial research in Canada that may be assigned to it by the (Privy Council Committee on Scientific and Industrial Research). 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 research for national benefit."[31]

This is a broad mandate, and it is not exclusively oriented towards industrial research. A very large proportion of the research at NRC is scientific in

nature, and not likely to produce transferable technology. This is especially true of the relatively large amount of basic scientific research undertaken in NRC laboratories.

Industry, as referred to in NRC's mandate includes much more than manufacturing industry. For example, a considerable effort is expended on building research to meet the need for science-based information and knowledge in support of the construction industry, of which only a part can be considered as manufacturing industry. Nevertheless, a significant proportion of NRC's resources is devoted to research related to the needs of manufacturing industry, with the greatest concentrations found in the Division of Mechanical Engineering, the National Aeronautical Establishment, and the Radio and Electrical Engineering Division.

Although NRC is later discussed in detail, it can briefly be stated here that on the whole NRC does not view technology transfer as an important means of exercising its responsibilities towards manufacturing. NRC views its primary role as one of creating knowledge, and seems more concerned with knowledge transmission than with technology transfer. Except for Canada Patents and Development Ltd. and the Technical Information Service of CISTI, there is no direct on-going concern with technology transfer. Technology transfer is employed as a tool from time to time, but there is apparently no sustained program for moving new technology into manufacturing in such a way as to ensure its application.*

In regard to technology transfer to manufacturing, therefore, we find a rather odd situation. No government R & D organization, with the exception of NRC, is charged with the responsibility of conferring a benefit on the manufacturing sector. Yet, in the course of fulfilling their missions, several organizations make quite frequent use of technology transfer to manufacturing and

* NRC is in the process of changing its role and intends to be more consciously involved in the process of technology transfer to industry. See footnote 24 in Chapter IV.

manufacturing has benefitted considerably. On the other hand, NRC which has a responsibility towards manufacturing, largely fulfils its role by means of knowledge transmission and only occasionally uses technology transfer in a conscious manner.

9. Types and Circumstances of Technology Transfer to Manufacturing Industry: Without Source Direction

Earlier in this chapter a distinction was made between technology transfer with source direction and technology transfer without source direction. When there is no source direction, we may say that we are dealing with random technology transfer which can arise when someone or some organization is in receipt of information transmitted from a source with no commitment to ensure ultimate utilization or application of the knowledge.

Most of the knowledge generated by government R & D establishments, whether scientific or technological in nature, of value to manufacturing or not, is transmitted rather than transferred. Even though transfer potential may exist, little systematic attempt is made by the establishments generating the knowledge to ensure that it is put to use.

The most common form of transmission employed is the printed word. The particular form taken varies from one establishment to another. Establishments with a strong involvement in basic science are much more likely to transmit knowledge through the scientific journals than establishments chiefly concerned with applied engineering problems. Establishments trying to reach a particular sector, group or audience produce literature or forms of transmission appropriate to that audience; an establishment that tries to reach the Canadian farmer will use different forms of transmission from an establishment concerned with water pollution problems and their control.

Transmission is not transfer, but it is frequently the first step on the way to transfer. It is axiomatic that no technology transfer will occur until potential recipients of a technology, or information with technological implications, become aware of that technology or information. Technology transfer arising from transmission

normally has to do with simple technological changes or simple techniques, e.g., new agricultural cultivation practices or minor improvements in construction techniques. Anything other than the most simple technological information would not normally be amenable to transfer between source and recipient without further interaction between them.

A recipient of information may only partly understand the knowledge he is receiving, yet believes it may be of value to him in some way. The recipient may therefore approach the R & D establishment sending out the information, and in this way an interaction is established between the source and the recipient, and technology transfer consisting of one, two or several steps may occur.

Once the recipient of information approaches an R & D establishment many different outcomes are possible. A short conversation with a scientist or engineer may satisfy the inquirer, and subsequently he may or may not try to adopt the technology in question, and/or adapt it to his needs. On the other hand, the initial approach made to an R & D establishment may set in motion a long chain of interactions, possibly involving an exchange of personnel between a firm and the establishment. As the degree of interaction between the source and recipient grows, transfer, should it occur, may no longer be lacking in source direction since the source may become interested in effecting transfer. These innumerable person to person contacts are believed to be of vital importance in passing information, the receipt of which may be the first step toward technology transfer.[32]

The original event or act creating the potential for technology transfer, such as transmission or personal contact, need not originate in the government establishments; the initiative may come from the potential recipients of technology. Establishments very frequently receive inquiries concerning scientific and technical matters which may stimulate an interaction with an establishment and may be starting points for technology transfer. Inquiries may also serve to introduce an establishment to a new type of problem and may even have an impact on the work program of the establishment.

10. Technology Transfer with Source Direction

Quite frequently, government R & D establishments are not content to play a passive role in securing applications or utilization of the knowledge they have generated and deliberately set out to effect a transfer of technology. Some of the circumstances leading to this more active involvement are discussed below.

In dealing with technology transfer with source direction, we should recognize a distinction between technology transfer that is unrelated to fulfilment of establishment missions, and technology transfer undertaken to fulfil establishment missions in some way. It has been repeatedly emphasized in this report that the responsibilities of R & D establishments towards manufacturing are far fewer than is commonly supposed. A very large number of establishments have no concern with the welfare of manufacturing, and there is little in their work that is of interest to manufacturing or likely to produce benefits for it. But, at the same time, rare indeed is the establishment or laboratory that does not occasionally generate an idea, a technique or device of interest to manufacturing. When such a circumstance arises we may have either 'incidental' technology transfer unrelated to establishment mission or 'incidental' technology transfer related to establishment mission.

The first case involves an effort to effect technology transfer to manufacturing when it is not the role of the establishment to do so or when no benefit will accrue to the laboratory by doing so. This type of philanthropically motivated technology transfer is sporadic, but it does exist and it should be noted.

Rather than seek out a firm on its own initiative, a laboratory may pass on a new device, instrument, etc. to Canadian Patents and Development Limited. This is an alternative which is frequently employed, and one which has resulted in the transfer of technology to manufacturing. Initially CPDL, which is a wholly- owned subsidiary of NRC, was intended to handle "their assessing, patenting, development, promotion, licensing and related aspects of NRC's inventions".[33] This mandate has since broadened, and CPDL now serves all Canadian government departments and agencies in the handling of inventions made by the public service.[34]

Most of the inventions brought to CPDL have arisen as solutions to problems encountered in carrying out basic and applied scientific research. Most of them require a great deal of development before they are ready for commercial production or use. "About 40% of the inventions are instruments or methods for measuring, analysing, testing, etc., i.e., they are new 'tools' which the researcher invented in order to accomplish his research project."[35] These 'tools' usually comprise high technology and their market normally consists of other researchers or developers. The majority of the inventions arise not as spin-offs but as unique solutions to the problems the research projects set out to solve. The distribution of inventions among chemical, biological, metallurgical, mechanical and electrical fields is fairly even.

That the nature of most of the technology handled by CPDL is 'incidental' is quite clear. The missions of the laboratories producing inventions are quite unrelated to manufacturing industry, and no concern with commercial possibilities for manufacturing was in the minds of the inventors.[36]

Many of the inventions sent to CPDL are patented, and attempts are made to find licensees who will develop and commercially produce the invention. If a firm is found, interaction between the laboratory producing the invention and the firm trying to develop it may prove to be very useful, and in some cases essential. CPDL emerges as an important intermediary in the transfer of technology from R & D establishments to manufacturing industry.

The other type of incidental technology transfer is different in that it is related to establishment missions and can be useful or essential in allowing the establishment to carry out its work. Although many establishments have no mission related to manufacturing needs, and perform work which on the whole is of little interest to manufacturing in terms of commercial possibilities or opportunities for cost saving, etc., they do occasionally obtain advantages in interacting with manufacturing. Such interactions may lead to, or necessitate the transfer of technology to manufacturing.

In many establishments the need for interactions with manufacturing arises in relation to the development and production of equipment required for basic or applied scientific research. For example, at the Bedford Institute of Oceanography, the only direct interaction with manufacturing relates to equipment required for its research in oceanography. Incidental technology transfer appears to work in the following manner. In response to requests from their scientists, the technology services or metrology divisions work out designs and specifications for equipment which meets the specified needs. They give these to a company and ask if it is interested in the development and production. If they believe there is a market for a device beyond the immediate needs of the R & D establishment they will try to avoid paying the development costs. If on the other hand it is a once-and-for-all job, solely of value to the laboratory, they will pay the company the development costs. In every case we have examined of this type of technology transfer there appears to have been considerable cooperation between the laboratory and the company. The laboratory does evaluations and testing, and sends people to help the firm with its problems.

This type of incidental technology transfer results from an initiative based on need shown by an establishment and from the interest manifested by manufacturing firms. Sometimes, however, the initiative is taken by business; government research establishments receive sporadic visits from representatives of industry for the purpose of ascertaining whether or not they have ideas or inventions which may be of economic value to manufacturing. Such visits can be the starting point for the incidental transfer of technology.

Earlier in this chapter, we noted that with the exception of NRC no government R & D complex has a mandate to attend to the welfare of manufacturing industry, and certainly none has a mandate to develop and transfer technology appropriate to manufacturing interests. On the other hand, we have observed that the R & D establishments of some departments and agencies must interact with manufacturing industry, frequently if not continually, as an intermediate step in the comple-

tion of their missions, and therefore in fulfilment of their functions. Hence a distinction must be drawn between incidental technology transfer involving small discrete pieces of technology and 'non-incidental' transfer which relates to large and complex bundles of technology, often composed of a variety of technological elements, and which is of central and continuing importance to the missions of some establishments.

AECL probably provides the best example of an establishment which relies heavily on technology transfer in order to fulfil its mission. Its interactions with manufacturing have been described in some detail by one of its senior professionals annd we draw heavily on this paper.[37]

There are three major ways in which AECL interacts with industry and technology transfer tends to be an element in all three. The first type of interaction involves the purchase of equipment by AECL's laboratories for their own R & D program. The laboratories require a vast array and quantity of equipment. Some of it can be bought off the shelf, but much of it requires research and development before the final detailed design can be completed, and this in turn necessitates cooperation and exchange of information and know-how between the laboratories and the firms providing the equipment. The industrial firm may ultimately benefit from the acquisition of a new technological capability or a new product of interest to consumers other than AECL.

The second type of interaction concerns research and development contracts with industry. These have been employed by AECL for over fifteen years and cover fields such as fuel, heat transfer, fluid flow, mechanical components, materials, chemical process development, instrumentation and engineering design. The best example of this type of interaction is provided by AECL's cooperative program with industry for the development of nuclear fuel. Its result has been the emergence of two Canadian nuclear fuel manufacturers capable of supplying high quality fuel at a low price. "Additional cooperation was obtained by having both companies make the experimental fuel required for AECL's own program, and by both companies attaching staff to participate in the program." The inter-

action was long and involved, and provides an excellent case study of the difficulties and impediments to the creation of a new product line from the conceptual stage to commercial viability. Some contracts, by contrast, have the purpose not of creating new products but of creating within a company a team of experts which can then be used by AECL in a consultative capacity.

AECL's development contracts have tended to relate to the objective of improved operation and easier maintenance of nuclear plants. "In choosing the company, preference is given to those that are willing to apply the results of their work in the field by offering a contract service to the power station owner."

A lot of technology transfer has involved instrumentation. From time to time AECL requires assistance from industry to create a reliable field instrument from a laboratory-developed instrument.

> "The developing laboratory is often too far removed from the operating organization that will eventually use the instrument. The scientist doing the development often does not realize that the technical staff in the field may be of a lower quality than that in the laboratory and that there are many changes in the plant environment in which the instrument has to operate which cannot be reproduced in the laboratory. Therefore it is not uncommon to experience difficulties when an instrument goes directly from the laboratory to the field. An industrial contract to engineer the instrument into something which will be accepted in the field is generally required. Such contracts have the added advantage that the industrial company manufacturing the instrument can offer a maintenance service in the field....
>
> The development of detectors for the measurement of neutron flux in reactor cores is a good example of an AECL invention and development transferred to industry. To transfer the technology the manufacturing company attached staff to the Chalk River Nuclear Laboratory (CRNL) and did product development under contract to CRNL. During this work problems

arose which necessitated the use of disciplines that were available within CRNL but which were unavailable within the industrial company. Within a few years a small new Canadian company was established which has also been able to compete successfully in the U.S. market".[38]

A third type of interaction with manufacturing industry is to have industrial staff attached to AECL laboratories. The purpose of such attachments is to enable the industrial company to build up its technological expertise in a specific field. Staff are attached for one or two years and are technically a part of AECL's work force. The number of such staff varies considerably from year to year but generally is about 25.

11. Technology Transfer to Manufacturing: Problems and Impediments

The greatest impediment to the transfer of technology from government R & D establishments to manufacturing industry comes from the roles and functions of the R & D establishments themselves. As long as most R & D establishments lack the mandate to work in direct support of manufacturing, technology transfer from one to the other will remain as it is now: tangential, instead of central, to the work of the R & D establishments; relatively limited in occurrence; and confronted by many difficulties. Compared to this single factor all other impediments to the transfer of technology to manufacturing are trivial.

There does exist a potential for the transfer of technology to manufacturing, however. Most of the rest of this chapter is concerned with the impediments to the exploitation of this transfer potential and is not concerned further with explaining why the overall potential is low in the first place. The influence of roles and functions is all pervading.[39]

12. The Problem of Discordance Between Technology Supply and Demand

We can think of industry as constantly generating a demand for new technology, mainly relating to products and processes, and government R & D estab-

lishments creating a supply of new technology. However, industry and government are generally working towards quite different objectives; each requires technology for its own particular and different purposes. The result is a discordance between the supply provided by government and the demand generated by industry. Such a discordance has to be expected and is bound to persist if government establishments are not directed to create a supply to meet industrial demand. It is axiomatic that the finding of a commercial application for a technology created and developed without commercial application in mind is highly fortuitous.[40]

When an establishment seeks to find a wider application for know-how or technology created to meet its own purposes, thereby promoting the transfer of technology, it is asking industry to behave in a way that runs counter to the normal pattern. Manufacturing tends, as does government, to move from the perception of a need (e.g., lower production costs or new products) to the development of technology or know-how to meet the need. The transfer of technology from government to private industry implies a reversal of this pattern of behaviour. Firms are presented with a laboratory-developed technological solution for a problem which they may never have considered, and asked if they are interested in finding a commercial application. In other words they are asked if they are interested in fitting a need to a partially developed technology (Figure IV.1). There are of course exceptions to this and they will be considered in some detail later in this chapter. Briefly, the most important exception is when the government establishment itself defines the need, and follows the sequence outlined above. Industry is enlisted in helping the establishment meet the need and this is only possible if technology transfer to industry occurs (Figure IV.2). However, Figure IV.1 describes the more normal case. Solutions are defined and applied using the internal resources of the establishment. It is only afterwards that industry is presented with the technological solution as developed by the establishment and asked to consider its possible commercial application.

Offering technological solutions to industry (as in Figure IV.1) is rather like reversing the

Figure IV.1 - Patterns of Activity

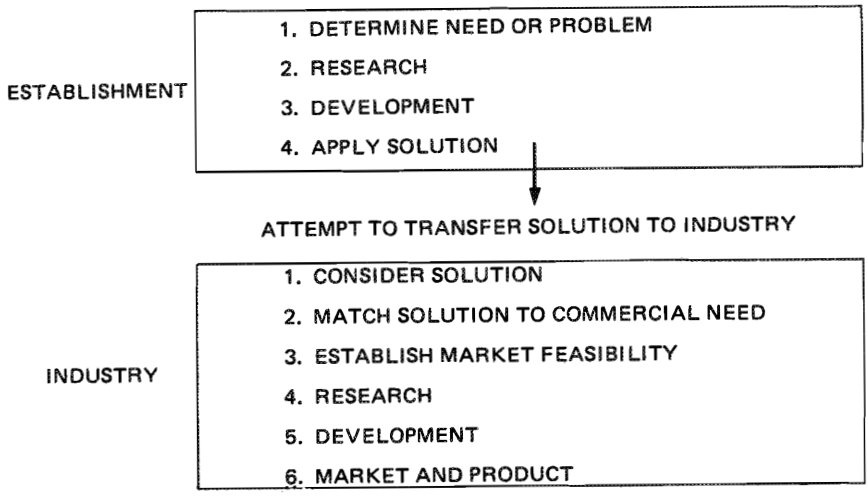
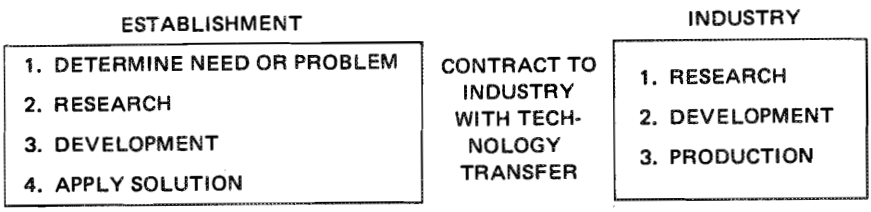


Figure IV.2 - Patterns of Activity



normal shopping pattern of the consumer. Consider the woman who decides she needs a new dress. In selecting it she considers the functions for which it is required, her budget, her size, the nature of her accessories, her best colours, and so on. If however a woman received a dress at random through the mail, it is highly unlikely that she would be in need of a new dress at that particular time, and even if she were, it is highly unlikely that the dress would be of suitable cost, size, colour, etc. Of course, clothing firms or retail stores do not send dresses to women through the mail, but they do advertise and send out catalogues in the hope that the goods they are offering will meet the needs of at least some of their readers. This latter situation is more analogous to an establishment trying to find a commercial use for a solution to an establishment-perceived problem than is the first situation, with its total randomness.

Most establishments have a fair idea of which firms are potential recipients of any particular piece of technology, and are well aware of the futility of approaching firms at random. A selective approach to the possible recipients of a new piece of technology helps reduce the random element in this type of attempted technology transfer but does not eliminate it. When an R & D establishment approaches the very small number of firms that may be interested in a particular piece of technology, it faces formidable obstacles if the transfer is to be effected. Some of these obstacles are located within the establishment itself, but for the moment these will be ignored, and attention concentrated on the potential obstacles on the industrial side. There are many reasons why potential recipients will not even consider the development of a new product. Firm A may just have completed an expansion program. Firm B's director may be in the process of recovering from his last nervous breakdown which was related to an unsuccessful product innovation. Firm C may be content to rest on its laurels. Firm D may be experiencing financial difficulties. Firm E may have already committed all its available resources to the development of an innovation of its own. The reader can no doubt envisage other reasons why a particular firm may show no interest in the proffered piece of technology.

Normally, only one or two firms will ever seriously consider adopting the technology with a view to commercial production and sales. Even this does not inevitably lead to a decision to attempt a technology transfer. Before committing itself a firm has to take many factors into consideration, for example, the estimated size of the market for the innovation; does the estimated volume of sales justify the estimated research and development costs? Ironically, it appears that government inventions frequently offer sales prospects far too small for large firms, and require production levels too large for small firms. Would international sales be required to make adequate profit levels? Small Canadian firms without a wide sales network often hesitate to enter international markets. What is the technical complexity of the invention or process? What is the anticipated development time? Will it require diversion of scarce resources? Will it require manpower and capital expansion? What is the availability of venture capital? Another, quite separate, factor is the extent of assistance and cooperation which the source of the technology, namely the government R & D establishment is prepared to offer the firm. Sometimes the establishment is prepared to do no more than hand over plans and specifications. Alternatively, it may offer to cover the development costs and to provide the services of some of its own scientists and engineers. It may be willing, indeed anxious, to purchase and use the finished product. The role played by the establishment is crucially important and we shall return to consider its influence.

Once a firm has decided to find and develop a commercial application for an idea or piece of technology emanating from a government R & D establishment, there is still no absolute guarantee of successful technology transfer. The development work may run into all sorts of unforeseeable difficulties. The firm's resources may become overstrained. Difficulties arising from within or outside the firm may nevertheless cause the curtailment of such activities.[41]

We have already noted that the receptivity of manufacturing is by no means entirely dependent on its internal circumstances or its perceptions of risk, but is also dependent on the attitude, motivation and assistance offered by the establishment

which is making the technology available. Technology transfer is a movement of knowledge and/or expertise between two individuals, two organizations, or two groups. There is a source and there is a receiver. The circumstances surrounding the source's interest in and motivation for technology transfer are as important as the circumstances determining receptivity in manufacturing.

Many different motivations may underlie an establishment's urge to transfer technology. These range from public-spiritedness at one extreme to vital necessity (to complete its program and thereby fulfil its functions) at the other. Whichever motivation prevails, the implications for technology transfer are very important. As a general rule we may say that the greater an establishment's desire or need to effect a transfer, the greater the likelihood of transfer taking place. A strong desire to transfer is usually associated with the enlistment of industry's assistance in meeting the R & D establishments own needs (situation portrayed in Figure IV.2). Or, to put matters another way, the more urgent are the source needs, the greater the source direction, and the smaller the element of randomness in technology transfer. Conversely, when there is no pressing reason for an establishment to make a transfer, the more passive will be its role, the less the source direction, and the greater becomes the element of randomness in technology transfer.

When an establishment has no need to effect technology transfer to meet its own program requirements it will normally assume a rather passive stance as far as technology transfer is concerned. It may do no more than make industry aware of certain technological developments and leave industry to interpret and use the information in whatever way it sees fit. Laboratories relying solely on the transmission of information are leaving the likelihood of technology transfer strongly dependent, at least in the initial stages, on the factors affecting the manufacturers' receptiveness. When a laboratory is specifically oriented to the problems of a particular sector or industry, e.g. the relationship of NRC's Division of Building Research to the construction industry, simple transmission can initiate a lot of technology transfer. However, when a laboratory is not oriented to manufacturing,

as is the normal case, transmission to manufacturing seldom leads to technology transfer.

Beyond the simple act of transmission we have the non-essential, or philanthropic, attempts to transfer technology. We can regard this as technology transfer with weak source direction. It applies almost entirely to incidental technology. In the typical example of this, the establishment has nothing to gain in furthering its program by involving itself in transfer. Funding for development is not provided. A firm may be offered plans and specifications, but little other assistance is given. The most common motivation for this type of attempted technology transfer is the belief on the part of one or more laboratory personnel that a device or an idea developed to meet their own purposes has some commercial possibilities. Quite often industry cannot muster the same optimism about alleged commercial possibilities and the laboratory fails to find a receptive manufacturing firm. As a result, there is a commonly held view in the establishments that Canadian industry has failed in exploiting an innovation which subsequently proves to be highly profitable and useful. It is with this non-essential incidental technology transfer that the discordance between technology supply from government and technology demand in industry is most noticeable. From the industrial point of view the incidentally developed technology flowing from government establishments is not commercially oriented. Since the establishment motivation for seeking technology transfer is relatively weak, comparatively little energy is devoted to transfer activity, a circumstance which increases the importance of random elements. Only by chance will a firm perceive the commercial opportunity and be in a position to exploit it. In general, the industrial firm receives little help and assistance if it tries to adopt the technology, and the establishment gains neither in prestige nor in furtherance of its program if it does find a firm interested in commercial development.

When government establishments wish technology transfer to occur, or more important, when the transfer has to occur, all steps and measures necessary to success are taken. This type of technology transfer occurs when the aid of industry is necessary (or at least regarded as necessary) to

permit the establishment to carry out its program. Because such transfers are related to the establishment's own needs, i.e., the furtherance of its program and the program of its department, it is prepared to commit resources to effect the transfer. These circumstances greatly improve the possibility of successful technology transfer.

In the first place, potential risks to the industrial firms are greatly reduced and may almost be eliminated. Zero risk is impossible since even when a firm is totally guaranteed against financial loss it is foregoing alternative opportunities by involving itself with a government establishment. When the transfer relates to a product or process which can have a use other than the one for which the government R & D establishment requires it, the total costs of design development and production are likely to be met by the establishment. Total funding by the establishment is usually the rule in a project devoid of further commercial prospects.

In cases when there is likely to be a continuing demand for the transferred process or product, either in the government or outside, or both, only partial funding may be provided by the government. As a general rule the firm which has done development work for an establishment obtains the license to manufacture the product which it has developed. The anticipation of commercial prospects for a new product or newly acquired skills, is obviously important in influencing a firm's decision to work or not to work in cooperation with a government R & D establishment. Development contracts employed by DRB in the past probably provide the best examples of the transfer process enabling firms to produce new products for which there is a sizeable demand both in and out of government. For example, Bristol Aerospace cooperated with the Defence Research Establishment Valcartier in the design and development of the various Black Brant rockets. There was a significant transfer of technology. Bristol acquired the manufacturing rights and has succeeded in selling hundreds of Black Brant vehicles. One should also note that because of its past cooperation with DRB, Bristol is now capable of undertaking its own development work on rockets.

When an establishment has a pressing need to employ industry and thus has a strong motivation to

effect a successful transfer of technology, the sequence of activities often proceeds as follows. In the first place, the establishment has normally done a lot of R & D to establish the feasibility of a product, process or technique before it reaches the stage of considering the enlistment of industry's assistance. It may even have developed a crude but workable prototype. There are a number of reasons why the establishment may turn to industry at this stage, but the most common is industry's possession of expertise in development engineering that is either non-existent or scarce in the establishment. However, it may be implicit in the establishment's mandate, or even explicitly stated, that industrial cooperation in R & D programs should be sought whenever possible in order to build up industry's technological capability. At this point there may be no agreements concerning rights to commercial production, although firms frequently anticipate future involvement in commercial production. Indeed, such anticipation may be crucial to their decision to allocate manpower and other resources to government work.

While working on a development contract, a firm may receive varying types and amounts of assistance from the government establishment letting the contract. In the case of long and technologically complex projects the establishment may appoint one or more employees to manage the contract.* Facilities in the establishment may be made available to the industrial firms. Establishment personnel may be seconded to the firms for varying periods, or industrial staff may be sent to work in the establishment. The literature is in general agreement that the most effective way to transfer technology is by bringing together the

* AECL believes that cooperative research programs have the greatest possibility of success when the ratio of professionals in industry to directing professionals in the laboratory does not exceed 5 to 1. Above this ratio, the laboratory professional spends so much time monitoring the contract that he is unable to remain an expert in his own field. Such individuals work in a liaison capacity and help to clear obstacles in the way of technology transfer.

people who possess knowledge with those wishing to acquire, adapt and apply it. This is acknowledged as far more effective than other forms of information exchange and interpersonal communication.

A good example of an R & D complex which made extensive use of this mechanism was the Defence Research Telecommunications Establishment (DRTE) of the Defence Research Board. In considering the development of the satellite "Allouette II", DRB decided there was enough technological capability in Canada to produce a mostly Canadian-made satellite. The department embarked on a major technology transfer program. The first step was to bring 75 to 80 engineers from several firms into DRTE to work on the development of the satellite. Working closely with DRTE personnel, these engineers developed the basic systems requirements. Components of the system were then contracted out to various companies (for the most part those from which the engineers had been drawn) which had the necessary capability. These companies worked from the drawings prepared in the establishment. Eventually, all the components were fitted into the complete satellite.

DRTE then moved on to the "ISIS I" Satellite. By this time they had at their disposal a number of companies with appropriate expertise and experience. This time, competitive tenders were sought and firms were selected. The systems design was done in DRTE, and the manufacturing firms produced the prototypes and final products. This involved a lot of interaction between industry and DRTE. If a company ran into difficulties, DRTE would send one of its staff to spend a week or a month with the company to help it over its troubles. This applied even to companies in the United States. With the completion of "ISIS I" industry had acquired a solid foundation, so that in the development of "ISIS II", DRTE (by then transferred to the Department of Communications as the Communications Research Centre) played only a supervisory role, and industry did almost all the work.

When the writers visited the Communications Research Centre (CRC), work was underway on a new and more complex satellite (Communications Technology Satellite). As in the case of the early stages of Isis satellites, it was decided that CRC should

take the research initiative and the development risks in-house. At the same time it pursued a policy of using industry where it could, with the ultimate aim of transferring full capability to the industrial sector. At the time of our visit, CRC had approximately 125 people working on the new satellite program; of these only about 25 were government employees and the rest were from industry.

With non-incidental transfer and strong source direction the effects of discordance are greatly reduced because government and industry can combine forces in working towards the same goal and responding to the same need, i.e., a need perceived or generated by government. However, the effects of the discordance are not totally removed. Even when money is available and various types of assistance are at a firm's disposal, industry will not necessarily be interested in doing contract research. Drawing on AECL's considerable experience, Perryman says:

> "Such work is competing for the best staff which might be more profitably used on some other work which may have a shorter timescale. Another difficulty is that some research projects, especially those which are leading to a new product may be very long term before commercial viability is attained and the market potential may be very uncertain for the first few years.
>
> In such cases industry has got to be convinced about the eventual market potential before they are willing to cooperate."[42]

Nevertheless we can say that once an establishment realizes that industrial assistance is essential, an interested firm will almost invariably be found and the transfer will be effected.

The motivation of an establishment as it relates to technology transfer is dependent on particular sets of circumstances which we have attempted to describe. The motivation is strong when an establishment is buying the services of industry in order to meet its program requirements, but relatively weak when the establishment's concern is limited to offering a technological opportunity to

industry. In the latter case, the initiative required to exploit the opportunity rests with industry. And it is precisely at this point that the discordance between technology supply and demand makes its effects felt. Industry will not be interested in many of the proffered ideas or pieces of technology. What the lab personnel with their lack of business experience perceive as a possible commercial opportunity is not necessarily viewed in the same light by those who gain their livelihood in the commercial world. It is really a matter of luck if an establishment which has no mandate to create technological opportunities of commercial potential comes up with an idea or a device tempting enough to lead a firm into the risky process of innovation.

In the case of incidental transfer the firm has to find the commercial outlet for a crude technology developed by an establishment for its own non-commercial purposes. It is the firm which has to assess the market potential, and undertake the design, the development and the production. And it is the firm which has to take the financial risks associated with these activities. All things considered, we should be surprised if industry shows comparatively little interest in new pieces of technology emanating from government R & D establishments.

Both industry and the R & D establishments exhibit deficiencies which militate against successful technology transfer. Both are operating within a framework of circumstances unfavourable to technology transfer which they have inherited rather than created themselves. The establishments should not be blamed for providing ideas, information, or specific technology in which industry is uninterested, since it is not the role of most establishments to produce ideas for the enhancement of company profits. Indeed, one could argue that industry should be surprised and grateful that it has reaped as many benefits from the R & D establishments as it has. Industry should not be blamed for lack of initiative in picking up technology which it believes will not significantly lower costs or increase sales. Its perspectives and criteria are different from those of the R & D establishments, and so it is hardly surprising if it rejects items brought to its attention by the establishments.

We must remind the reader of the distressingly small number of firms in Canada which are potential recipients of new technology from government R & D establishments. In all industrialized countries there are only a few categories of manufacturing interested in innovation or likely to produce it. Within those categories one can expect to find only a small number of firms with the capability either of generating innovations on their own or of adopting and adapting technology generated elsewhere. Inventions, ideas or particular pieces of technology as they emerge from government R & D establishments always require a considerable investment of skilled labour and special facilities before they can appear as marketable products or processes. Even in the most dynamic of industrial countries very few firms have, or want to have, the professionals and the facilities necessary to bridge the gap between invention and innovation. In Canada only about 500 manufacturing firms out of a grand total of approximately 33 000 have any potential to be recipients of government generated technology, a much smaller proportion than might be expected. When discussing problems of technology transfer it is easy to forget that there must be potential recipients of the technology, and that in Canada there are not enough firms to whom transfer can be made.*

Among the impediments the problem of discordance is probably the most important, and one likely to continue unless the mandates of some establishments are changed to give industry's needs and opportunities central importance in the actual R & D programs and activities undertaken. We should point out the ethical/political problem which would be raised by such a reorientation of establishment mandates. Why should public funds be expended for the purpose of augmenting industrial income? Is there not greater social justice in the present situation in which our establishments pursue roles of general societal value, while at the same time industry enjoys occasional financial benefits?[43]

* The problem of finding a potential recipient is compounded by the high degree of foreign ownership in precisely those industries which could use the technology flowing from government establishments.

13. NRC and Other Special Cases

As noted earlier, NRC and parts of the research arms of certain departments (e.g., the Forest Product Laboratories of the Department of the Environment, certain small parts of the Department of Agriculture, and sections of the Mines Branch of EMR) are exceptions to the rule since they are charged with responsibilities either to manufacturing as a whole, or to certain sectors of it. This being so, they merit special and separate attention partly because the greatest impediment to the transfer of technology to manufacturing, namely, inappropriate mandate, seems to have been removed, and partly because the problem of discordance, the focal point of discussion in the previous secction, should be eliminated or at least greatly reduced in severity.

In view of its size and its current and historical importance in government R & D, the greater part of the discussion will refer to NRC. In Chapter I we recognized the widely held view that NRC has neglected its responsibility to foster a strong national industrial research capability. We generally agree that some fault should be accepted by NRC for this situation. However, we also make the point that it was not so much that NRC neglected its industrial responsibilities, rather that its approach was too narrow. Too much emphasis was placed on training scientists and engineers who might ultimately find employment in manufacturing, and not enough attention was given to the problem of generating an industrial demand for these very same scientists and engineers. In addition, and of perhaps greater importance, we have suggested NRC had and continues to have great difficulty in carrying out this part of its mandate because of Canada's unique industrial development and structure. Strong foreign control of Canadian manufacturing inhibits healthy interaction between NRC and the manufacturing sector.[44]

In considering NRC and the transfer of technology to manufacturing industry, it is helpful to examine NRC's own interpretation of its mandate. NRC has no instructions about the manner in which its responsibilities to manufacturing are to be exercised. Clearly, the transfer of technology is one mechanism which could be employed to meet its mandate, but NRC has never regarded technology

transfer (particularly with strong source direction) as an important tool in its job of fostering a national industrial research capability. Since it is practically impossible to assess the total impact exerted by NRC (or any other R & D organization) on industry, it would be imprudent to conclude that NRC has pursued the wrong policy. All we do know is that NRC was to help Canadian industry develop a research and development capability and that Canadian industry is still woefully lacking one.

There seem to be several reasons for NRC's relative inactivity in the sphere of source directed technology transfer. One reason lies in the breadth of NRC's mandate. Not only is NRC responsible for developing a national industrial R & D capability, but it is also responsible for developing a national scientific research capability. Historically, the latter has been given priority. Thus a very large proportion of the R & D output tends to have a low transfer potential. NRC devotes much of its energy to fundamental research which in the long term may have significant implications for innovation, but in the short term tends to provide neither new products nor processes amenable to technology transfer. Several divisions of NRC are almost entirely devoted to basic research. For example, the Chemistry Division regards it main function as the extension of scientific knowledge. There is no overt attempt to produce industrially useful results, yet it does have tenuous links with the development of technology and interacts, to some degree, with industry, especially in a problem-solving capacity.

Another reason for NRC's "failure" is that it has never interpreted the industry referred to in its mandate as consisting solely of manufacturing industry. Rather it has addressed itself to the solution of scientific and technological problems which are of importance to such industries as communications, transportation, agriculture, construction and certain service industries. Naturally, this has diminished NRC's potential to create transferrable technology for manufacturing.

Finally, the broad organization of NRC's work program is by discipline rather than by the responsibilities described in its mandate. Even in those

divisions with the strongest orientation towards manufacturing the two major responsibilities of scientific and industrial research capability are combined. Hence no division is entirely or even mainly oriented towards the research needs of manufacturing industry. This reduces the possible output of products or processes useful from the manufacturing point of view. The one exception to this is the Division of Building Research which can be regarded as completely mission oriented.

More important than the breadth of its mandate is NRC's interpretation and implementation of it. Technology transfer has not been viewed as a particularly appropriate means of meeting NRC's responsibilities to industry. During one interview, a leading official of NRC said: "We have no active on-going program to move technology to industry or elsewhere. This is not part of the mandate of N.R.C. Our concern with transfer is with knowledge transfer. The true raison d'être of the Council - to which other aims are ancillary or secondary - is the creation of knowledge". Taken at face value this statement perhaps seems to be a repudiation of a major part of NRC's mandate. But in saying that NRC is involved not with technology transfer but with knowledge transfer, the official is in effect saying that NRC is not concerned to transfer product or process technology to manufacturing (this is not entirely true: NRC possesses CPDL, the only government organization centrally involved with technology transfer) and, more to the point, that it is not in the business of creating new hardware for the purpose of providing manufacturing with innovations. The distinction made between technology transfer and knowledge transfer is between specific hardware as opposed to technological and scientific knowledge. This distinction is fundamental to NRC's interpretation of its responsibilities towards manufacturing and other industries.

The philosophy of NRC is contained in the following statements made by officials in the Division of Building Research concerning its functions and objectives. Because of their importance we quote them at length.

> "The Division of Building Research is a sort of information agency. It exists to provide information to the building industry, to the

consumers of the products of the building industry and to the industries and individuals related to the building industries. To do this we carry out research. The function of this research is to meet informational needs that cannot be met elsewhere in the country".

"In choosing projects there is a strong collective psychology not to try to earn money for industry. This is not our prime concern. Our concern is not to increase the profits of the construction industry by means of new technology. If anything our aim is to save money through better materials, better protection, better techniques, etc.".

"We are creating a knowledge base which is a public good, and on which the nation can draw. We are promoting scientific and technical knowledge for the benefit of all Canadians. In relation to that objective we are transmitting knowledge as information and trying to ensure the information receives the widest possible transfer. We do not transfer innovation per se. The technology we transfer is in the form of information which is useful to the consumer, useful to the construction industry, useful to designers, architects, engineers, etc."

These are very revealing statements and although they emanate from a unique division of the NRC, they nevertheless have validity for the NRC as a whole. The Division of Building Research makes no attempt to earn money for industry. It does not aim to increase industrial profits by dispensing new technology. Rather it strives to create a knowledge base accessible to all who need to use it and can benefit from it; it creates knowledge which becomes a public good. This notion of producing a public good permeates the entire NRC. It is believed that NRC, at public expense, provides a vital service to the nation which no single private organization or group could perform. Given the prevalence of this belief at all levels of NRC, it is scarcely surprising that there is little concern with on-going source directed technology transfer to industry, for this runs counter to and indeed offends the notion of NRC existing to create and provide a public good.

Technology transfer from government R & D establishments to manufacturing industry implies conferring benefits on only one or two firms to the exclusion of others. The laboratory with a new piece of technology to transfer has to find or select a recipient firm. The firm is only interested if the technology promises to give it a competitive advantage. Thus public funds have been employed, in effect, to increase the incomes of a few private individuals.* This differs markedly from the transfer of technology to agriculture. All farmers are in a position to benefit from the transfer, and as a result of lower costs or better products the public in general benefits directly. When technology is transferred to agriculture or fisheries or construction, the whole industry, or a good part of it, benefits and the notion of producing public good is not violated.

If NRC in general does not favour the employment of technology transfer, how does it try to meet its responsibilities to industry and to manufacturing in particular? To some extent the answer is provided in the statements made by the officials at the Division of Building Research. Rather than pursue a policy that would result in a few selected firms being favoured, NRC attempts to provide a service of value to all industry, first by collecting and generating information useful to manufacturing as a whole or, at the very least, an entire industry, and second by developing a pool of scientific and technological expertise on which industry can draw. As one official put it, NRC's greatest asset is its people. The Division of Building Research exemplifies just how successful this approach to NRC's mandate can be. It seems barely capable of keeping up with the demand for information and expert advice. Indeed, the Division is so overwhelmed with inquiries and requests for help that it seems to be suffering from its own success. In a normal month this one Division of NRC handles approximately 1000 inquiries. In an average year, the Division distributes 600 000 copies of its publications and, as noted earlier in

* Through the "trickle-down" effect, however, jobs are created and the overall economy ultimately benefits.

this report, employs a barrage of other mechanisms to disseminate information. This includes its professional personnel serving on 488 different committees.

A considerable proportion of the information made available to industry is the end product of NRC's own R & D activity, but a much larger proportion has been collected by NRC from sources around the world. According to its mandate, NRC is authorized to operate the Canada Institute for Scientific and Technical Information (CISTI) which provides a complete scientific information service to the nation. This is the most important source of scientific and technological information in Canada and its resources are as accessible to industry as to other sectors. Within CISTI is the Technical Information Service of NRC. TIS is unique both to NRC and to the government scientific complex; it has a specific mandate to help industry solve technical problems. It is oriented to smaller firms, especially those without an R & D capability. Without charge it will send reprints of technical articles or specialized information to individuals to help solve a specific problem. Some 4000 firms receive monthly lists of information which relates to their specific interest/activity profile. With its field offices across Canada, TIS handled 30 000 inquiries in 1974. It also serves as a clearing house and, where appropriate, will direct inquiries to other areas within the federal government research complex. TIS handles inquiries, provides technical advice on plant design, material handling, production engineering and quality control, and disseminates to interested firms articles of interest selected from a world list of technical journals.

The activities of TIS consist of knowledge transfer and often involve technology transfer. More important, individual firms can engage the services of TIS without cost. In 1974, over 800 firms were assisted in a wide range of industrial engineering services. The activities of TIS confer a benefit on manufacturing as a whole and on specific firms in particular.

NRC also provides a vital service to industry in originating codes and standards. In accordance with its policy of helping industry, NRC has built

up a large inventory of research tools and facilities including wind tunnels, antenna ranges, and ship testing basins. The National Aeronautical Establishment operates the wind tunnels. "The low-speed wind tunnel alone has been involved in the aerodynamic development of at least twenty different types of Canadian-produced aircraft, ranging from the CF-100 to the Beaver-Otter-Caribou series, for which the total sales have been estimated to exceed two billion dollars".[45]

Although they are not actively concerned with transferring technology to individual firms, all NRC laboratories respond to requests for industrial information or help when there seems to be no conflict with NRC's interpretation of its mandate. They give assistance to an individual firm which seeks it, but in conformity with the general philosophy of NRC, do this only if there is no existing private commercial expertise capable of assisting the firm. This gives NRC a sort of "clearing-house" function and avoids conflict with the notion of providing a public good. Most laboratories, if and when they undertake R & D related to current industrial problems, prefer whenever possible to give priority to industry-wide problems rather than to those of individual firms. Some laboratories have a policy of charging a firm if it wishes the results of the research on its problem kept confidential, and of not charging if the firm agrees to publication of the results.

There are several strong similarities between NRC and the few other establishments with mandates encompassing industrial needs. For example, the Forest Products Laboratories of the Department of the Environment interpret their responsibility to the industry as one of developing, collecting and disseminating information useful to it. They see themselves as doing the looking ahead which industry cannot or will not do for itself, and like NRC attempt to be useful to the industry as a whole and not confer a competitive advantage on any individual firm. As one official put it, "The results produced by the laboratory are generalized results and usually have to be modified by each firm to suit its own particular requirements". Like the Division of Building Research of NRC, these labs are far more concerned with the general efficiency of the industry. The same official summed

up his position as follows: "The problems investigated by the laboratory are industry-wide: it is not the policy of the laboratory to do research on or carry out work on particular problems of individual companies".

With the exception of a very small section of the R & D arm of the Department of Agriculture, the most interesting characteristic of the organizations charged with responsibilities to manufacturing is their hesitation to employ directed transfer of product and process technology. It is mission-oriented organizations like AECL with, paradoxically, no direct responsibilities to manufacturing which use source directed technology transfer in order to get specific jobs done. The enlistment of manufacturing assistance is a means to an end, and it is unavoidable if one industry or firm is favoured and others are not. But for NRC assistance to manufacturing is the end not the means. It tries to accomplish this task without involving itself in specific missions. There seem to be no grounds on which NRC could decide to make a concerted effort to transfer this or that particular piece of technology to this or that industry.[46] Because of its mandate to assist industry in general, NRC probably has no choice but to adopt a relatively passive position. Its reliance on knowledge transfer, not technology transfer, in nurturing a national industrial research capability seems almost the only permissible interpretation of its mandate.[47]

The effectiveness of NRC's (and other organization's) knowledge transfer activity is impossible to assess. The total volume of its interaction with industry is impressive. Its attempts to provide useful knowledge to manufacturing are considerable; publications, bulletins, reports, papers, etc., flood out of its laboratories. There is not a manufacturing firm in Canada which has not been invited to explore the ways in which NRC may offer it assistance. It welcomes industrialists to its laboratories. Through TIS and through many other less formal mechanisms it sends personnel to firms throughout Canada to offer various types of assistance. There is no way of assessing the ultimate significance of a 20-minute phone conversation between an NRC engineer and a perplexed engineer in a private industrial company.

Two salient questions emerge. Is NRC generating the type of knowledge which Canadian manufacturing can fruitfully use? Is Canadian manufacturing capable of making use of NRC? Much of the next chapter is devoted to an examination of the first question, for in it we look at the R & D establishments (including NRC) from the standpoint of manufacturing industry. To some extent an answer to the second question was given in the introduction. Because of the extraordinarily high degree of foreign ownership in Canadian manufacturing, its innovative capacity is very low, and this being so, we must suspect that it cannot make a full and proper use of the services and knowledge offered to it by government R & D establishments. In the next section we examine this suspicion by studying the perceptions of Canadian manufacturing held by scientists and engineers in government R & D establishments. In particular we are concerned to establish whether or not government personnel perceive attributes of Canadian manufacturing which inhibit successful technology transfer between the labs and manufacturing industry.

14. Canadian Industry: Some Perspectives of Government Scientists and Engineers

We have emphasized the fact that technology transfer involves an interaction between a recipient and a source. The impediments to transfer can lie in either the source of the recipient or in the interaction mechanisms itself. Clearly, all is not well in Canadian manufacturing. As suggested above in Chapter I it seems to possess attributes which reduce its potential to be a recipient of technology emanating from government laboratories.[48]

Government R & D personnel hold views that vary according to their experiences and the different circumstances under which they have interacted or tried to interact with manufacturing. Few have praise for Canadian manufacturing as a whole; they differ mainly in the severity of their criticism.

Director of an establishment: "The problem with technology transfer is convincing industry that the laboratory has something which is commercially exploitable. The greatest difficulty in Canada in transferring technology from government to industry is the amateurishness of industry. Canadians are

not risk takers. Canadian manufacturing likes everything to be a sure thing. This establishment and the R & D arm of which it is a part, have come up with idea after idea only to find that industry was quite uninterested."

Section head within an establishment: "In general, Canadian firms are too small to do development of a new product line unless they are subsidized. Or alternatively, the firms are too large to be interested in small product lines. Many of the smaller ones sometimes cannot afford to go into joint financing deals to develop a new product line".

Director of an establishment: "There is a very big dilemma in Canadian industry at the present time. Partly because of its scale and partly because of the branch plant syndrome and its attendant attitudes, a great deal of Canadian manufacturing is not keeping up with the innovation in the rest of the world. Technological progress is being made in Britain, France, Germany, the United States and other countries. Canadian companies are not on the whole contributing directly to their progress but are absorbing this progress via their U.S. parent companies. In receiving their new technology in this way, they are losing the capability to maintain design competence. When most technology is imported, the country quickly loses its design capabilities. Sometimes Canadian subsidiaries of foreign firms have their own R & D facilities, but particular problems attach to this type of situation. American parent companies want quick results from their branch plants. They want quick profits. This greatly reduces any risks Canadian companies may take in innovation."

Director of an establishment: "Canadian industry has never been very innovative. They would rather buy a machine with new technology incorporated in it than develop their own technology. The branch plant situation exacerbates the lack of innovation in Canadian industry."

Project Manager: "The industry most closely related to our work is the electronics industry, which has no research to speak of in Canada. Even when the government scientists indicate to industry what their needs and those of the Ministry are, nobody is interested - not even when the Ministry would

pay the tab. There is a general malaise in Canadian industry. It is much more interested in making profits out of existing products than in developing new products. If we go to industry and say we have a need for new equipment, they show no interest, but if we say we have the plans for new equipment and we need 50 units made - they come running. If you say to the electronics industry, - what would you try to develop if money were no object? - there is no response. The branch plant syndrome has a lot to do with it. Branch plants have to make a buck. They are not allowed to stick their necks out. Industry seldom comes to the Ministry with an idea."

Senior official of R & D agency: "The majority of industrial firms never come near us. There is a basic lack of expertise in Canadian industry and this is a major part of the reason why we do not try to transfer more technology. More important than transferring technology is building up the research capability of Canadian industry. But a real obstacle is the presence of so many small firms in Canada and the fact that the good growing ones tend to be bought up by Americans."

Director of an establishment: "There is a great shortage of technical entrepreneurs in Canada. So few people from government or business have tried to set up a type of small high technology business so prevalent in the United States."

Section Head within an establishment: "The technology transfer in which we have been involved has been very much a one-way process. What we mean is that on the whole it is the laboratory that has taken the initiative. Industry is not interested in beating a path to our door. Most of the companies with which we have had dealings are too conservative and are not prepared to break out of domestic markets. Industry in Canada does not seem to be interested enough in new technology. In my opinion, the large number of branch plants in high technology in Canada is a considerable obstacle to the transfer of technology."

Many of the above statements are expressions of opinion based on factual experience, and they are of great value, since they remind us of the multi-dimensional nature of most behavioural problems, and the process of technology transfer is,

in large part, a behavioural phenomenon. Each group views a problem from its own particular standpoint, inevitably reflecting the group's special interests. To properly evaluate the nature and dimensions of a problem all standpoints should be considered. Over time, there has been a tendency to consider and lend credence to industry's perception of the labs and of lab/industry interactions and to neglect the lab's perception of these interactions and of industry. The remarks quoted serve to redress the balance a little but they much be considered alongside the views expressed by industry in the next chapter. In all probability the truth lies somewhere between the two.

As a caveat, it should be noted that government scientists and engineers often have a poor appreciation of the hazards and difficulties faced by industrial firms that become involved in the innovation process. Some tend to exaggerate or overestimate the commercial potential of technology or know-how with which they have been associated and to underestimate the difficulties which would have confronted attempts to find commercial application. We must treat with caution the views of those who have no experience of industry in general, and more particularly of activities vital to industry, such as marketing.*

Despite these necessary reservations, the observations of deficiencies of Canadian industry are too widespread to be merely the product of inexperience or ignorance. In our discussions with establishment personnel, we learned of case after case of technological opportunities which were disregarded by Canadian companies but subsequently exploited by foreign concerns, particularly American ones. The views on industry expressed by government scientists and engineers must not go unrecorded. There is a general lack of interest in innovation in Canadian industry and this presents a fundamental obstacle to the transfer of technology from government R & D establishments to industry.

* A recent Public Service Commission paper showed that only 10% of the research scientists in government establishments have had any industrial experience. Public Service Manpower Survey, Scientific Research Group, March 1974, p. 26 (unpublished).

The statistics on R & D in Canadian industry describe the severity of the problem. Only firms with an R & D capability will show any interest in using government-generated technology. Earlier background studies of the Science Council provide a sizeable part of the explanation for the lamentable lack of industrial R & D.[49] Central to the problem is foreign control of our industry. Until measures are taken to reduce or eliminate the effects of foreign control on the R & D activities of Canadian industry, government establishments will face above-average difficulty in transferring technology and in achieving a greater use of the masses of information which they generate and disseminate.*

Significantly, relatively few complaints about Canadian manufacturing were voiced in the R & D establishments which have employed technology transfer with strong source direction in order to meet their program requirements. These are the establishments which provide fully funded development contracts and many different types of assistance (including the lure of potential markets) to the industrial firms with which they interact. The establishments that leave the greater part of the

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* See also H. Crookell, "The Transmission of Technology Across National Boundaries", Business Quarterly, Autumn 1973, pp. 52-60. Prof. Crookell notes that (p. 60), "The absence of innovation in Canada is so extensive and of such long duration that it has become difficult to find research managers and industrial designers with experience in innovation." Another problem may be in the structure of the Canadian manufacturing sector itself. See Eric Kierans "Arctic Gas - And the National Purpose", a Conference on the MacKenzie Valley Pipeline, sponsored by the Canadian Arctic Resource Committee, 23-24 May 1974. "In 1970, 229 of the 207 424 corporations in Canada (or 0.18%) owned 53% of the total corporate assets. In manufacturing, 62 of the 21 000 firms (or 0.3%) owned 40% of the total assets. It is my thesis that these few firms must be considered the relevant firms in the economy and cannot be lumped together with proprietorships, partnerships and small and medium-sized corporations. They have a life and a dynamic of their own that must be considered apart from the people who nominally own or manage them."

initiative to industry, allowing it to assume most of the risks of innovation, tend to express the greatest misgivings about Canadian industry: these are the majority of our establishments. They harbour a general feeling that within the considerable constraints placed upon them they are doing their best to promote a healthy interaction between themselves and industry. One unfortunate but perhaps inevitable effect of this situation is to breed cynical resignation in government scientists and engineers. If this attitude pervades a laboratory, the possibilities of successful technology transfer are even further reduced. One government engineer said, "Why bother to try to transfer a good idea to manufacturing - it's a waste of time". Should this attitude become more widespread we have to be pessimistic about the future of the interaction between government R & D establishments and Canadian manufacturing industry.

15. Structural Attributes of R & D Establishments - Their Bearing on Technology Transfer

Only an establishment empowered to transfer technology to manufacturing is going to develop the structure, organization and skills appropriate to that function. Very few government R & D establishments have a mandate to attend to the R & D needs of manufacturing, and no R & D establishment has a mandate to transfer technology to manufacturing. It therefore follows that almost all establishments are not organized or staffed to facilitate technology transfer. They are established, structured and staffed in order to meet the roles and functions assigned to them, with the result that when technology transfer to manufacturing is attempted it is done within a framework that hinders rather than facilitates the process. An establishment with technology transfer as a central goal would possess the general institutional incentive to achieve that goal, and in turn, this would condition the incentive to individual employees. When technology transfer is not a goal, such incentives will not be present.

Government scientists and engineers, like any other employees are evaluated according to the quantity and quality of their contribution to the achievement of the collective goals of the organization. They differ little from employees of other

organizations in wanting to succeed, to fulfil their potential, to rise within the ranks of their organization, to gain power and/or prestige, and not least to gain greater financial reward. There are few establishments in which involvement in technology transfer to manufacturing helps the scientist or engineer meet these aspirations. The criteria employed to evaluate him, with a strong bearing on his career advancement, have little to do with technology transfer. In other words there are few incentives for the professionals to interest or involve themselves in technology transfer. Such involvement is usually in addition or incidental to the activities by which they are evaluated.*

Evaluation procedures vary from one establishment to another in terms of criteria and the rigidity with which they are applied. The following statements from four establishments give some indication of the variety.

Establishment A - "Programs and individuals are evaluated following the guide set down by the Treasury Board. The norms for productivity are well spelled out. For the scientist, the following are taken into account. Papers, patents, ability to inspire subordinates, committee work, etc. It is a very thorough going over. We try to introduce into the assessments consideration of the environment in which scientists are operating.

Establishment B - "The scientists are evaluated in a formal annual procedure. Each scientist submits a report outlining his activities over the year. This report includes information on publications in scientific journals, other publications and reports, contributions to design, any patents achieved during the year, external relationships, administrative activities and participation in R & D con-

* Royalties and license fees on inventions by government scientists will total $500,000 in 1974. CPDL receives payments from 150 companies that hold rights on 265 inventions. Government scientists are not becoming wealthy from their inventions: they get 15 per cent of royalties, which in 1974 will amount to less than $400 for each invention or technical development. See, "Many Problems Encountered Marketing Inventions in Canada", St. Thomas Times - Journal, 1 May 1974.

tracts. The scientists and their reports are considered by the director and his assistant directors. A promising scientist may be given a merit increase and/or promoted.

Establishment C - "I evaluate my personnel by examining what they have produced. In doing this I have no fixed criteria in guidelines. My judgements must be based on what was expected and wanted of my personnel. Sometimes one wants brilliance of a man, sometimes one puts him on a job which requires doggedness, in other cases one wishes to have adroitness. Publications can be important, but they are not terribly important and many people are involved in work which will not lead to publication. Once you have been director for a while and move around your laboratory you get to know your people. You get to learn of what they are capable. One is in the process of judging them all the time. However, one's judgements are not intuitive. One gets to know very well what level of performance to expect of any particular individual. The only time intuition enters into evaluations is when one is hiring someone. People are promoted because they are judged to have a capacity for greater performance than is demanded of them at that present level".

Establishment D - "The professionals are appraised on an annual basis. The process is commenced by the division head writing an appraisal of each member of his group. The next step takes the form of the director working with the division heads in further appraisal. After that, the appraisal moves to a higher level, namely the science directorate. The most important criterion is productivity. This is measured in a variety of ways. First of all, there is a scientific output in the form of papers, and other publications. Second, there is a man's contribution to development work, and his supervisory responsibilities. It should be noted that much of the work does not necessarily involve the production of research papers. We also consider professional consulting and a number of other factors."

Despite the variation exhibited in the above statements, and in government R & D establishments as a whole, certain common elements are discernible. Although there are signs of its waning importance, the "publish or perish" syndrome still

exerts a powerful influence on evaluations and promotions. This is particularly so with scientists as compared to engineers, and in establishments with a large basic research component. The stress put on publication reflects the fact that a greater emphasis has, generally, been put on the quality of the science done in the laboratories than on its application. And this is perfectly understandable, if not always desirable. In the first place professionals seek the praise and recognition of their peer groups and in the second place it is much easier to judge the quality and significance of scientific adjustment within its own field than on the basis of its external impact. Publication in an international scientific journal both contributes to the prestige of an R & D organization, and is interpreted as giving a strong indication of the worth of the author as a scientist.

It is very difficult to evaluate an R & D professional in activities outside his research or development work. This is especially so in the case of his interaction with organizations, groups and individuals either in other parts of government or in the private sector. Although such interactions may be very fruitful, there appear to be no criteria on which to base an evaluation.

Of course, one must always be wary of generalizations. Strongly mission-oriented establishments are less likely to overstress the significance of publication records than, say, establishments with a broad mandate to further science. And those establishments whose programs necessitate interaction with manufacturing (including technology transfer) tend to place a higher value on the ability of professionals to cooperate effectively with industry than do those which interact only incidentally. Most establishments belong to the latter category. It is in these that participation in technology transfer by the professional receives relatively little encouragement or recognition. More often than not the professsional who attempts to secure the application of his work in industry receives no recognition either monetarily or through promotion. Indeed he may be jeopardizing his career advancement through failing to match the efforts of his colleagues who confine themselves to activities consonant with the major role and functions of the establishment. Two profession-

als with a very good record of participation in technology transfer, both attached to an establishment with no responsibilities to manufacturing, made the following comment: "Perhaps there should be more recognition of technology transfer in government laboratories, and perhaps there should even be incentive schemes. There may be some merit in a system which gives rewards to scientists or to laboratories which successfully transfer some device or important information to industry."

16. Some Ways to Improve the Transfer Mechanism

When an establishment has no responsibilities to manufacturing industry, involvement in technology transfer with strong source direction (undoubtedly the best way to effect transfer) necessitates a reduction or a suspension of some of the activities in which the establishment feels it should properly be engaged. Establishments have finite resources, and for most of them such involvement would mean a re-allocation of resources to the detriment of activities they were set up to perform. For most of them, technology transfer to manufacturing is a sporadically occurring event. Only when it is regarded as essential to the completion of one of its programs will the establishment use its resources to effect technology transfer with strong source direction. Otherwise it will be reluctant to cut back its own activities, and at best will attempt technology transfer with weak source direction. However, as we have demonstrated throughout this chapter, it is technology transfer with weak source direction which so often cannot breach industry's own internal barriers to technology transfer.

It was suggested by some officials that one possible way of breaking this impasse would be to offer incentives to establishments that would encourage more active involvement in technology transfer to manufacturing. One such incentive would be to allow establishments to charge industry for services rendered, with the revenue flowing directly to the establishment concerned. In this way involvement with industry would be less likely to reduce the activities relating to the establishment's main functions. Revenue earned could be used to replace the resources employed to cooperate with industry and possibly give the establishment greater flexibility in expanding and changing its pro-

grams. The intent would be to provide a positive financial incentive for laboratories to interact with industry. As we have seen in earlier chapters, many establishments are in a salary squeeze; the ratio of salaries to total budget has risen to a point where little is left for capital expenditures of any type. Many establishments would like to augment their budgets. Charging for services rendered would encourage establishments to gear more of their activities to meeting the needs of industry. The results could be positive: increased revenues flowing to labs that successfully interact with industry; increased awareness of establishment/industry transfer potential; possible increase in the incidence of technology transfer. Some establishments do now charge for certain services, but the practice is not common and tends to reflect special circumstances. For example, the National Aeronautical Establishment imposes a charge on the users of its wind tunnels. A few establishments levy a charge if they carry out work related specifically to one company's problems and the results are to be kept secret. However, revenues earned do not accrue directly to the establishment, instead they flow to the Treasury Board, and do not compensate the establishment for resources directed to industrial work incidental to its main functions.

There are, of course, some objections to a widespread policy of charging for services rendered. First, it would stand in strong conflict with the public good role given to or adopted by NRC and other establishments with responsibilities to manufacturing industry. Second, it could cause the growth of unhealthy biases in the work programs of certain establishments: the incentive of greater revenue might begin to determine programs and activities rather than considerations of public needs.* And industry's needs do not necessarily equate with public good. These objections notwithstanding, there may be some scope for considering a system of charging more extensively than at present.

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* This possibility could be lessened if the establishment was only allowed to augment its revenues by a fixed percentage of its original budget, for example 20 per cent.

Another possibility is to free the establishments, or establishments which only transfer on an incidental basis, from any involvement in technology transfer. First, as we have noted, their mandates and limited resources hamper them in effecting successful technology transfer. Second, because they transfer only sporadically they may not be particularly skilled in interacting with industry. Third, such establishments may not even try to effect transfers when the potential exists because of their lack of appreciation of industrial needs and interests.

The promotion of incidental transfers could then be made the responsibility of a new agency especially created for the purpose or, alternatively, the responsibility of an enlarged and altered Canadian Patents and Development Limited (CPDL) with greater powers and greater freedom to take risks, and to prod industry than at present. In association with this, or even separately, some means could be introduced for facilitating the secondment of staff to industry for longer periods than some establishments now allow (if at all). Some establishments are reluctant to free good men for industrial work even for short periods, but if for example they were financially compensated by CPDL or some other body, the deprivation felt by the establishment could be lessened.

One further possibility is to attach to each establishment or groups of establishments, a specially trained and skilled person (or persons) whose sole job would be to facilitate interaction between government R & D and manufacturing. The functions of such an individual are well described by the terms "coupler"or "knowledge broker". It would be the coupler's business to become thoroughly acquainted with the programs, activities and research output of the lab or labs under his jurisdiction, and to be equally well informed about the activities, needs and problems of the industries or firms whose interests coincide with those of the establishments to which he is attached. In his liaison capacity the coupler could make both industry and the establishments much more aware and appreciative of each other's problems and needs, and thereby facilitate technology transfer, both in and out of the establishments, as well as exchange of information and ideas in general. The role of the coupler or knowledge broker would be demanding:

"A communications gulf exists... between the principal generators of new knowledge and large bodies of potential users. This is not a simple problem of language, but a complex problem involving attitudes, values, goals, work patterns, orientations, environments, and other variables."[30]

Couplers would, by definition, be generalists. As well as having a broad understanding of the R & D work in several fields, and a knowledge of the workings and collective psychology of industry, they would require the ability to maintain the good will and cooperation of diverse types of people. Conceivably, the couplers would be employees of an outside organization, such as an expanded CPDL, and not employees of the establishments to which they are attached. This would help promote the neutrality and objectivity so essential to the coupler's functions.

Another consideration in favour of couplers has to do with the timing of technology transfer to manufacturing. Officials of one R & D organization, commenting on their technology transfer activities, observed that they may not be transferring early enough in the process of developing devices or know-how in their establishments. In most cases an industrial firm has to undertake considerable adaptation of any technology received from a laboratory. The more complete a piece of technology is before it is brought to industry's attention, brought to industry's attention, e.g., a scientific instrument, the greater the probability that an individual firm will have to undo the establishment's work and recommence the design process. This situation may inhibit technology transfer, especially to smaller firms with limited resources. One official said, "Industry will always want to redesign, so it's silly to take things too far". There would seem, therefore, to be some merit in encouraging attempts to transfer technology at an earlier stage. The presence of couplers may facilitate this.

17. Summary and Conclusions

In this chapter we have examined technology transfer, provided an operational definition of the phenomenon and, most important, have seen the extent to which technology transfer activities are

found in government establishments. This chapter, and indeed this entire report, should serve to dilute the criticism of those who in a shot-gun fashion attack government labs for "not being relevant", or "not being responsive to the needs of industry", or "not helping to stimulate the process of economic growth". The establishments are carrying out their mandates; the roles and functions of the establishments often lead to technology transfer; but, in large part, technology transfer is a by-product or a means of achieving a goal desired by the establishment. It is usually not an end in itself. For technology transfer to become an end and not merely a means there would have to be an extensive change in the mandates, role and function of most government establishments. This, of course, is possible, but would require active political intervention in the workings of the governmental science complex.

The problem of what and how government research establishments should be doing what they do is part of the overall problem of science policy itself. Science policy is also a means and not an end. Doern provides an interesting contrast between science policy and economic policy:

> "The ability to develop some aggregate economic framework rests in part on the fact that economic policy has been viewed more as a substantive policy end in itself. The present interest in "science policy" seems to be concentrated on science in policy, that is, science as a means to other ends. Therefore, we have no grand theorists like Keynes because we are dealing with something that exists, in part, in a conceptual vacuum, and probably always will."[51]

And Doern cites Professor Gilpin who notes that,

> "What is taking place in France, the U.S. and other Western societies is in effect a Keynesian revolution in the relationship of science and state. Rejecting the laissez-faire-rechercher philosophy of the past, the science planners seek a role for the state in science affairs that can balance the need for central direction against the need for scientific freedom and initiative. But it is a

Keynesian revolution without a Keynes, for no one has or can formulate the appropriate magnitude and direction of state intervention."[52]

Thus the problem of technology transfer from government establishments inevitably leads to the question of what the establishments are doing, how much they are doing, and whether they are doing the "right" things. That government should be involved in scientific activities for the benefit of the nation was explored in Chapter I.[53] But how the expenditures should be allocated and on what is unclear. Harry Johnson sums up the economic value of science to society: "That is about the only message economics can give you: we are still confused, but we are confused at a much higher level of understanding."[54]

The choice of whether or not the labs should be changed in order to achieve a different outcome should be made by the Canadian taxpayer who is, after all, paying for the entire exercise. Should more publicly financed benefits be conferred on private firms? Should government establishments transfer technology to both Canadian and foreign-owned subsidiaries? If so, how can we be certain that taxpayer-financed technology will not flow out of the country through the efficiently constructed technology pipelines of the multinational firms?

There are trends at work which indicate that, over time, the governmental scientific establishment will contribute more and more to the well-being of the manufacturing sector. The "make-or-buy" policy, which involves contracting out activities from government laboratories, appears to be accelerating the process of technology transfer.[55] The policy is too new to draw a definitive conclusion; however, in the following chapter we shall present some preliminary perceptions of industry on how well the policy is working. The criticisms levelled at government labs, although unjustified in view of their mandates, roles and functions, have had some impact. A number of people interviewed are aware of the process of technology transfer and, within the constraints attached to their work, appear to be looking for ways to transfer technology either for the first time or in a more effective manner.

V. Technology Transfer: the Industrial View

Chapter V. Technology Transfer: The Industrial View

1. Introduction

Despite its many complex forms technology transfer always involves an interaction between a source and a recipient of a technology. So far, this study has concentrated on the source end of the interaction. In Chapter III, we examined the nature of the source, namely the roles, structure, functions, and behaviour of government research establishments, in the belief that an understanding of the characteristics of the source is essential to an understanding of its participation in, and attitude to, the transfer of technology. In Chapter IV we directed our attention to understanding the process of technology transfer and to describing its place in the functions and activities of government laboratories. A lot of attention was given to the government laboratories' potential to transfer, to the problems and impediments in the process when there is a potential, and to the perceptions that government scientists and engineers have of the difficulties of technology transfer.

In this chapter the viewpoint is reversed. Technology transfer is examined from the standpoint of one set of potential and actual recipients of technology, i.e., the actors and production units in the goods producing sector (for the most part manufacturing establishments). Both the viewpoint and the analytical approach are different. In the case of the R & D establishments it was considered essential to provide the reader with a detailed structural and functional analysis. This was done because, despite the many recent statements and reports on government R & D, we were unable to find an objective descriptive statement about why we have R & D establishments and what they are supposed to do. The absence of such a statement has contributed to the widespread misconceptions about the establishments, and we believe these misconceptions have been at the root of many criticisms levelled at the establishments.

There is no need for a corresponding descriptive chapter on the functions, structure, activities, etc., of Canadian industry. Perfectly adequate descriptions are to be found in a number of widely available publications. Nor do we need to discuss the general question of innovation before proceeding to the finer question of technology transfer to

industry and the place of technology transfer in innovation. Earlier studies and background reports of the Science Council, in particular, Innovation and the Structure of Canadian Industry, by Pierre Bourgault, have very adequately described and analysed innovation and its attendant problems in Canadian industry.[1] Thus, this chapter launches directly into a consideration of the industrial view of technology transfer from government R & D establishments to industry.

2. Sources of Information: The Industrial Sample

There are many more production units in Canadian industry than there are laboratories in the Government R & D complex. In manufacturing industry alone, Statistics Canada recognizes approximately 35 000 establishments. Most of these have had no connection with and no knowledge of government R & D laboratories. The vast majority are not capable of being at the recipient end of technology transfer except where technology can be transferred in a fully embodied form. However, government R & D establishments do not generally engage in this type of transfer to manufacturing industry.*

In order to obtain the most useful views and opinions of the government laboratories, we decided to confine our investigations to those firms most likely to have interacted with government R & D establishments in one way or another, and which would therefore base their answers on personal experience. For the most part, fact gathering was confined to firms with R & D units, i.e., firms capable of being recipients of technology generated in government laboratories.

To gain as rounded a picture as possible of the industrial view we wished to pursue our investigations in depth, yet at the same time obtain a range of information and opinion as comprehensive as possible. This led to the adoption of a two-pronged approach to industry with the first approach providing the desired depth and the second providing the necessary breadth.

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* The exceptions are the Division of Building Research and the Technical Information Service of NRC. The latter specializes in transferring packaged information to small and medium-sized firms which have no research capability.

Two separate samples of manufacturing were taken. The first consisted of 70 and the second of 213 firms. The firms in the first sample were asked to fill in a lengthy questionnaire, and at a later date representatives of the firm (especially R & D managers) were interviewed at considerable length. Interviews were held with 63 firms, and 51 usable questionnaires resulted from this part of our research. The 213 firms of the other sample were asked to complete a mailed questionnaire. This yielded 179 more or less complete returns.*

Although the first sample is the smaller it is the more important to the study. In view of that importance some comments on the selection criteria and the characteristics of the firms are in order.

The 70 firms were selected to provide a cross-section of the different kinds of firms known to have some history of interaction with government R & D establishments. Also chosen were some firms which might have been expected to have had some interaction but which had not. The sample contains firms of widely varying size; the range is between a tiny firm with three employees and a multinational corporation with approximately 27 000 employees. In terms of annual sales, the range was between $50,000 and over $1 billion. The sample took account of the distribution of firms across Canada, and steps were taken to ensure that all parts of the country were represented. Approximately 75 per cent of the firms are located in Ontario and Quebec (thus the sample under-represents the Canadian industrial core), and the remainder are located in the other provinces. The matter of ownership was also important to the selection of firms. Earlier studies of the Science Council[2] have revealed important relationships between the high level of foreign ownership of Canadian industry and both Canada's poor innovative performance and industry's relatively small contribution to the total R & D undertaken in Canada. Approximately 30 per cent of the selected firms were foreign owned. Of these, just under two-thirds were American and the remainder European.

* Throughout this chapter the Statistical Tables will be identified as to whether they are based on the large or small sample. Quotes are from both samples.

Although the firms selected produce a wide variety of products and fall within most of the major manufacturing groups classified by Statistics Canada, no attempt was made to obtain proportional representation from these groups. Many major groups are very poorly represented, e.g., food processing, textiles, tobacco, wood, furniture, printing and publishing. On the other hand, the groups comprising what are loosely called the middle to high technology industries are more than proportionately represented, particularly the electrical products group, which contains firms in the electronics and communications equipment area.

In terms of other attributes, the sample firms exhibit a high degree of variation. Included in the sample are a number of new, small, private, high technology firms, some of which still rest on shaky foundations. Some of them are directed by owner/managers who were employed in universities and government or industrial laboratories before the inception of the firms. A few of these small firms were set up to develop and produce technology originating in government laboratories, and have had particularly strong connections with certain government laboratories. They stand in rather marked contrast to the large multi-national firms, whether Canadian or foreign owned. The small firms normally have only one production unit and a limited product range, while the latter may have several production units in two or more countries, and a very wide product range. Between these two extremes are many medium-sized firms both foreign and domestic. Some are private and others are public companies; some are single plant while others are multi-plant. They are engaged in the production of a wide range of products.

Although differing in so many respects, most of these firms have one thing in common, and it is a feature which makes them rather different from the majority of manufacturing firms in Canada: they have R & D units. Table V.1 describes a few of the characteristics of the R & D units of the 51 firms which filled in the questionnaire.[3] The industrial laboratories are of widely varying size

Table V.1 - Size Characteristics of Industrial R & D Units[1] (Small Sample)

Firm	No. of QSEs[2]	QSEs as percentage of total Employees	R & D Budget as percentage of Annual Sales	Firm	No. of QSEs	QSEs as percentage of total Employees	R & D Budget as percentage of Annual Sales
1	N/A	13.0	1.5	27	85	13.6	4.0
2	5	10.0	12.0	28	20	50.0	25.0
3	3	4.8	0.65	29	4	33.0	39.0
4	33	20.0	25.0	30	7	6.0	0.4
5	2	N/A	N/A	31	2	0.75	0.5
6	7	10.0	20.0	32	305	7.0	19.8
7	1	0.6	1.7	33	22	11.0	2.5
8	9	32.0	55.0	34	76	17.0	12.5
9	5	6.0	20.0	35	1	0.25	0.5
10	N/A	10.0	20.0	36	6	15.0	11.0
11	2	4.0	3.0	37	54	5.0	2.5
12	1	0.4	4.0	38	N/A	8.8	0.2
13	11	19.0	55.0	39	11	2.0	1.0
14	6	35.0	1.0	40	39	1.0	0.1
15	N/A	3.0	4.5	41	17	9.0	3.5
16	29	5.0	2.1	42	87	N/A	N/A
17	51	2.8	0.36	43	132	18.0	25.0
18	N/A	4.5	N/A	44	21	0.70	1.6
19	15	15.0	12.0	45	6	5.0	2.0
20	N/A	35.0	15.0	46	3	6.0	8.5
21	N/A	N/A	N/A	47	4	20.0	20.0
22	N/A	2.0	8.0	48	N/A	N/A	N/A
23	154	20.0	16.6	49	36	33.0	5.2
24	120	7.0	6.0	50	18	22.0	113.0
25	N/A	4.0	3.0	51	2	66.6	15.0
26	N/A	1.0	0.55				

[1] In most cases the figures refer to the total operations of a firm in Canada, and in a few others, to only one production unit of the firm.

[2] QSEs - Qualified Scientists and Engineers.

Source: Derived by the Science Council.

ranging from a unit with 305 QSE's* to those with only one or two. It is apparent that the relative importance of these R & D units varies greatly from one firm to another. Some idea of relative size is given in Table V.1 by expressing QSEs as a percentage of annual sales.** A few firms in the sample are virtually engineering R & D consulting firms with no standard product, with the result that QSEs form a very large proportion of the total employees. Other firms manufacture highly standardized products and retain only small R & D units chiefly intended for testing purposes.

Table V.2 provides some idea of purpose and function of the industrial laboratories. R & D budgets are divided between three major categories: research, development and related scientific activities (RSA).*** This table serves to bring out a fundamental distinction between industrial laboratories and government R & D establishments. A clear majority of the industrial laboratories has no interest in research, either basic or applied. Most of them are mainly interested in development, either of new products or the improvement and adaptation of existing products. The orientation is therefore quite different from that of government labs which for the most part are not interested in product development, being much more heavily involved in research, both basic and applied. On the surface, at any rate, government laboratories and industrial R & D units should be complementary to one another and not in competition.

The final characteristic considered for comment in this section is the source of the funds for the industrial R & D units. Table V.3 shows reliance on different sources of funds, and much varia-

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* QSEs - Qualified Scientists and Engineers. This includes only those with bachelors, masters or doctoral degrees. Most laboratories have other employees but these are not considered to be QSEs.

** The reader may feel that in the case of certain firms, some of the figures are highly questionable. However, we have simply reproduced the firms' answers. It should be noted that most of these figures are for 1974. Percentages are likely to vary from one year to another.

*** RSA - data collection, information, library, testing, feasibility studies, other.

Table V.2 - Allocation of R & D Budgets (Small Sample)

Firm	Percentage of R & D Budget Devoted to: Research			Development			RSA[1]
		Basic	Applied		New Products	Improvement and adaptation of existing Products	
1	0			100	25	75	0
2	0			100	35	65	0
3	0			80	30	50	20
4	70	10	60	10	5	5	20
5	0			100	N/A	N/A	0
6	30	0	30	50	N/A	N/A	20
7	0			100	40	60	0
8	40	5	35	55	50	5	5
9	0			100	75	25	0
10	10	0	10	90	50	40	0
11	N/A			N/A			N/A
12	N/A			N/A			N/A
13	35	10	25	55	45	10	10
14	0			100	90	10	0
15	0			95	10	85	5
16	0			95	65	30	5
17	5	N/A	N/A	75	15	60	20
18	75	0	75	25	25	0	0
19	15	0	15	75	60	15	10
20	0			100	0	100	0
21	0			75	75	0	25
22	5	3	2	80	50	30	20
23	0			100	97	3	0
24	0			90	70	20	10
25	0			85	20	65	15

Table V.2 (cont'd) -

Firm	Percentage of R & D Budget Devoted to: Research	Development					RSA[1]
		Basic	Applied		New Products	Improvement and adaptation of existing Products	
26	20	N/A	N/A	55	35	20	25
27	40	10	30	30	15	15	30
28	60	10	50	20	10	10	20
29	77	0	77	23	20	3	0
30	0			90	5	85	10
31	0			70	10	60	30
32	5	N/A	N/A	95	33	62	0
33	20	N/A	N/A	70	60	10	10
34	1	N/A	N/A	94	60	34	5
35	0			100	50	50	0
36	23	0	23	74	41	33	3
37	2	0	2	55	5	50	43
38	30	0	30	70	N/A	N/A	0
39	0			50	30	20	50
40	78	10	68	21	0	21	1
41	50	0	50	40	20	20	10
42	100	0	100	0			0
43	0			98	94	4	2
44	2	0	2	74	64	10	24
45	5	1	4	65	25	40	30
46	15	N/A	N/A	50	13	37	35
47	30	N/A	N/A	60	N/A	N/A	10
48	0			100	90	10	0
49	2	N/A	N/A	83	40	43	15
50	0			90	72	20	10
51	0			95	25	75	5

[1]RSA - Related Scientific Activities.

Table V.3 - Sources of R & D Funds (Small Sample)

Firm	Percentage of R & D Funds Obtained From:					
	Retained Earnings of Firm	Parent	Federal Government: Incentives and grants for research	Contract Work for Government	Other	
1	92		8	N/A	N/A	
2	75		25	25	0	
3	52		48	48	0	
4	10		80	0	80	10
5	40		60	60	0	
6	10		80	40	40	10
7	100					
8	40		60	55	5	
9	70		30	30	0	
10	N/A		N/A	N/A	N/A	N/A
11	70		27.5	25	2.5	2.5
12	95		5	5	0	
13	25		45	40	5	30
14			100	10	90	
15	100					
16	45		45	N/A	N/A	10
17	87		13	10	3	
18	25	25	25	25	0	25
19	60		40	40	0	
20	35					65
21	100					
22	45		55	45	10	
23	45	50	5	5		
24	40		45	40	5	15
25	100					
26		83	17	17	0	
27	60		40	40	0	

Table V.3 (cont'd)

Firm	Percentage of R & D Funds Obtained From:					
	Retained Earnings of Firm	Parent	Federal Government: Incentives and Grants for Research		Contact Work for Government	Other
28	10		60	25	35	30
29			53	53	0	47
30	100					
31	94		6	6	0	
32	35		48	46	2	17
33	15		85	5	80	
34	72		28	28	0	
35	50					50
36	67		33	33	0	
37	5		95	5	90	
38	N/A	N/A	N/A	N/A	N/A	N/A
39	96		4	4	0	
40	88		12	12	0	
41	64		36	36	0	
42	N/A	N/A	N/A	N/A	N/A	N/A
43	7		88	5	83	5
44	90		10	10	0	
45	50		50	50	0	
46	95					5
47	45		55	50	5	
48	80		20	20	0	
49	78		22	22	0	
50	40	20	40	40	0	
51	98		2	2	0	

tion from one firm to another. A majority of the firms in the small sample rely most heavily on retained earnings to finance their R & D unit, but almost all of them also make use of the federal government to a greater or lesser extent.* About one- third of the firms supplying information on this question rely more heavily on the federal government than on any other source. The greater part of the government financing comes under incentives, e.g., IRDIA, and grants in aid for R & D, e.g., PAIT, IRAP, DIP, DIR,** and the remainder comes from contract work for the government. For a few firms contract work for governments is the most importance source of R & D. However, the situation in any one firm may change greatly from one year to the next.

The second sample consisted of 179 firms. Their R & D units represent approximately one-third of all Canadian manufacturing R & D units. The exact proportion is not known because a complete record of all existing R & D units of manufacturing industry apparently does not exist. The firms were selected from the Directory of Industrial Research and Development Establishments.[4] Firm chosen for the smaller sample and listed in the Directory were eliminated and a stratified random sample was taken of the remainder. In this larger sample no steps were taken to insure the inclusion of firms with particular characteristics, such as a known history of interaction with government R & D establishments.

Just as with the smaller sample, the 179 firms which responded to the postal questionnaire (213 were contacted) varied in size, ownership, products and geographical distribution.

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* Forty out of the forty-eight firms supplying information make use of federal government funds.

** IRDIA - Industrial Research and Development Incentives Act. PAIT - Program for the Advancement of Industrial Technology. IRAP - Industrial Research Assistance Program. DIP - Defence Industry Productivity (program). DIR - Defence Industrial Research (program). For a description of these, see Andrew H. Wilson, Governments and Innovation, Science Council of Canada, Background Study No. 26, Ottawa, 1973, pp. 62-66.

3. Interaction with Government R & D Establishments: Awareness and Knowledge - The General Situation

In Chapter III, manufacturing industry was listed as only one of the many "audiences" of government R & D establishments. Certainly, many government laboratories regard manufacturing industry as an important consumer of their output. However, does manufacturing regard itself as an audience of the laboratories? Is it a consumer of the laboratories' products? Is it aware of or interested in what government laboratories are doing? Technology transfer from government laboratories to manufacturing industry requires affirmative responses to these questions, since if there is no audience there can be no actual or potential recipients of technology. Moreover, a poorly informed audience may have false expectations leading to frustration and disappointment and, ultimately,to unjustified criticism.

Manufacturing industry is not as well informed as it could be about the roles, functions and structure of government R & D. Even in the specific fields of interest to particular firms the level of knowledge was found to be rather low.

Of the 179 firms in the larger sample, less than half, i.e., 44 per cent, claimed to be aware of the activities of government R & D establishments in their fields of interest. In the smaller sample 81 per cent of the firms claimed to be aware of what government laboratories are doing in their fields of interest. Since most of these latter firms were chosen because they were known to have interacted with government R & D establishments, little significance can be attached to this higher figure.

No attempt was made to precisely measure awareness or knowledge since it would have been too costly an exercise. An industrial R & D manager who claims to be aware of work going on in his field of interest may or may not be well informed. One person may think he is well informed when in fact he is not, while another, of a more modest and perceptive nature, and who is fairly well informed, may feel he is comparatively ignorant and say so. Our interviews clearly revealed a high level of awareness on the part of some individuals; on the other hand, we encountered some respondents who claimed a level of awareness which turned out to be

false when conversation revealed the true state of their knowledge.

We now turn to those government establishments designated by the firms that claimed to be aware of government research in their field of interest. Table V.4 depicts a percentage distribution of the degree to which a particular establishment or laboratory was mentioned by different firms (in the large sample). Table V.5 depicts the same information for the small sample.

The picture presented by these two Tables is a revealing one, for it confirms findings presented in earlier chapters, and confirms earlier expressed opinions concerning the difficulties of transferring technology to manufacturing industry. NRC obviously plays a leading and central role in the total pattern of interaction between the government R & D complex and those few industrial firms which attempt to derive direct benefits from that complex. Clearly, NRC carries out more work of interest to industry than any other R & D agency or arm in the government. As a corollary, firms are more acquainted with NRC's work than with the work of any other R & D arm or agency. Industry approaches NRC far more than it approaches other arms or agencies. NRC's lead over other agencies is overwhelming. For example, of those firms who are aware of the activities of government research establishments, 41 per cent (of the large sample) and 32 per cent (of the small sample) are aware of NRC. Similarly, 46 per cent (large sample) and 40 per cent (small sample) contacted NRC within the past five years.*

Excepting the Forest Products Laboratories of DOE and some elements of other establishments, the laboratories of NRC are the only ones charged with responsibilities to manufacturing industry. The establishments of other agencies may and indeed do interact with manufacturing, but that interaction is rarely an end in itself; rather it is a means to the achievement of departmental goals. This is

* In both cases the degree of contact is greater than the degree of awareness. This probably reflects the nature of the contact, i.e., with only one or two individuals and not with the establishment.

Table V.4 - Awareness of and Contacts with Government R & D Establishments (Large Sample)

Government Establishment or Division	Firms claiming awareness of government R & D establishments			
	Percentage naming establishment		Percentage claming contact during past 5 years	
		% breakdown by division		% breakdown by division
1. NRC	41		46	
National Research Council (unspecified)		33		19
Division of Mechanical Engineering		21		14
Division of Building Research		13		12
Division of Chemistry		8		14
National Aeronautical Establishment		5		5
Radio & Electrical Engineering Division		5		6
Division of Physics		3		5
Division of Biological Sciences		2		1
Other (CPDL, TIS, NSL)		10		21
Prairie Regional Laboratory		0		1
		100%		100%
2. DOE	14		13	
Forest Products Laboratories (Eastern and Western)		48		57
Canada Centre for Inland Waters		14		14
Fisheries Research Establishments		10		10
Other		28		19
		100%		100%
3. EMR	13		15	
Mines Branch		89		88
Other		11		12
		100%		100%
4. AGR	11		11	
Research Branch		88		78
Other		12		22
		100%		100%
5. DND	9		7	
Defence Research Establishments		100%		100%
6. NHW	5		3	
Drug Research Laboratories		38		40
Other		62		60
		100%		100%
7. AECL	3		2	
8. DOC	2		2	
Communications Research Centre		100%		100%
9. Miscellaneous Establishments	2		1	
	100%		100%	

Note: Based on the 80 firms (of a total of 179) who claimed to be aware of the activities of government R & D establishments as they related to the firm's own activities.

Table V.5 - Selected Aspects of Awareness of and Contacts with R & D Arms[1] (Small Sample)

R & D Arm or Agency	Percentage of Firms Aware of Related Activity	Percentage of Firms to Contact R & D Arm in Last 5 Years
NRC	32	40
DND/DRB	17	10
EMR	13	10
DOC	13	13
DOE	10	10
AGR	5	6
MOT	5	5
AECL	4	6
NHW	1	-

[1] Based on the 41 firms (of a total of 51) who claimed to be aware of the activities of government R & D laboratories as they related to the firm's own activities.

especially the case with some establishments of DND (formerly of DRB), AECL and DOC. In contrast to these organizations NRC has a mandate to help industry in certain ways. This is clearly reflected in Tables V.4 and V.5.

As expected, Tables V.4 and V.5 reveal that by far the greater part of government R & D effort is marginal to the interests of manufacturing industry. DOE, for example, with the largest R & D organization in the federal government, is obviously regarded by manufacturing in general as of limited value. Were it not for the two Forest Products Laboratories (see Table V.4) with their specific orientation towards the problems of a particular segment of manufacturing, the R & D of this department would be even less well known to manufacturing.

Attention is drawn to the differences between the interaction patterns of the large and small samples. For example, in the large sample only 2 per cent were aware of work related to their field of interest in DOC and similarly 2 per cent had contacted that department. By comparison, in the small sample 13 per cent were aware of related work in DOC and a similar percentage had contacted the department in the preceding five years. A similar difference between the samples occurs in the case of DND, and to a lesser extent in the case of AECL. In large measure, the differences are a response to the criteria used in the selection of firms in the two samples. Most of the firms in the small sample have had a history of interaction with government laboratories and firms of this nature tend to be most numerous in the electrical products and the transportation equipment industries. It is with these industries that mission-oriented laboratories such as those of DOC, DND and AECL find the greatest need for interaction to fulfil their missions. Firms in these industries possess the special expertise, capabilities or facilities needed by technology-oriented laboratories (as opposed to science-oriented laboratories).

In the larger sample, firms were more evenly spread between industrial groups, and this accounts for the lesser degree of knowledge of, and interaction with, DOC, DND, etc., and with the government R & D complex as a whole.

A laboratory must be known to a manufacturer before his firm can derive benefits or help from it. For the large sample we tried to ascertain the type and quality of information held by firms. What do they know about laboratories in regard to such matters as products, services, results, achievements, functions, missions, expertise and facilities? Of the firms which do claim to have an awareness, it appears that the mission or purpose of government laboratories is the most widely known feature. However, information produced by the interviews raises strong doubts about whether or not most firms have the correct idea of the function of these laboratories. As a general rule the knowledge possessed by members of the business community is far from complete. There seems little doubt that this lack of full understanding is a major contributor to unwarranted expectations, subjective assumptions and misplaced criticisms regarding the performance of government R & D establishments as it relates to industry. Few industrial spokesmen were aware of the multi-functional nature of most laboratories, and most believe the laboratories have a greater responsibility to manufacturing than is actually the case. There is a general lack of appreciation of the great size of the governmental R & D complex, a lack which leads many spokesmen to make general statements about government R & D based on their experience of one or two small groups in one or two establishments. In many cases knowledge of these establishments is limited to familiarity with the work of one or two individuals. This barely justifies drawing conclusions about a single establishment, let alone the total government complex.

After mission or purpose, firms appear to be knowledgeable about expertise and facilities, individual scientists and engineers, research results, and research activities, in that order. It is important to note that government laboratories are not so much identified with a specific product or research results, i.e., with identifiable <u>actual</u> contributions, as with their <u>potential</u> to contribute, i.e., their expertise, staff and facilities.

Some attention must be paid to firms which are not aware of what government R & D establishments are doing and make no attempt to approach them.

Most firms do not interact with government R & D establishments because they have little or no need to do so. This is true of manufacturing in all countries. Most firms never have been and never will be interested in innovation. There are few pioneers in production methods and products, and in most industries production technology and products remain comparatively fixed over long periods. In all industrial countries only a tiny minority of firms are innovative and maintain some kind of R & D facilities. It is the firms in this small select group which can be expected to interact with government R & D establishments. In Canada, this minority is relatively smaller than in most industrial countries. However, not even all the firms in this group interact with government R & D establishments. There seem to be a number of reasons for this.

It has to be remembered that large as the government scientific complex is, it is still neither able nor anxious to cover the whole of the scientific and technological waterfront. Limited resources necessitate selectivity in the areas of interest to be developed. The roles of government laboratories as discussed in Chapter III provide criteria for selection. The second criterion (justification) for in-house government R & D was: "Where the R & D requirement needed to perform the mission of the department is inappropriate to industry, or where no suitable industrial capability exists and it would not be of benefit to Canada to create one." This criterion has been applied both positively and negatively. We mean negatively in the sense that we should not expect government laboratories to be heavily involved in R & D appropriate to industry, or to attempt to duplicate well developed industrial capability. There is some overlap between the R & D capabilities of government and industry; some of it perhaps unavoidable, some of it probably unavoidable and/or necessary. On the whole, however, the government has tried to supplement and complement, not compete with, industrial R & D capability.

In negatively applying the second criterion, the government has deliberately avoided involving itself in certain types of R & D because the private sector is quite capable of undertaking it. There are many instances of such avoidance, e.g.,

in some branches of the chemicals industry such as pharmaceuticals, fertilizers, pesticides (although there is government R & D for the purposes of testing and evaluating these products) and food processing. In many cases, firms producing these products find little or no value in interacting with government laboratories. It is not the government laboratories which have the expertise and capability but the firms themselves. Thus, one reason for firms being unaware of and not contacting government labs is their high self-sufficiency in R & D and their knowledge that the labs are doing virtually nothing in their field of interest.

Some comments from firms which do not contact laboratories were as follows. Spokesman for a large pharmaceutical company:

> "We are quite self-sufficient in our R & D work. The federal government is not doing anything in new pharmaceutical products, and if it were it could not do a better job than industry in the pharmaceutical products field. Government labs and universities belong in the same category. They are scientifically competent, but in product development they are unable to provide useful results. The chemical industry in general is self-supporting in its R & D activities... There is little opportunity for government labs to contribute to its in-house activities."

Manager of the Research Division of a large industrial chemicals firm:

> "We have very few interactions with government labs. We do not know and we do not care what government labs are doing. The work of government labs is of no interest because they are working in entirely different areas. Their expertise is generally not suitable for this company. Each company has its own business slot and has its own specific needs for technology. There is, for example, nothing going on at NRC that would fit in this company's slot, thus NRC's work is irrelevant to the firm."

Research Director - Multi-national food processing company:

> "The Department of Agriculture is indifferent to the food processing industry. It has a definite crop bias. In most cases we don't know what the current functions of government labs are, but we believe the labs in the Department of Agriculture are terribly misdirected. The labs in this department are too crop-oriented."

Another reason for lack of awareness and failure to approach government research establishments stems from the kind of R & D facilities maintained by some firms. Many of them in the large sample have only one to five R & D employees who perform routine testing procedures, and have little incentive to interact with government establishments.

A third reason seems to be plain indifference, if not thoughtlessness. Many firms have simply never taken the trouble to find out if government laboratories can be of value to them. This point is captured in the remarks of a manager of a medium-sized metal working firm in southern Ontario:

> "We are not aware of what government labs are doing in our areas of interest. I suppose their world doesn't touch mine. No one ever made the initial contact. We've never dreamed of giving a laboratory a contract to solve hardware problems. Anyway, we feel we are generally better equipped to deal with problems relating to our own products."

A few firms replied that, as a matter of principle, they do not like working with government labs in general or with civil servants in particular. Thus, for a number of reasons most firms are neither aware of government activities in their field of interest nor do they contact government research establishments for assistance.

4. Ways of Keeping Informed

In our consideration of technology transfer, it is important to identify by what methods industrial firms keep informed of the activities of government laboratories in their fields of interest. Table V.6 provides a summary of the various methods used by individual firms to keep informed. In answering

Table V.6 - Methods Used by Industrial R & D Units to Keep Informed of the Activities of Government R & D Establishments (Large Sample)

Method	Relative frequency of use
1. Publications of laboratories	23
2. Informal personal contacts and visits to the laboratory	21
3. Attendance at meetings, seminars	18
4. Formal contacts with laboratories	14
5. Other publications (non-lab), news media, etc.	12
6. Fortuitously, no continuous effort	6
7. Indirectly, through a designated person; liason officer	4
8. Indirectly through contacts in industry	2
	100

Table V.7 - Most Frequently Used Method to Keep Informed (Large Sample)

Method	Percentage of Firms
1. Informal personal contacts and visits to the laboratory	39
2. Publications issued by the laboratory	25
3. Formal contacts with the laboratory	14
4. Other publications (non-lab), news media, etc.	7
5. Attendance at meetings, seminars	7
6. Fortuitously, no continuous effort	3
7. Indirectly through designated person, liaison officer	3
8. Indirectly through contacts in industry	2

this question firms could select one or more items. In Table V.7 the firm selected from all methods the one it employs most frequently. Here it should be noted that for almost 40 per cent of the firms the informal personal contacts with the staff of a government laboratory is the most frequently used method to keep informed about the laboratories' activities. Such contacts, as we have seen, are the essence of technology transfer.

The degree of difficulty experienced by individual firms in attempting to keep abreast of government R & D activities varies among industrial firms. For about 11 per cent of the 80 firms that were aware of these activities it was very difficult to monitor the activities of government R & D establishments. However, many firms (46 per cent) thought that it was only moderately difficult, and over one third (36 per cent) had no difficulties in this respect. Six of the firms (7 per cent) were unable to express an opinion. The degree of difficulty varies with the particular firm and the specific government laboratory, but in general it is not difficult for firms to know what government laboratories are doing.

All firms in the large sample, regardless of their state of knowledge of government R & D, were asked to suggest changes in federal government R & D that would increase the transfer of useful knowledge to industrial R & D units. The answers from the firms unaware of government laboratory activity reveal a common human trait - the tendency to believe that something untried is more difficult than it really is. Furthermore, there is a general tendency to believe that the onus should lie with the labs to keep industry informed. These unaware firms seem to believe that the labs should come to the firms rather than the reverse.

The following are representative of dozens of similar comments.*

Metal fabricator:

"Government must make our R & D unit more aware of its capabilities, facilities and

* Fifty-six per cent of firms in the large sample were not aware of the activities of government establishments in their field of interest. For the small sample the "unaware" figure was 19 per cent.

publications."

Pharmaceutical manufacturer:

"Federal government R & D establishments should try to make their programs, services and capabilities known to the firms either by writing, verbal briefing or visiting."

Commercial refrigeration equipment manufacturer:

"At present time I do not know of any R & D program which in any way is of use to us. When there is - we must be informed about it."

Manufacturer of aircraft engine components:

"Make industry aware of what is available but give them only that information that is pertinent to their field of endeavour."

Pump maker:

"More information in specific terms of what exactly is available to industry. Frequent visits by lab people to industry to familiarize government agencies as to what is going on in industry."

Communications equipment manufacturer:

"Improved communication with the industry, i.e., we were not aware of government laboratories before receiving your questionnaire."

It is hard to accept that firms are not aware because it is difficult for them to keep informed. All the evidence indicates that firms which wish to be informed do not experience serious difficulties. Lack of awareness in most cases is lack of interest of the firm rather than a lack of accessibility or openness on the part of government R & D establishments.

5. Motivation and Purpose for Approaching Government R & D Establishments

Table V.8 provides a summary of the various purposes for which firms contacted a government establishment. Here again each firm could list one or more reasons for contact. The item that appeared most often was for "general printed information, e.g., publications, data, maps". Almost two-thirds of all interactions between manufacturing firms and government laboratories were related to a request for printed information, assistance with product development, the provision of services and the use of special facilities. Table V.9 gives a summary of the proportion of firms which mention a specific purpose as the most frequent purpose of inter-

Table V.8 - Purpose of Interaction (Large Sample)

Purpose	Percentage Distribution of Purposes
1. General, printed information, e.g., publications, data, maps	18
2. Assistance with technical problems encountered in product development	16
3. Services, e.g., testing, calibration	15
4. Use of special facilities of the laboratory	13
5. Assistance with theoretical problems encountered in research	8
6. Suggestions for new R & D opportunities, new product ideas	7
7. Advice on general technological trends, market trends	6
8. Advice on new applications of the firm's product(s)	6
9. License for a product invented by a laboratory	6
10. Assistance with problems encountered in design production	5

Table V.9 - Most Frequent Purpose of Interactions (Large Sample)

Purpose	Percentage of firms
1. General, printed information, e.g., publications, data, maps	24
2. Services, e.g., quality, assurance, testing, calibration	22
3. Use of the special facilities of the laboratory	18
4. Assistance with technical problems encountered in research	13
5. Assistance with theoretical problems encountered in research	7
6. Assistance with problems encountered in research	6
7. Advice on general technological trends, market trends	4
8. Suggestions for new R & D opportunities, new product ideas	4
9. License for product invented by the laboratory	1
10. Advice on new applications of one of the firm's products	1

actions with government R & D establishments. For most firms (64 per cent) the most important purpose of their interactions with government establishments is to obtain printed information, specialized services and the use of special facilities, that is, for assistance, advice and information which does not require a person-to-person interaction of government and industrial employees. In these kinds of interaction the knowledge and/or the assistance provided by establishments is not tailored to the specific needs of a particular firm. It is general information on a general service. And as we noted earlier, it is just such general information and services which many labs prefer to provide, for it is consonant with their idea of providing a public good.

The knowledge or the assistance becomes progressively more specific to the individual firm as we move down the table. At the same time, the need for person-to-person contact increases. Certain kinds of interaction occur only infrequently. For example, it is difficult and, in some cases, impossible for a government R & D establishment to advise on market trends, on the commercial aspects of innovation, on new product ideas or on new applications of products. The government laboratories neither possess nor were they intended to develop expertise in these areas. Nevertheless, it is precisely their deficiency in this expertise which evokes much criticism from the manufacturing sector, a fact which at once demonstrates the existence of misconceptions about the role and function of government laboratories. This point will be discussed in detail later in this chapter.

For one firm in four (26 per cent), the main purpose of contacting a government R & D establishment was related to assistance with the solution of problems encountered in product development - research, design or production (Table V.9). For only one firm in ten does a government establishment play a major role beyond the scientific and technical aspects of the R & D. Contributions from government R & D establishments to manufacturing firms become increasingly difficult the more a knowledge of the market is required. However, well established firms should require minimal assistance in the marketing aspects of their operations; this should be the area of their greatest expertise. The

older and larger a firm is the more difficult it is for an external source to make a meaningful contribution. Some laboratories try to assist, but it is difficult and probably not an efficient way to help well established existing industry.

Successful commercialization of a product invention requires an entrepreneurial and technology-oriented management attitude, but most existing firms tend to emphasize the administrative, financial or legal aspects of management. Existing businesses and new ones require different types of managers in terms of their experience, motivation, vision and temperament. It is no accident that many of the product innovations produced by government R & D establishments are picked up by newly established firms, that is, transfer has been to a recipient which has emerged to receive the technology.

6. Reasons for Contacting Government Laboratories

Firms were asked their reasons for contacting a particular government establishment. The intent of this question was to determine why, when a specific need arose, a firm would turn to a particular government establishment instead of to some other external source. A firm could select more than one reason for making the contact. Results are given in Table V.10. Next the firm was asked to choose the single most important reason for contacting a particular government research establishment. The results are shown in Table V.11. The single most important reason given (40 per cent) was "high quality of expertise, availability of special expertise." It should be noted that the interest and motivation of government laboratories' staff scored low (7 per cent). The firms' views regarding this factor will be discussed later in this chapter; it will be seen as a criticism of the government establishments by industrial firms. The other factors were important for only small numbers of firms. The ability to assist quickly was not mentioned once by any firm as the most important reason. It appears that the expertise and the facilities of government R & D establishments are their major attraction to manufacturing industry; approximately two-thirds of the firms indicated these as the most important reasons for contacting a government establishment.

Table V.10 - Reasons for Contacting a Particular Government R & D Establishment (Large Sample)

Reason	Percentage Distribution
1. High quality of expertise, availability of special expertise	24
2. Special facilities of the laboratory	22
3. Interest, motivations of the staff	10
4. Dependable quality of advice and information	10
5. Reputation of the establishment	9
6. Cheaper or more convenient than any other source	7
7. Variety of expertise	6
8. Ability to assist quickly, few other commitments	4
9. Quality of service, dependable delivery efficiency	4
10. Terms of license from CPDL or contact	2
11. Last resort, no other sources available	2

Table V.11 - Most Important Reason for Contacting a Particular Government R & D Establishment (Large Sample)

Reason	Percentage of firms
1. High quality of expertise, availability of special expertise	40
2. Special facilities of the establishment	30
3. Interest, motivation of the staff of the laboratories	7
4. Cheaper or more convenient than other sources	5
5. Last resort, no other sources available	4
6. Variety of expertise	4
7. Dependable	4
8. Reputation of the establishment	4
9. Quality of service, dependable delivery, efficiency	1
10. Terms of license from CPDL or contract	1

Table V.12 - Reasons for Not Utilizing Knowledge and Information (Large Sample)

Reason	Percentage Distribution
1. Request for information purposes only	44
2. Not sufficiently pertinent to the problem	24
3. Too late, service too slow	8
4. Technical deficiencies	8
5. Miscellaneous reasons internal to firm	8
6. Too theoretical; not sufficiently close to practical applications	6
7. Out dated, behind the state-of-the-art	2

7. Usefulness of Transferred Knowledge

The firms were asked to comment on the usefulness of knowledge obtained from government R & D establishments.* Of the firms which responded, 38 per cent found the knowledge to be very useful; another 53 per cent felt that the knowledge was moderately useful and the remainder indicated that the knowledge or information received was not useful. The knowledge obtained by manufacturing from government R & D establishments was therefore moderately or very useful.

There are many reasons why even those firms which have found the information to be very useful have not always used the knowledge obtained. Table V.12 summarizes the reasons why knowledge obtained from government R & D establishments was, on occasion, not utilized by the firms responding to the question.

The most common reason for non-utilization of information was because the information was requested for information purposes only. Thus government establishments appear to provide a service to industry by adding to the background information needed by the firm. However, a significant group did not utilize knowledge and information obtained from a government establishment because it was "not sufficiently pertinent to the problem." In other words, the solution did not fit the problem, or the answer did not fit the question. There can be a number of reasons for this, and they can lie within both industry and the government establishments. Spokesmen of establishments were clearly aware that their information does not always meet the needs of manufacturing, chiefly because of the failure on the part of firms to define their problem adequately or even to understand the problem they are presenting. As a result, the government lab can sometimes only make intelligent guesses by way of response, and obviously these are occasionally wide of the mark. In essence, therefore, the problem is one of communication between laboratories and specific firms. The solution will require an improvement in the presentation of problems to government

* The question related to knowledge and information obtained from contacts in the preceding five years.

R & D establishments at the same time as an improvement in the transfer to manufacturing of information related to these problems. Establishments with no responsibilities to manufacturing are under no strong pressures to improve their communications with manufacturing. Some forms of incentive might enable government R & D establishments to significantly increase their effectiveness vis-a-vis industry by stimulating and encouraging communication in order to identify industrial problems more accurately.

Other factors, such as the slow service, technical deficiencies, and the 'over-sophistication' of knowledge are of about the same order of importance as the existence of barriers internal to the firms. They appear to be features inherent to the information transfer process itself rather than inadequacies within the government R & D establishments themselves. No doubt there is some room for improvement, but there will always be firms for which the service is too slow or the knowledge being transferred exceeds their conceptual capability.

8. Commercial Repercussions

Very few firms in the large sample (which is representative of all Canadian manufacturing firms with R & D units) have, on their own initiative, attempted to develop, manufacture and market a product invented in a government laboratory. Eighty-nine per cent, or 160 of the 179 firms, indicated they had never tried it. Of the 19 which tried none was very successful. Four were moderately successful; another four admitted to little or no success. For eleven firms it was too early to measure the degree of success.*

Twelve of the 19 firms indicated that at least

* The technology transfer process, even when it is working well, can often be very slow in producing results. For example, there was a six-year interval between the invention of the transistor and the commercial exploitation of the first transistorized amplifier. See: Assessing Technology Transfer, by Richard L. Lesher and George J. Howick, U.S. National Aeronautics and Space Administration, Washington, 1966, p. 28.

some percentage of their expected revenues over the next five years would come from the sale of products invented in government laboratories. This percentage appeared to average 15 per cent, with a range of between 1 and 95 per cent of total sales. The absolute amounts varied among individual firms from $45,000 to $2,000,000 per year.

Nine firms, almost half of the 19 firms involved, indicated that commercial success of these inventions fell short of expectations. In five cases the knowledge of the product appeared to be incomplete. In the other four the lack of sufficient capital to launch the product was cited as significant. Lack of access to known markets, legal problems as a result of patent infringements, and the fact that the product appeared to be too early for the market were each mentioned twice.

There is seldom one single reason for the lack of commercial success and in most cases it is a combination of a number of the factors mentioned above.[5] What is important, however, is that with the exception of the incomplete knowledge of the product, the reasons for commercial failure are beyond the influence and responsibility of the government R & D establishment which generated the invention. Even with respect to the incompleteness of knowledge, it is inevitable that attempts to commercialize a product idea will have to overcome a variety of technical problems which cannot be foreseen by the industry. It is precisely the purpose of product development to discover these hidden problems before major commitments of capital, equipment, market development, etc. have been made. It is also inevitable that some of the hidden problems will prove to be insurmountable, resulting in the abandonment of attempts to commercialize an invention.

Commercial repercussions from products developed under development contracts have been far greater than with those stemming from initiatives of industry on its own. However, discussion of development contracts is combined with the consideration of industrial perceptions of technology transfer later in this chapter.

This description of the interactions between industry and government R & D establishments is by

no means exhaustive. However, it is enough to provide the factual base necessary to the consideration of industrial views and criticism of government R & D establishments which occupy most of the remainder of this chapter.

9. A Closer Look at Industrial Perceptions and Criticisms of Government R & D Establishments

Few industrial spokesmen attempted to provide objective, non-partisan observations and evaluations of government R & D establishments. For the most part, they made no attempt to view the government scientific complex in the round, or to evaluate it in terms of its multifarious functions and responsibilities to the nation as a whole. Observations and criticisms tended to be related to what industry was gaining or not gaining from government establishments. In general, benefit to industry is the central criterion for evaluating establishments: when industry received what it considers to be benefits, the labs receive some praise and when industry received no benefits the labs are subjected to varying degrees of criticism.

This attitude arises from a lack of understanding by industry of the roles and functions of government research establishments. This is particularly so for the government science complex as a whole, but is almost as true for individual departments, Crown corporations and single establishments. Time and again we encountered criticisms of establishments that have no responsibilities to manufacturing industry other than those they have voluntarily assumed. Most industrial spokesmen are clearly quite unaware of the minor significance of industry in the priorities and responsibilities of government R & D establishments. There are, of course, some establishments, particularly those of NRC, which do have responsibilities to manufacturing. In general, these are better known by industrial people, but even so, there is little understanding of their aims and objectives. Manufacturing firms must be better informed about the aims, objectives and responsibilities of government R & D establishments. Possession of more information and better understanding by industry may allow more constructive criticisms of government establishments and ultimately facilitate changes of mutual benefit to the labs and industry.

Industrial perceptions and criticisms of government R & D establishments are many and varied and it is difficult to find common threads among them. Moreover what one industrial spokesman may see as a virtue, another sees as a flaw; what one industrial R & D manager would regard as a desirable change, another would see as a retrogressive step. Industrial views vary in response to certain factors, the most important of which are:

1. Knowledge of and information about establishments. As we have noted, knowledge varies in type and volume from one firm to another. Some firms know only one small group in one establishment, others have a fairly comprehensive understanding of several establishments.

2. The nature of a firm's past and present interactions with government R & D establishments. Some firms have enjoyed very successful and fruitful interaction with government establishments, others seem to have known only frustration, obstruction and unsuccessful interaction.

3. The nature of a firm's products. The degree of assistance which a firm can obtain from government R & D depends on whether or not a laboratory with the appropriate expertise exists. Since the government makes no pretence of covering all foreseeable industrial needs, some types of manufacturing firm are in a better position to obtain assistance than others.

4. The expectations firms have of government R & D establishments. This relates to the first factor. The less a firm knows about government R & D establishments, the more likely it is to cultivate unwarranted expectations and ultimately to experience disappointment and voice unjustified criticism.

These and other factors impinge on industrial views and perceptions of government R & D establishments. In the following paragraphs we try to bring some order and organization to these views.

Certain industrial spokesmen (a small minority only) have nothing good to say about government R & D establishments. Their criticism is so scath-

ing and bitter, that one wonders if it has its roots in personal disappointments rather than in honest observation and evaluation. Although it is of little value to this study it must be taken into account for it is an attitude which severely impedes government/industry interaction and cooperation. It is important to note that most firms had some criticism to make of government laboratories, but that the most outspoken and least constructive criticisms came from firms with a very poor knowledge of government labs and a history of limited interaction with them. Some examples of "emotional" criticisms are as follows.

Firm 1. "The scientists sit there in Ottawa like high priests - far too preoccupied with protecting pure research and publishing papers."
"Even to perceive, define and articulate your problem to NRC requires a continuous high level of competence."
"We use consultants regularly, but not NRC. This is because NRC sets a very leisurely pace and doesn't want to be contaminated by the real world. According to NRC scientists, pure research is done by good scientists, and applied or practical research is done by... well, other scientists. And, it is disrespectful to ask them (NRC scientists) to consider practical research problems."
"Good old government scientists - they have to win points for their careers through pushing papers and patents."

Firm 2. "I would not go to a government lab, because they do not have the know-how. At NRC there is only one guy who is extremely good: all others are "ivory tower" people whose subject matter in R & D is not related to reality."

Firm 3. "The Canadian government invested heavily in government laboratories. But the government laboratories do not have access to the best technology or the most advanced knowledge. Industry is far more advanced but is not interested in telling labs how they should do their job, at least, not without a charge."

"Government labs think they know a lot, but they don't, because they have an advice base which is too narrow. They get drawn into many programs which turn out to be unsuccessful in the end. However, some individuals in government laboratories have done very good work."

"NRC is not cohesive. There is no concerted effort. Scientists are involved in work which is interesting to them as individuals, but in the meantime, they are not doing the job NRC is supposed to do. A basic problem in government research is caused by the fact that government scientists report to the unsophisticated. It is easy to publish your papers in a journal."

The above firms, and some others which have not been quoted, could find little good in government R & D establishments. However, the majority of the firms interviewed (the small sample) could see positive and negative effects of the government laboratories from their position as potential or actual customers of the labs. A small minority, of about the same size as the totally critical group of firms, was fullof praise for the government side. We quote some of their comments, and those of firms which could see both strong and weak points, to offset the negative remarks quoted above. It is important to note satisfaction as well as dissatisfaction, particularly as the causes of the one may be found in the other.

Firm 1. "CRC and NRC scientists are really doing a fine job. The attitude of CRC is very good, and NRC is very helpful."

Firm 2. "NRC is a fantastic resource. CRC is a very good operation."

Firm 3. "I have worked with government labs for many years, and not only do I have the highest respect for people within them, but we lean on them a lot. We have many years of experience with EMR. We have developed an extremely high respect for most groups within that department. They are doing what they think industry wants and needs, and most of the time they are right on."

Firm 4. "NRC has a wonderful attitude, they are always prepared to help us. NRC is a tremendous asset: it is an enormous treasure. I can pick up the phone and make an appointment with the Director or Chief right away. This is impossible in France (where parent company is located). The people in France are surprised every time that contacts with government labs are so easy in Canada. The laboratories are doing excellent work, they are fulfilling an important and very valuable role for industry, and if possible they should continue as they are."

Firm 5. "NRC has excellent facilities. Their foresight has been damned good. They are very competent people. Their perception of industry's needs in terms of facilities has been very good. DRB is superb."

Firm 6. "The Western Forest Products Laboratory is a very fine group. They are hard to beat because they are knowledgeable, and if you approach them, they get on it right away and give the answers very quickly. They have some of the best guys in the business. There is a definite need for Forest Products Laboratories. I can call libraries, universities, etc., for certain information, but there is nobody but the government labs who looks at the chemical properties of wood. There is nobody better equipped to do this than a government lab. Through the government labs we have achieved a better marketing insight of wood products. It is now regarded as an engineering material. We could never duplicate the effort of the Western Forest Products Laboratory. In industry there is always a limit to the amount of money invested in R & D as a function of the payoff period. R & D is not undertaken in industry if the benefits are not short-term. Answers to a lot of our problems would not be known if the government lab hadn't decided ten years ago to do some research in certain areas."

Firm 7. "There is, and there will continue to be a need for government laboratories, since they seem to know everything about particular areas. Government labs can afford to acquire and keep a lot of knowledge - much more so than the private sector where profits must be earned on all activities."

Firm 8. "Government laboratories are exceedingly important. They should not be regarded as industrial labs. Many firms do not want to carry the modest expenditures of even a small R & D effort, and thus a large number of firms are not doing any research at all. And then they are not satisfied and very critical of government laboratories if they do not want to become their own personal R & D units."

The matter is clearly not a simple one, and manufacturing firms obviously lack the unanimity of opinion about government laboratories that parallels the unanimity of opinion about Canadian manufacturing industry among government scientists and engineers. The remarks made by Firm 8, above, give one clue to the reasons for this divergence of opinion among industrial firms. Possibly, some firms have certain expectations of government laboratories which cannot be fulfilled, a situation which promotes hostility.

Between the small severely critical minority (not all of it without basis) and the small minority which was very laudatory lies the majority of firms. These could see both strengths and weaknesses in government R & D establishments in their relations with manufacturing industry. They regard government scientists as being of high calibre in general and believe they do work of high quality. However, many firms had reservations or criticisms of the type of work on which government R & D personnel are engaged.

There also exists a group of firms which finds that government laboratories are doing little or nothing of direct value to them. (In making this observation most of them neglect to consider less direct benefits such as standards, codes, controls, etc.) Typical comments are as follows.

Firm 1. "There is not much going on in government labs of interest to me. For our business we go to companies in the United States. I don't waste time trying to find irrelevant information. There is not much government labs could do for our company in the development of new products."

Firm 2. "Lab X is very competent. However, they have a free course of action and their work happens to have very little in common with the interests of this company. They are not interested in the problems which interest us, although they are very happy to talk when contacted."

Firm 3. "People in government laboratories are not lacking sufficient expertise: by and large they are pretty competent. However, they lack the relevant expertise. They are working on the wrong problems, and are not interested in specific industrial problems."

Firm 4. "We cannot use the things they are doing. This does not mean that the quality of their research is too low or too far away from practical application. It is too far away from our practical applications."

Firm 5. "Our business does not have much to do with things going on in government laboratories. For instance, no government lab is involved in radar development. There is no centre within the government where a group is looking at advanced concepts."

This group of firms did not claim that government labs were not working on or were uninterested in industrial problems. They were simply making the point that nothing is going on which is of direct value to their particular interests. However, another group of firms expressed the view that government labs, in general, really have no interest in the needs of industry. Examples of such views are as follows:

Firm 1. "Most government labs do not have the right philosophy to assist a commercial organization. Most individuals in government labs have the wrong attitudes

and are not suitable to help industry. Industry does not have a good image in most government labs."

Firm 2. "Government labs are biased against industry. Industry is profit oriented and government labs are not and there is too much of 'them against us'. This complex goes back to the days when government employees were paid badly; but this is not true anymore."

Firm 3. "There is not enough work of a practical nature. It is too far removed from industrial applications. They are scientists and scientists like to write papers and therefore a lot of their work is really 'way out'. Industry is frustrated that it has been unable to turn around the direction of the lab's activities."

Most firms which commented on the nature of the R & D activities in government establishments, and perceived gaps in these activities and/or detected failings in the attitude of government scientists to industry, made constructive suggestions on how the perceived defects might be reduced or eliminated.

Firm 1. "In general, government labs should look more at industry, or maybe industry should look more at the labs."

Firm 2. "If industry is not willing to take the initiative, labs should go out and visit industry and get advice from it. You cannot do research in a vacuum. You have to talk to the users of the R & D results."

Firm 3. "R & D that is to be useful to industry should reflect in its direction and objectives the requirements of industry. Only industry, because of its knowledge of the customer's requirements, is in a position to define and specify the product, identify the technological gaps, and as a consequence, define the fringe areas where more research is required."

Firm 4. "Government laboratories should improve communication with industry. They should get detailed industry advice on what should be done. There should be a mechanism to indicate to NRC that a certain new discipline or expertise will be needed in a government lab."

More firms than not believe that government labs are doing useful work in their areas of interest and, in contrast to the few firms quoted above, believe that government R & D personnel generally try to be helpful and cooperative with industry. However, although the activity is in the appropriate areas and the attitude of government scientists is positive, firms nevertheless perceive several serious deficiencies in government laboratories' ability to assist manufacturing. The first is what many firms would describe as the lack of market orientation in the laboratories, and the second is the failure of government scientists and engineers to understand the commercial world. These are important criticisms because more than any others they call into question the roles and functions of government laboratories, and the ordering of the laboratories' responsibilities to the public and the various subdivisions of the private sector. Since NRC is the most frequently mentioned R & D establishment these criticisms have particular relevance for it. In relation to the lack of market orientation in the labs, some examples of industrial observation are as follows:

Firm 1. "The major objection against government labs is that they do not know how to get an idea into the commercial market."

Firm 2. "Products invented in government laboratories are not useful. Government labs do not consider any market potential before they start work."

Firm 3. "Government laboratories are too far removed from the market place. They don't know what the needs of the market are, what is required in design, etc. They have very little incentive to develop a marketable product; in fact, there are a large number of disincentives. I would not trust their advice on new products."

Firm 4. "They are doing research which is too far back from the market, and their interface with industry is too weak although their research is clearly industry oriented. The basic problem is that research in government labs is too isolated. Government labs are too secure. There is no incentive; there is no competition. There is a big difference between doing things right and doing the right things. Industry is judged by what it does but also by what it does not do and therefore, by what is being done by its competitors. This norm provided by feedback from competitors is absent in government labs."

On the failure of government people to understand the commercial world, the following are some of the many comments made.

Firm 1. "Scientists and engineers in government labs are civil servants. They do not have sufficient pressures and urgencies to get a job done. They don't have any appreciation of the rough and tumble of commercial life."

Firm 2. "Government labs do not have a clear appreciation of industry. They do not have the same financial pressures. There are no risks. They have no long term financial and managerial planning."

Firm 3. "There are a large number of individuals who work very hard, are interested in industry, are entrepreneurial and are willing to help. However, they insist on doing R & D their own way: they insist on detailed methodological work. The work is too good, too well documented, but therefore too slow. The work method defeats the purpose. There are no market pressures; there is no sense of urgency. The theoretical documentation of the work is excellent but it takes too long and therefore becomes useless. A lab, for example, may suggest a new product to a firm. Later the firm goes back to the lab to suggest improvements and the lab wants to investigate these improvements and starts a six

year program to do this. By that time the product may be in excellent shape, but it is too late."

These latter comments contain elements of less fundamental but fairly frequent criticisms. One of these is that government laboratories have no sense of the urgency characteristic of work in industry. In brief, government scientists respond too slowly to industrial requests for assistance. Some comments were made:

Firm 1. "The different time frame of government labs is a barrier to successful interaction."

Firm 2. "I visited several labs. Nobody seemed to be doing anything, nobody was working. This was my impression and it is probably not a correct one, but it was certainly not a very dynamic environment which I visited."

A quite different minor criticism is that it is difficult to grasp the organization and functions of government laboratories sufficiently well to establish contact. One industrialist observed:

"How do you approach NRC? We don't know how to deal with government labs. We don't know how to contact them in the first place. If we do establish contact, do they want a clear-cut description of our problems? What kind of interaction do they want?"

Another said:

"Government labs have a definite knack of making information unavailable."

A third said:

"In general, we find it very difficult to find our way through NRC."

Before considering the implications of these industrial observations, a few additional but crucial points have to be considered. First, we did not find unanimity of opinion among the firms interviewed; for every criticism made by one firm,

one or more other firms would disagree with it. Second, in discussing problems of interaction, the majority of firms perceived one or more barriers originating on the lab side, but none on the industrial side. However, a minority was prepared to say there are at least as many problems originating in industry as in the government, and that any changes made should not be unilateral. There is no doubt that this latter group is considerably better informed about the roles and functions of government laboratories than the former. The majority group were inclined to criticize the labs for not doing what they are supposed to do, or don't try to do. On the other hand one or two companies with histories of very successful interaction with government laboratories, although not regarding the labs as flawless, argued that the real difficulties lie not in the labs but in industry. One spokesman said:

> "Industry itself is certainly responsible for more than half the problem. Many firms are too demanding. They insist on receiving all the help and assistance immediately. They pay taxes and think that is all that is required to qualify for cooperation and assistance. Industry's attitude towards government labs is often negative. Many firms have emotional reasons for not working with government labs - they don't like governments and civil servants. I wonder whether some firms who have been extremely critical of government labs really want to be helped. In any case, they are interacting with the people in the labs definitely in the wrong way. They are using the wrong approach. Seventy-five per cent of the barriers to successful interaction with government labs are the result of the lack of industrial empathy."

Other relevant comments included:

Firm 1. "If government labs are working sincerely to achieve worthwhile objectives, if the morale is good and if their people command a high degree of expertise, then the onus is on people in industry to find them, visit them and to liaise with them. NRC should be protected from the whims of politicians and industry."

Firm 2. "The big thing is that it is nice to know that they are there. It is an emotional feeling. We don't look at labs as developers of new products. We regard the labs as a potential or actual source of technological information on which industry can fall back anytime it needs it. It is a kind of assurance. It gives confidence that these labs exist and that they are accessible. Industry relies too much on Government for R & D. The labs are doing excellent work, are fulfilling an important and very valuable role for industry, and if possible, they should continue as is."

Firm 3. "You cannot legislate R & D. You should not dictate what government labs can do. The country requires a certain number of people thinking about ideas. We are not in agreement with people who are critical of government laboratories."

Firm 4. "Whatever criticism industry and science policy committees may have with respect to NRC, you can make an equally good case for letting NRC continue as is."

Firm 5. "Government labs don't understand the problems of private industry, and we shouldn't expect them to understand our problems since they operate in a different time frame and have a different set of priorities."

10. Interpretation of Industrial Criticism and Possible Implications

When we summarize the views expressed by industry about government R & D establishments, the following main points emerge:

(1) A small minority of firms is entirely dissatisfied with government labs and with NRC in particular. Firms in this group identify incompetence, inappropriate research orientation, remoteness, etc.

(2) A similar sized minority is entirely satisfied

with government laboratories and believes they should be allowed to continue their work in the same manner as at present.

(3) The majority believes government labs are doing excellent work, produce much of value and constitute a valuable potential resource for industry. Nevertheless, they also perceive problems and deficiencies, the most frequently mentioned being:
(a) Government labs do good work, but appear to produce little of direct value to manufacturing.
(b) Government labs do good work, and produce much that is of direct value to industry in general, but do little work of direct value to particular companies or particular types of manufacturing, e.g., food processing, radar, pharmaceuticals, aircraft engines.

Recommendations for change, related to these two deficiencies, were that the R & D of government laboratories should reflect the requirements of industry, that labs should accept detailed industry advice on what should be done, and that the mechanism for achieving a reorientation is improved communications between industry and government labs. In particular, government R & D personnel should visit manufacturing firms much more than they do at present, and there should be more joint projects.

Other major deficiencies noted were:

(c) Government labs do good work and produce much of direct value to industry, but there are obstacles to fruitful interaction with them because of
(1) their lack of market orientation;
(2) their failure to understand the commercial world and how it operates; and
(3) their different time frame, and their lack of a sense of urgency - their work may be too detailed and "too good".

(d) It is difficult to know how to establish contact with government labs.

How well founded are these industrial views and criticisms? How much attention should be paid to them, bearing in mind especially that industry

is only a minor audience of government labs? Should they form starting points for the implementation of change in the R & D establishments?

In many ways these views have strong force, for they rest on a firm foundation of truth. They are for the most part sincere, serious, well-intentioned views deserving of serious consideration. However, unless there is a readiness to embrace a fundamental reorientation in the philosophical underpinnings of government laboratories, industrial complaints in themselves are not sufficient to justify major changes in the labs. Such a reorientation would require a major policy decision taken at the highest levels. The question of the desirability of this kind of change cannot be answered by examination of the material collated for this study. The answer will be found through examination of personal views and values - political, moral and social.

Although the industrial criticisms are founded on truth, they arise because of a basic misconception of the role of the government research establishments. Many industrial spokesmen have accurately described what they regard as ailing conditions, but they are misled about their causes. It is fair to say that government research establishments are not characterized by a market reorientation; and it is equally fair to retort - why should they be when it is neither their role nor function to be so? It is true that certain areas of R & D of acute interest to some manufacturing firms receive little or no attention in government laboratories; but given the designated roles and functions of government labs this is only to be expected. R & D of value to industry should only be undertaken when certain circumstances are met. It is true that government labs may miss certain vital areas which they should be addressing and that some of the R & D undertaken is of little value to industry; however,the labs do not exist to provide a complete R & D service to industry. Some firms and/or industries are bound to be disappointed.

Unfair as it may sound, most industrial criticisms of government R & D establishments must be rejected as long as it is believed that the present roles and functions of most of the establishments are valid and useful. It seems unreasonable to expect a laboratory concerned with R & D on ocean-

ography to be conversant with the problems of the commercial world, or to bear in mind the marketing needs of various industries while developing instruments needed in its own research, or to send its scientists to visit manufacturing firms to find out what sort of R & D they would like the lab to do. That would be preposterous. Most general industrial criticisms are invalid in relation to the vast majority of the government laboratories. This includes such large mission-oriented R & D complexes as DND, AECL and DOC. Although these organizations interact with manufacturing industry in a variety of ways, they do not exist to help industry or to provide it with services. Their interaction with industry is largely based on self-interest. They interact in order to gain help and assistance from industry in achieving their non-industrially oriented goals.

But not all government R & D establishments can so easily escape the industrial criticisms. A significant minority has an official responsibility to industry of one form or another. Of greatest importance is NRC, for it completely dominates this minority group. Also in the group are the Forest Products Laboratories of DOE and some subdivisions of the Mines Branch of EMR.

When industrial spokesmen comment on and criticize government laboratories, two times out of three they are referring to NRC or, more commonly, one of its divisions. NRC is better known to industry than any other government R & D establishment, a fact clearly illustrated in Tables V.4 and V.5. Being best known it is therefore subjected to most comment, both positive and negative. Do the industrial observations and criticisms have greater validity for NRC than the rest of the government science complex?

The answer can only be yes. NRC has a clear mandate to assist industry in a number of ways, and many of the actual or potential beneficiaries of the assistance are dissatisfied with aspects of the service they receive. To understand the roots of this dissatisfaction we have to consider the points of view of both NRC and industry.

In Chapter IV an attempt was made to explain how NRC interprets its mandate. A key statement quoted in that explanation was: "We (NRC) are

creating a knowledge base which is a public good, and on which the nation can draw. We are promoting scientific and technological knowledge for the benefit of all Canadians."

Our discussions with industrialists reveal quite clearly that, even among the small minority of Canadian firms which have interacted with NRC, its mandate and raison d'etre are for the most part misunderstood, misinterpreted or simply not known at all. The breadth of NRC's mandate is not appreciated and the nature of its responsibility to manufacturing is misunderstood.

The point about NRC most frequently missed by industry, and it is a crucial omission, is that NRC's responsibility to manufacturing is to nurture a national industrial research capability. That is, NRC exists (among other reasons) to help develop and encourage R & D in manufacturing industry, so that industry itself will be more effective in product and process innovation. As far as NRC is concerned, its contribution to innovation and improvement is indirect, not direct. It interprets its responsibility as the provision of knowledge, expertise and special facilities to industrial R & D units, and not as acting as an external R & D unit of manufacturing industry with the object of providing profit-oriented innovations. Failure to understand this is central to much of the criticism levelled against NRC.

Despite this we must concede that NRC, and therefore the federal government, may be mistaken about the kind of help industry wants from government labs. NRC's mandate and the interpretation made of it may be out of step with current industrial needs and deficiencies. Perhaps there is a need for a new policy which would make at least part of NRC an extension of industrial R & D capability and which would pay more attention to the operating conditions of the commercial world and the demands of the market place than at present. Indeed, it seems NRC is making changes in these directions.*

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* The Role of NRC in Canadian Science and Engineering: A Redefined Policy Framework." Letter from the President to all Staff, 3 December 1974. An excerpt from this letter is given in footnote 46 in Chapter IV.

For the moment, however, our concern is with NRC's present mandate and its implementation. Much of the criticism of NRC relates to its mandate rather than to the way in which this is carried out. It is worthwhile re-examining industrial criticisms in the light of this discordance between what NRC supplies and what many firms demand or expect of NRC. But first it is useful to consider the views of those firms which are most satisfied with NRC. Not surprisingly these are the firms

which have enjoyed the most fruitful interactions with NRC. Usually they have developed close personal working relationships with one or more scientists or engineers in an NRC division. Their knowledge of NRC's roles and functions is the most complete, with the result that they know what to expect of it. They regard NRC as a rich resource which will yield results if properly explored. They find the scientists and engineers as helpful as possible within the constraints imposed by their various obligations, although often regretting the lack of greater flexibility in the availability of scientists whose expertise is needed. They do not look to the labs as developers of new products; they regard them as a valuable source of scientific and technological information on which they can draw when the need arises. They have in many cases been recipients of technology originating in NRC labs. Since they are aware that NRC is not really in the business of transferring technology (except via its special subdivisions, TIS and CPDL) they know that the major initiative must come from themselves if successful transfers are to be effected. Their most important attribute is their positive attitude towards NRC. Having come to understand NRC as it now is and now operates, they approach NRC in such a way as to maximize their benefits from it. They are usually not disappointed.

The importance of this attitude can easily be shown by a comparison of two companies. The first firm has had very little interaction with government laboratories. Its spokesman made the following observations - "The major objection against government labs is that they have not the faintest idea

and do not know how to get an idea into a commercial market." The second firm has enjoyed prolonged and successful interaction with NRC. They have had several commercial successes from instruments developed at NRC. These instruments were "initially intended for use by the scientists themselves". In other words, the instruments were developed without a thought being given to their commercial potential or applicability. The difference between the two firms is one of attitude and expectation. The second firm, knowing the workings of NRC, recognizes that industry has to extract help from NRC rather than wait for it to be handed out. "They (industrial firms) should visit NRC on a continuous basis. They should be pacing the corridors of NRC instead of sitting around complaining." Significantly, however, the same spokesman then added, "maybe NRC should have a liaison service, so that more industrial firms would have the kind of interaction we have."

We suggest that one immediate lesson from our study is that many firms which are critical of NRC could be considerably more active than they are in trying to make use of NRC's rich resources, and that NRC in turn could do more to facilitate their attempts to make effective use of its knowledge and expertise.

Most firms do not have such a positive attitude to NRC as the firm whose views have just been considered, with the result that the discordance between industrial expectations of NRC and what NRC actually provides will continue to cause varying degrees of dissatisfaction.

However, on the basis of some of our findings in Chapters III and IV, we suspect that useful steps could be taken to reduce the strength of present dissatisfaction without significantly altering the roles and functions of NRC. Certain organizational, structural and attitudinal changes are possible without the need for major policy and role changes. For example, greater encouragement could be given to scientists and engineers to interact and cooperate with manufacturing firms. Alterations in evaluation procedures and in the criteria for promotion of R & D personnel would be important in this. As many industrial spokesmen and government employees have observed, there may

still be too strong an emphasis on publishing papers, and not enough credit given for cooperation and work with industry. Means could be introduced to make it easier for laboratories to close down old or stagnant R & D programs and to start up new ones. This would give laboratories greater flexibility and enable them to be more responsive to industrial R & D interests. Also, the movement of staff between different parts of NRC and between NRC and industry should be facilitated. Secondment of NRC staff to individual firms for varying periods of time should be easier and more frequent than at present, and could be achieved without major disruptions of lab programs.

Even with these changes, a number of basic dissatisfactions would remain. The kinds of changes discussed would probably not close the many gaps in NRC's research as perceived by industry. They would not make NRC totally responsive to market and profit orientation, nor cause its employees to be fully conversant with the special constraints and operational modes of the commercial world. But they would create change in the right direction.

Basic problems would remain, and one cannot help wondering if a new kind of NRC is the only solution. Perhaps NRC should be bifurcated, with the creation of a new distinct part which would exist solely to respond to and serve industry. The remainder of NRC would continue the present roles and functions of NRC while providing "back-up" to the industrially-oriented portion. However, this would be a very major departure and it is raised here only as a possibility for consideration.

11. Technology Transfer from Government R & D Establishments - Industrial Perceptions

To a great extent the information collected from industry reinforced the observations and findings set down in Chapter IV. Industry had a great deal to say about the barriers and impediments to technology transfer, but most of their comments had been quite predictable on the basis of the knowledge we had gathered from the laboratories. Industry showed us the other side of the coin and there were few surprises. On the mechanism of the transfer process itself, the industrial spokesmen had very little to say. The real problems are the

barriers; once the potential and the will exist to effect a transfer, the mechanistic problems are relatively insignificant and rarely prove to be insurmountable.

In the questionnaires employed for both the small and large samples, firms were asked questions intended to identify the main barriers to effective and successful interactions with federal R & D establishments. The questionnaires listed a series of statements about the labs and firms were asked to say whether these were true or false. True indicates the perception of a barrier to interaction with industry; false identifies a situation favourable to interaction. Responses from firms in the small sample are described in Table V.13 and those from the firms in the large sample in Table V.14.

There are certain differences between the two surveys, but they are differences of degree rather than nature. Both samples identified the same factors as barriers, but the small sample also had the opportunity to make a "don't know" response. The large sample could only answer yes or no. In addition, in Table V.14 (large sample) there is a graph which indicates the width of the barriers to successful interaction with government research establishments.

From the point of view of the government laboratories, at least some of the results should be gratifying. Most industrial firms appear to be satisfied that government labs are adequate in expertise and competence; only 6.6 per cent of the firms responding in the small sample believed they are not. Most firms find that government labs are interested in their problems, and very few believe they are difficult to approach because of distance or other communication problems. However, as might be expected, some firms located in provinces other than Quebec and Ontario did cite distance from Ottawa as a serious obstacle to interaction with government R & D establishments. In some instances "regional nationalism" underlay comments about distance as a barrier. For example, one manufacturer in the Prairies said:

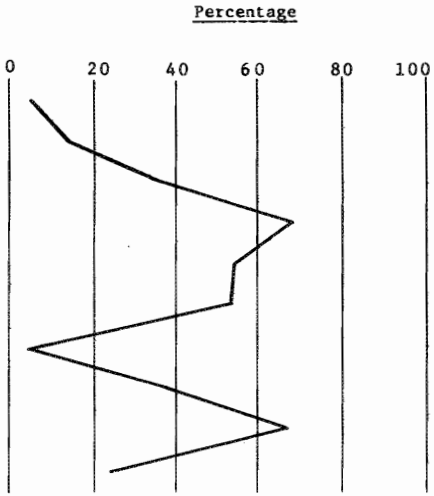
> "Government labs should be spread over the country. You have to understand the psychology of the Western Provinces. We are a colony of

Table V.13 - Barriers to Interaction with Government Laboratories (Small Sample)

Barrier	Percentage of respondents answering: True	False	Don't Know
1. Government laboratories lack sufficient expertise and competence	6.6	68.4	25.0
2. are not interested in your problems	8.5	61.0	30.5
3. have a different time-frame and lack sense of urgency and efficiency	58.0	17.0	25.0
4. do not understand work and needs of the private sector	38.7	35.5	25.8
5. have a poor information dissemination system	13.8	43.1	43.1
6. are conducting high quality research but it is too far removed from practical applications	40.0	43.6	16.4
7. are difficult to approach because of distance or other communication problems	16.0	76.0	8.0

Table V.14 - Barriers to Interaction with Government Laboratories (Large Sample)

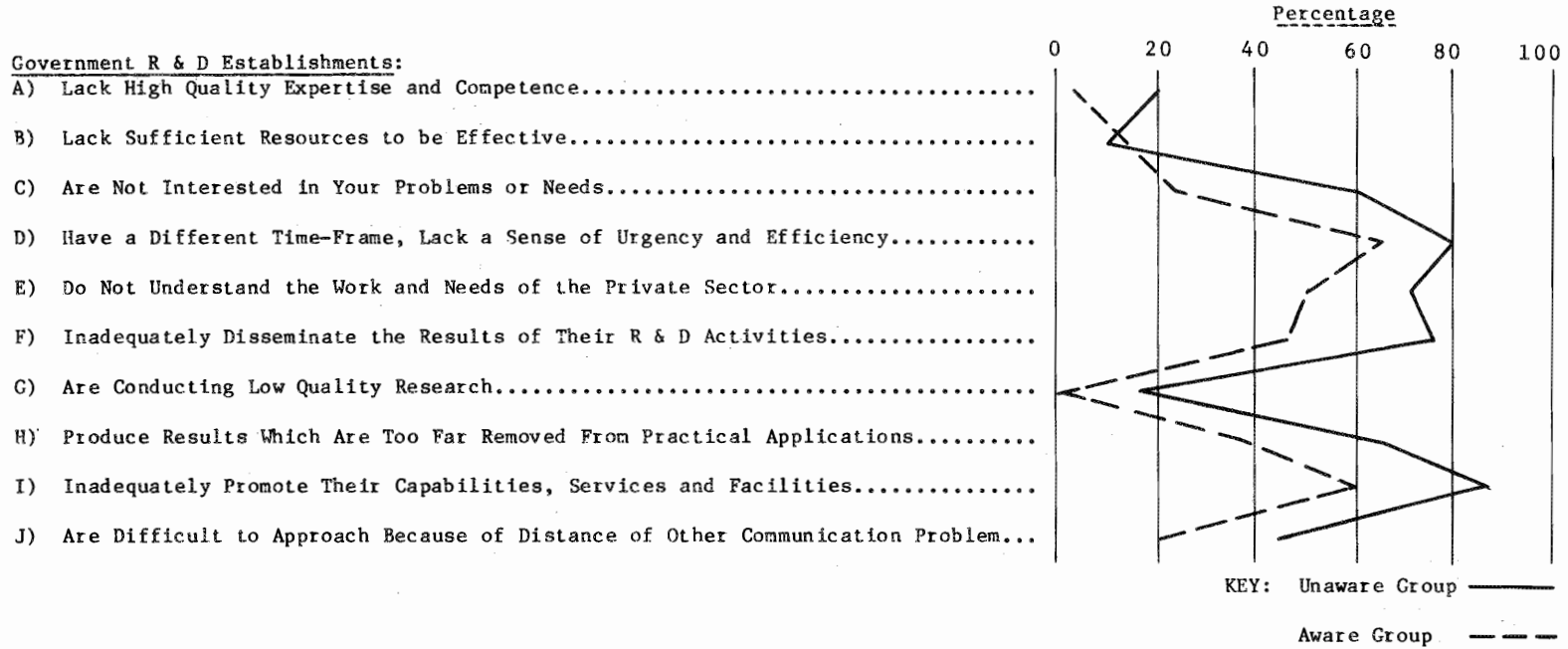
Government R & D Establishments:



	Percentage of Respondents Answering	
	True	False
A) Lack High Quality Expertise and Competence	7	93
B) Lack Sufficient Resources to be Effective	13	87
C) Are Not Interested in Your Problems or Needs	34	66
D) Have a Different Time-Frame, Lack a Sense of Urgency and Efficiency	69	31
E) Do Not Understand the Work and Needs of the Private Sector	56	44
F) Inadequately Disseminate the Results of Their R & D Activities	56	44
G) Are Conducting Low Quality Research	4	96
H) Produce Results Which Are Too Far Removed From Practical Applications	42	58
I) Inadequately Promote Their Capabilities, Services and Facilities	69	31
J) Are Difficult to Approach Because of Distance of Other Communication Problem	27	73

Note: the higher the percentage positive response the more significant is the barrier to interaction. Thus both barriers D and I with 69% positive response are perceived by industry as the greatest barriers to successful interaction with government research establishments.

Table V.15 - Barriers to Interaction with Government Laboratories: Comparison of Firms "Aware" and "Unaware" of Activities of Government Research Establishments in Firm's Field of Interest (Large Sample)



the East. We are second class citizens in the West, we feel left out, we feel neglected. Decentralization, if properly implemented, could have a considerable psychological effect on the people in the West."

Among other expressed concerns about distance, the following is fairly representative:

"The basic barriers to interactions with government labs are cost and distance. We are aware of what is going on but this does not cut the cost. It takes at least two working days to visit a lab in Ottawa, but we can get to San Francisco in about one hour. Even contacts by telephone are difficult because of the different time zones. We go for scientific and technical information where it is convenient and this is the west coast. If the labs were in Vancouver we might discover some specific projects of interest to us. At the present time we do not have enough information, and we do not know exactly what they are doing."

In the small sample a majority of the firms (58 per cent) believe that government labs have a different time-frame from industry and lack a sense of urgency and efficiency. This is obviously a potential barrier to technology transfer. In the large sample 69 per cent of the firms found the government labs deficient in this factor. Approximately the same percentage of firms in the large sample believe that government laboratories inadequately promote their capabilities, services and facilities. Fifty-six per cent (large sample) believe the labs do not understand the work and needs of the private sector and the same proportion feels that government laboratories inadequately disseminate the results of their R & D activities. We tested the hypothesis that firms which believe they are aware and informed about government labs are less likely to see barriers to interaction than firms which are not aware and informed. In Table V.15 the responses of "aware" and "unaware" firms have been separated.* The differences between the two are differences of degree, but they are revealing.

* Some 44 per cent of the large sample were aware of the activities of government research establishments as they related to the fields of interest of the firm; the remaining 56 per cent were unaware.

"Unaware" firms believe that the barriers to interaction are much more severe than do the "aware" firms. For example, about 90 per cent of the former believe that government laboratories inadequately promote their capabilities, services and facilities, compared to 60 per cent of the latter. A very significant difference is shown by answers on whether or not government laboratories are interested in industrial problems or needs. Sixty per cent of the "unaware" firms believe this is so but only 24 per cent of the aware firms agree.

A number of messages can be read from these differences in perception and belief. The most important is that industrial criticism of government laboratories should be closely analysed. Industrial firms seem prone to voice criticism and opinion on the basis of very limited knowledge. They have a tendency to assume the existence of certain conditions in government R & D establishments, and to believe their assumptions are established facts. Industry is not wholly at fault in this. Conventional wisdom and media accounts of government science policy statements and reports leave the impression that the government science complex is failing to meet the needs of industry and is therefore not carrying out its mandate. The primary emphasis of this report is that the government science establishment is for the most part meeting its mandate - and in so doing may be failing to meet the needs of industry. In order to meet industrial needs, the roles, objectives and functions of the government research establishment would have to be modified, in some cases rather drastically. This is a socio- political question which has been touched on in Chapter IV.

Despite the reservations one might have about the validity of many industrial opinions the data presented in Table V.14 indicate that from industry's standpoint the following three are the most important barriers:

1. Government laboratories have a different time-frame and lack a sense of urgency and efficiency.
2. Government laboratories inadequately promote their capabilities, services and facilities.

Three other barriers also can be treated as significant:

3. Government labs do not understand the work and needs of the private sector.
4. Government labs inadequately disseminate the results of their R & D activities.
5. Government labs produce results which are too far removed from practical applications.

Respondents were also asked to suggest any additional factors which they consider to be barriers to interaction. This elicited some interesting comments, but on the whole the observations mainly corroborated earlier findings. Some representative comments are as follows:

Firm 1. "Government people are reluctant to share information. They want to publish the information in learned journals and earn their brownie points."

Firm 2. "The reward system in government labs is geared to work against exploitation of results."

Firm 3. "The choice of the projects and the work of the labs has not been such as to be of great help to industry."

Firm 4. "When development occurs in government labs, there is a greater need to transfer staff to industry to complete the innovation."

Firm 5. "I seriously doubt that the broad body of activities carried out in labs is really directed towards Canadian industrial needs."

Firm 6. "There is a need for technical personnel to travel and visit industry in order to attain greater awareness of their technological interests."

By contrast, some firms assented that no barriers stem from the conditions and attitudes of the government labs. Comments from this minority include:

Firm 1. "The only real barrier is lack of initiative on the part of industry to take advantage of the facilities available."

Firm 2. "There is no barrier, providing the firm takes the lead and initiates the contact with the appropriate laboratory."

At this point we realize we have come almost full circle, since a major conclusion of Chapter IV was that the greatest barrier to technology transfer from government R & D establishments to manufacturing industry arises from the roles and function of the R & D establishments themselves. Industrial perceptions of the barriers to interaction automatically follow from this. If a laboratory has no mandate prescribing a direct responsibility to industry, we should not be surprised if it operates in a different time-frame from industry, and we should not expect it to promote its capabilities, services and facilities to a sector it is not supposed to serve. Nor should we expect that laboratory to understand the work and needs of the private sector or to produce results that are of immediate practical application in industry. In the majority of government research establishments the barriers to interaction perceived by industry are the inevitable consequences of the roles, functions and responsibilities of these establishments. As long as laboratories lack the mandate to go to industry and to help it, we must agree with the minority of firms which see the real barrier as being the failure of industry to take the initiative.

It is clear now that the general criticisms of government laboratories, the perceived impediments to interaction, and the roles, functions and responsibilities of government R & D establishments are inextricably interrelated. Industry perceives deficiencies in the laboratories; these deficiencies loom as impediments to successful interaction, thus becoming barriers to technology transfer; and lurking behind the scenes is the villain of the piece - the mandates of the vast majority of government R & D establishments.

In the absence of appropriate mandates, it follows that from industry's standpoint government establishments

(1) produce little of direct value to manufacturing;
(2) lack market and profit orientation;

(3) fail to understand the commercial world and how it operates;
(4) have a different time-frame and lack a sense of urgency; and
(5) are difficult to communicate with.

The last four of these attributes are a direct consequence of mandates and responsibilities. The first attribute is just another way of expressing the problem of discordance between the technology supply emanating from government labs and technology demand generated by industry. Discordance, too, is a consequence of the labs' mandates and of the peripheral status of manufacturing industry as only one of their audiences. Most of the knowledge emanating from government labs was not developed with industrial uses in mind, and most of the technology, if and when it appears, was not developed for the purposes of industrial application. In other words, most of the transferable technology is likely to be regarded by industry as marginal.

On the subject of the difficulties within the transfer process itself, industrial spokesmen had little to add to the findings of Chapter IV. On the whole, their observations corroborated the remarks made by government scientists and engineers as well as findings in the literature on technology transfer. It is interesting to note that the firms involved in the most successful cases of technology transfer had the least to say on the subject. Their general attitude seemed to be that once the potential for transfer is realized, the process itself is simply a matter of common sense, with as much give and take as possible between the source of the technology and its recipient. The key to success appears to be flexibility, in the sense of having the ability to adapt to each situation as it arises.

There seems to be general agreement that formal information dissemination systems and formal interaction systems between industry and government labs are of value only to the extent that such mechanisms lead to a close and informal bond between sources and recipients in the technology transfer process. How the two sides are brought together is immaterial: publications, seminars, visits to the laboratory are all of value. What is essential is close and frequent personal contact

between industrial and government personnel, so that transfer potential is established and the transfer mechanism itself is set in motion.[6] Some of the more valuable statements from industry were as follows:

Firm 1. "Transfer of technology goes through people, never through written stuff. The people are so important - their personalities, attitudes and values."

Firm 2. "We have had very successful interactions with government laboratories. The main difficulty we have identified and consciously avoided is the problem of personality con-flict. It is essential that company personnel deal with government lab personnel very carefully and diplomatically. Care is particularly essential in assuring government people that they will receive credit for ideas developed and that information will not be released which would compromise any future publications."

Firm 3. "Formal information dissemination systems are useless. Attempts to actually use the information obtained in a formal and systematic way have been very frustrating experiences. There are too many publications and we do not have the time to read any of them. The important information does not come through publications anyway, because at the time something is published it is outdated and it is too late."

Firm 4. "All our information is obtained through personal contacts for two reasons. First, we want to know what is going on before the project has been published. For example the catalogue published by CPDL is coming too late - when the invention appears in print a firm may already have picked up the license, is maybe already working on it, the inventor is committed and arrangements for financial support are being made already. The firms that wait for projects or products to appear in print, inevitably miss the boat.

> Second, the personal contacts are not just important, they are all and everything - they are the essence of the whole technology transfer process. If the scientist in the lab does not like the manufacturer or his representative, the firms would be better to leave. If the two individuals cannot get along, there is no directive, incentive, begging or pressure that will improve the interaction between them. The only solution then for the firm is to get out. We spent $80,000 in one case before this was realized. The interactions between people in government labs and in industry should be based on mutual respect, good will and understanding." (Emphasis supplied.)

Firms with experience of technology transfer agree that informal person-to-person contacts are the key to keeping informed about laboratories, to finding out about potentially transferable technology, and to effecting transfers between the government labs and industry. The same firms all agreed that free interchange of personnel between government R & D establishments and industrial firms is very useful in effecting transfers. A number of firms have had staff seconded to government labs for varying periods of time. Many firms think it would be advantageous if it were easier for government scientists to work with their R & D groups when the need arises.

The firms making these kinds of comments all had good working relationships with the directors and individual scientists and engineers in various labs. They know what is going on long before information appears in publications, bulletins, etc. Not all firms we talked to enjoy these close relationships, and they feel a sense of isolation. They complain it is hard to keep up to date on lab activities, and that they do not know whom to contact in this or that laboratory.

In Chapter IV the idea of "couplers" or "knowledge brokers" was suggested. Couplers could make both industry and the R & D establishments much more aware and appreciative of each others' activities, problems and needs, and thereby facilitate technology transfer, both in and out of the establishments, as well as the exchange of information and ideas in general.

This idea was well received by industrial firms, particularly those which found difficulty in communicating with government labs and keeping up to date on their activities. Some examples of industrial reactions are as follows:

Firm 1. "It is difficult to find out exactly what government labs are doing and to get the right person. There should be some kind of directory which indicates to persons outside the formal system who is doing what in government labs. An expanded project catalogue or a "knowledge broker" might be a good idea. Annual reports, etc., are not good enough."

Firm 2. "I'm generally in favour of having a man attached to each lab who knows exactly what is going on in-house. He could be the interface with industry. In some sense he is the marketing man for the lab and can tell the industrial sector what is going on in-house. He can then put the man from industry directly in touch with the scientist heading up a particular program."

Firm 3. "Distance to Ottawa causes some problems on a social basis and therefore a "knowledge broker" is a useful concept. In fact the knowledge broker and seminars are complementary in many aspects. However, it is important that the knowledge broker communicate with the technical people but also with the top management of the firm because they have to make up their budget about one year ahead."

One industrial spokesman noted that, "Firms should be invited to come to the lab. Those who don't show up are not interested." This is a useful reminder that no matter what steps are taken to increase the accessibility and utility of the government labs to manufacturing, successful interaction will always depend in part on the individual firm showing some initiative. There is reason to believe that some firms will always complain about difficulties of communications with the labs no matter what measures are taken by the laboratories.

The concept of the knowledge broker seems worthy of consideration. However, it should be made clear that knowledge brokers are unlikely to have any useful role to play in the technology transfer process per se. Their real value would lie in establishing contacts, promoting better understanding, bringing industrial interests to the attention of the labs, and keeping industry informed of developments in the labs. They may be useful in promoting opportunities for technology transfer, but once an opportunity is perceived, the transfer would be effected by interaction between the R & D personnel of both government and industry.

12. Technology Transfer and R & D Contracts

In dealing with industrial perceptions of technology transfer and its difficulties, some attention must be given to the role of development contracts between government R & D establishments and industrial firms. In Chapter IV a distinction was made between technology transfer with and without source direction. Development contracts to industry are usually closely associated with source directed technology transfer, and usually originate in mission- oriented R & D establishments such as those of DND and AECL, which use manufacturing industry to complete their R & D programs. It was widely agreed by industrial spokesmen that development contracts if properly handled can be an effective means of transferring technology from government labs to industry, and vice-versa.

Of the firms in the large sample, 23 (12 per cent) had developed a product during the past five years through a federal government R & D contract. For one-third of these firms the developed products were commercially very successful. Another third found that they were moderately successful: for the remaining third it was too early to tell. In no case of a product developed through an R & D contract was there failure to attain at least modest success. Three firms indicated that the products were not intended for commercial use.

Eighteen firms estimated the percentage of their annual revenues to be derived over the next five years from the sale of products developed through R & D contracts. The percentage varies between 3 and 80 per cent with an average of 33 per

cent. In absolute terms the value of these products sold annually varies among different firms from $75,000 to $52 million.

In those cases where commercial success of products developed through R & D contracts fell short of expectations, the reasons given were, in descending order of importance:

- insufficient capital to properly launch the product;
- product too sophisticated for a commercial market;
- product too early for the market;
- lack of knowledge of the market;
- market too small;
- product not competitive in quality and/or price.

In most cases the lack of success resulted from a combination of several factors. It is significant that lack of capital to launch products was of greatest importance in failure to achieve expected success. This demonstrates that the R & D phase of the innovation process is only one stage of innovation, and that commercial success or failure depends on far more than mere possession of an invention with apparent commercial potential.

Among the responding firms in the small sample just over 50 per cent had accepted federal government R & D contracts in the previous five years. Some firms had worked on thirty or more contracts during this period. Seventy per cent of the firms which had contracts succeeded in generating some form of commercial spin off. In most other cases it was still too early to tell the outcome. This considerably greater involvement in R & D contracts reflects one of the major guiding criteria for the selection of the firms in the smaller sample, namely a history of interaction with federal government R & D establishments.

Although R & D contracts may be of considerable value to government in getting a job done, they are not necessarily welcomed or actually sought by industrial firms. To understand this, it should be recalled that one of the major impediments to the transfer of technology between government laboratories and industrial firms is the discordance between the supply of technology and the demand for it. It was observed in Chapter IV

that "Technology transfer is more likely to occur if technology has been developed in response to specific needs as perceived by industry rather than in response to specific needs, usually unrelated to manufacturing, perceived by government engineers and scientists." Furthermore the transfer of technology from government to industry usually involves a disruption of the normal innovatory pattern of industry. This pattern is well described by Cox, in Figure V.1.

Technology transfer from government laboratories involves the creation of a piece of technology prior to the identification of a commercial need.* It is this which makes technology transfer random, and causes many businessmen to have strong reservations about accepting R & D contracts from government. There is some value in looking at industrialists' own comments on the subject:

Firm 1. "R & D contracts are just too much trouble. We would only accept contracts for work in areas in which the in-house expertise is below the critical level; or if a good business opportunity is perceived. We do not accept a contract if the work under it does not have a further application in our general business. If it goes right into our business objectives, that is fine."

Firm 2. "We would accept government development contracts if there would be a reasonable chance for commercial spin-off. The profit allowed by government is 10% and this is not an incentive to accept development contracts. A development contract which does not lead to commercial spin-off causes diversion of effort by staff which is crucial to the firm."

Firm 3. "We would turn down a fully funded contract from the government. We are not in the business of making money through R & D work per se. All our efforts, even contract work from the government, should be product oriented."

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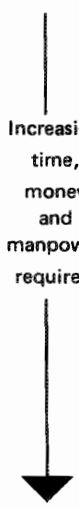
* See also Section 12, in Chapter IV.

Figure V.1 - Main Steps in Successful Innovation



1. Identify a client's NEED.
2. Generate good IDEAS (or an invention).
3. Review relative KNOWLEDGE and KNOW-HOW in science, economics, marketing, etc. (feasibility report).
4. Do DEVELOPMENT work – identify and solve problems;
   – do testing and market work.
5. Find venture CAPITAL.
6. IMPLEMENT changes – design, engineer and tool;
   – plant and/or market start up.
7. COMMERCIALIZE and get ORDERS for new products (and processes) and services.
8. DIFFUSE into market place to customers.
9. Satisfy client's NEED and meet corporate objectives.

Source: Lionel A. Cox, "Transfer of Science and Technology in Successful Innovation", *Forest Products Journal,* September 1974, vol. 24, no. 9, pp. 44-48.

Firm 4. "Products invented in government labs are not useful. Government labs work backwards and do not consider any market potential before they start. We would not accept an R & D contract as an end in itself. However, a lack of capital may force a firm to grab any contract it can get when business goes down although this may mean that the firm has to stop working on a project which appears to lead somewhere."

Firm 5. "We don't want government contracts, because we will lose our market position if we don't look first of all after our own products. And we don't have the flexibility to hire extra people when an interesting contract comes along because it is difficult to pick up staff and to let them go again when the contract is completed."

All the comments are a reflection in one way or another of the problem of discordance. Industrialists have additional complaints about government R & D contracts as the following comments show.

Firm 1. "There is no incentive for industry to take on R & D contracts since there is no exclusivity to the products industry develops through government contracts. A company could develop the product and the market and theoretically another company could walk in with equal status. There's no incentive there."

Firm 2. "The contractor does not have a preference position with respect to the rights to patents and know-how. Patents in the public domain have no value whatsoever and a non-exclusive license is useless. We should receive at least ome part of the patent or some share in the ownership of the rights. A better formula has to be worked out by the government."

Firm 3. "With contracts the government wants access to the total of the expertise we have developed over the years, at our own expense. They want the full rights to

> the knowledge and technology which is embodied in whatever material is transferred under the terms of the contract. In principle the government may turn round and go to one of our competitors with the information. There is nothing to stop them. Dollars are really not that important, but expertise is."

The two major reservations about R & D contracts seem to be: first, and most important that they are only of value if they relate to the commercial and market objectives of the firm, otherwise, the work invested in them represents a deviation from the major interests of the firm; second, that firms do not automatically receive exclusive rights to any products developed through government contracts. Since a firm normally invests its accumulated expertise and know-how in development contracts - that is, the real cost of the R & D is considerably greater than the immediate cost of the work - it can feel cheated of its unique and costly assets if a product developed under a contract is then transferred to another company for manufacturing. Our investigations indicate that this situation seldom occurs. Nevertheless, it seems many firms will remain uneasy about accepting R & D contracts until there are strong guarantees that rights to manufacture a product will not be given to another company once the contract has been completed.

13. Make or Buy Policy - Some Preliminary Observations

It is too early yet to ascertain the effectiveness of the government's Make or Buy Policy. Most industrial firms appear to welcome it, while expressing a certain amount of discontent about its implementation. So far, few of the projects have involved work of interest to industrial firms, and firms fault the policy for that very reason. There are no strong grounds for anticipating a greatly increased number of contracts of interest to industry. The reason lies in just those factors which have permeated every finding of this study. Most government R & D establishments have no orientation towards manufacturing industry, with the result that they are unlikely to be the sources of many more R & D contracts of interest to manufacturing

than there were before the Make or Buy Policy was introduced. In other words, the new policy will not diminish the implications for industry of the present roles and functions of government laboratories.

However, because of one salient feature the policy has led to an increase in the flow of contracts to industry, and should in time lead to an increase in the transfer of technology from government laboratories to industry. This salient feature is the introduction of unsolicited proposals. From the point of view of industry the possibility of receiving development contracts on the basis of unsolicited proposals is a most interesting aspect of the policy. Early problems involving implementation of this part of the policy have been overcome and a substantial number of unsolicited proposals have already led to contracts. The great value of the unsolicited proposals emanating from industry is their potential to reduce the severity of the problem of discordance between technology supply and demand. In so far as industrial R & D generally has as its motivation the perception of customer needs, there is likely to be greater commercial success attaching to contracts based on unsolicited proposals.* Although there is cause for modest optimism, it should be remembered that proposals must be of interest to government laboratories, and relate in some way to their programs. The problem of discordance will to some extent work in reverse; there will always be limit-

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* That industry should help in deciding which work could most beneficially be performed outside government was recognized in an earlier report of the Science Council, Innovation in a Cold Climate, Science Council Report No. 15, October 1971, Information Canada, Ottawa, where it was recommended (pp. 30-31) that "every effort should be made to transfer to industry, wherever practical, any work now carried out in-house by the government that may lead to industrial innovation. This applies particularly to research, development and project managements. This transfer of technology will require close cooperation with industry; in fact, proposals should be invited from industry to determine which activities should be transferred immediately."

ations on the extent to which the R & D interests of manufacturing will be in harmony with those of government R & D establishments with no manufacturing orientation.

The best hopes for a reduction of discordance through the Make or Buy Policy lie in the interactions between industry and the R & D establishments with a responsibility to manufacturing. With improved communications between industry and such establishments, particularly those of NRC, contracts with fruitful commercial results should be more likely than at present. If industry and government laboratories make the effort to understand each others' problems, to keep informed of each others' activities and to develop a mutual understanding and respect for one another, contracts arising both from unsolicited proposals and from needs perceived by the labs could be employed to increase the transfer of technology from government to the private sector.

14. A Note on Foreign Ownership and the Potential for Technology Transfer

In various parts of this study reference has been made to the problems of foreign ownership of Canadian industry. There are many reasons to believe that foreign ownership is probably the single most important factor in explaining the very poor innovative record and potential of Canadian manufacturing. The chief effect of foreign ownership is to limit the number of firms which have an innovative potential. No other industrial country has such a high degree of foreign ownership of its manufacturing as Canada, and no other country has such a relatively low proportion of firms with R & D units.

It seemed important to this study to ascertain whether or not foreign-owned firms with R & D units have a different attitude to, and different kinds of interactions with, government laboratories compared to Canadian-owned firms with R & D units. In the interviews with industrial spokesmen this topic was not raised, and no direct questions relating to it were employed in the questionnaires. However, by cross-classifying data from different parts of the questionnaire it was possible to make some useful comparisons between foreign and domestically owned firms. Since the findings were not derived from the

expressed perceptions of industrial spokesmen, discussion of this topic is kept separate.

In the questionnaires firms were asked about the importance of different sources of scientific and technical knowledge to their activities. They were asked to indicate if each source was very valuable, valuable, insignificant or inapplicable. In the small sample 51 firms responded to the appropriate questions. Of these, 49 (96 per cent) regarded their own R & D facilities as very valuable or valuable. Just over half (51 per cent) regarded government labs as very valuable or valuable. But when the sample is divided between foreign-owned and domestic firms a significant difference appears. Only 33 per cent of the foreign-owned firms regard government labs as very valuable or valuable, compared with 61 per cent of the domestic firms. Of the 51 firms, only 18 (35 per cent) stated that their parent or affiliated or subsidiary firms are very valuable or valuable. When the sample is divided between foreign-owned and domestic firms we again notice a difference. Of the Canadian firms some 26 per cent find their affiliated or subsidiary firms to be very valuable or valuable as sources of scientific and/or technical information. For foreign-owned firms that are subsidiaries operating in Canada, the percentage which finds parent, affiliated or subsidiary firms to be very valuable rises to 55 per cent.

It seems, therefore, that foreign ownership of Canadian manufacturing affects technology transfer from government laboratories in two quite separate ways. First, foreign ownership is a major factor in holding the total number of sophisticated industrial R & D units to a very low level. Second, even when foreign-owned firms maintain R & D units in Canada, they are much less likely to interact with and utilize Canadian government laboratories than domestic firms.

15. Summary and Conclusions

In this chapter we see once more the way in which the roles and mandates of much of the government's research complex condition the degree to which effective interaction with industry is possible. For some time now Canadian industry has been highly critical of the government research sector for

being remote, or not doing enough for industry, or being concerned with problems that are not relevant. We have demonstrated that these concerns are inevitable in view of the role that the major part of governnment research has been assigned.

Despite the constraints imposed on government-industry interaction there is still room for more communication and transfer of knowledge and technology. Although the reader may think that only a radical transformation of the roles and mandates of the government research sector can improve the situation, we have noted ways in which improvements, albeit marginal, could be made. Changes in the incentive mechanisms in government establishments, a fair trial of the "knowledge broker" concept, a more open approach to the needs of industry will, we think, all prove worthwhile.

Perhaps the most important finding of this chapter and perhaps of this entire report, is to expose the differences between government research establishments and the research needs of industry. Although tied together under a common name of scientific research and development, they really share very little else. If one group can share its experience with the other, both can profit from the interaction. Each, though, operates in a different sphere of interest and responds to different stimuli.

The authors recognize the "two solitudes" of government and industrial research. We hope that with this report unwarranted expectations will be removed and with them will go much of the rancour which has characterized the government-industry relationship. With a more realistic appreciation of this relationship, new and constructive ways of interaction and cooperation will, we hope, come about.

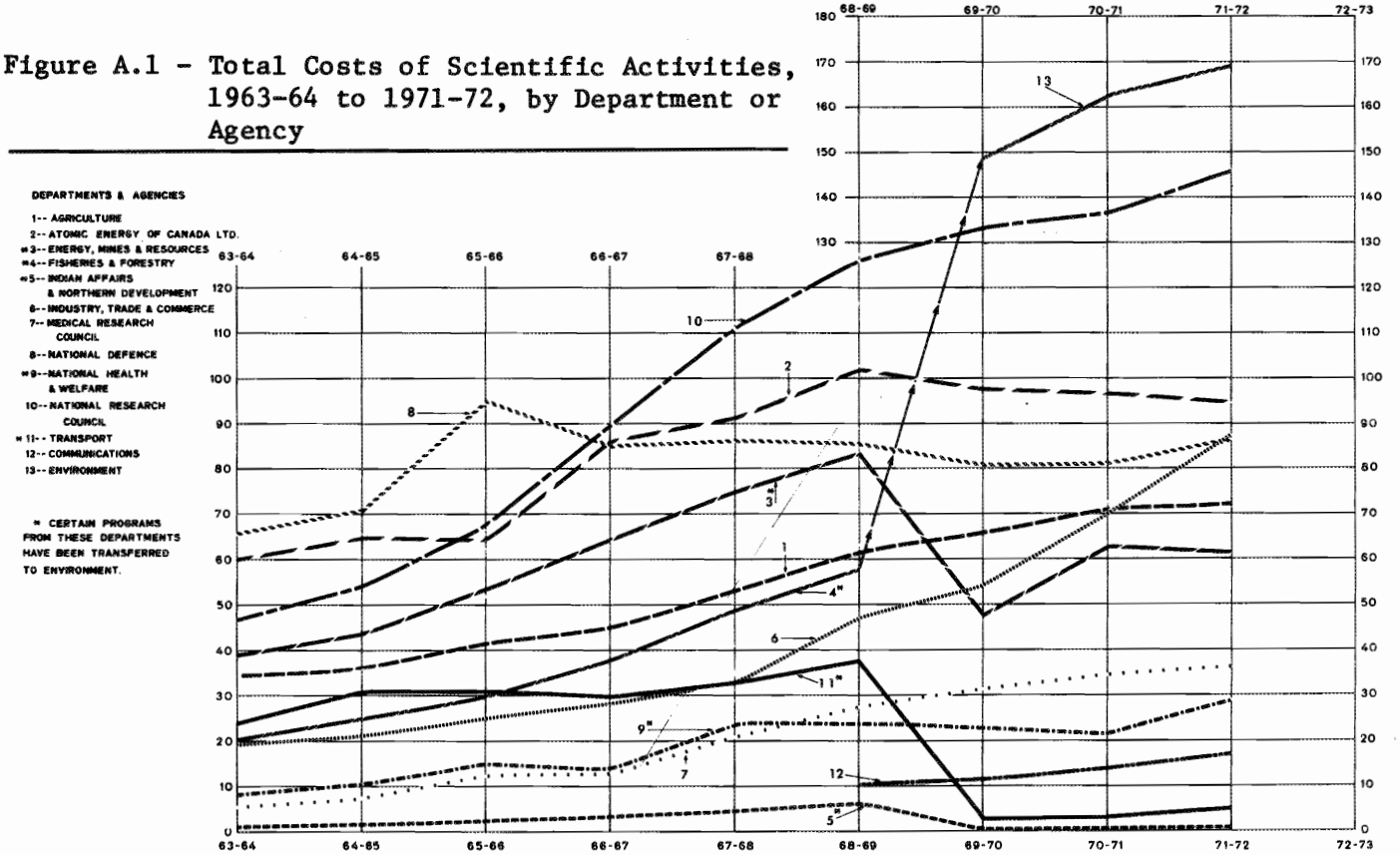
Appendix

Appendix

An Abbreviation Key for the Federal Government Departments and Agencies involved in Scientific Activities:

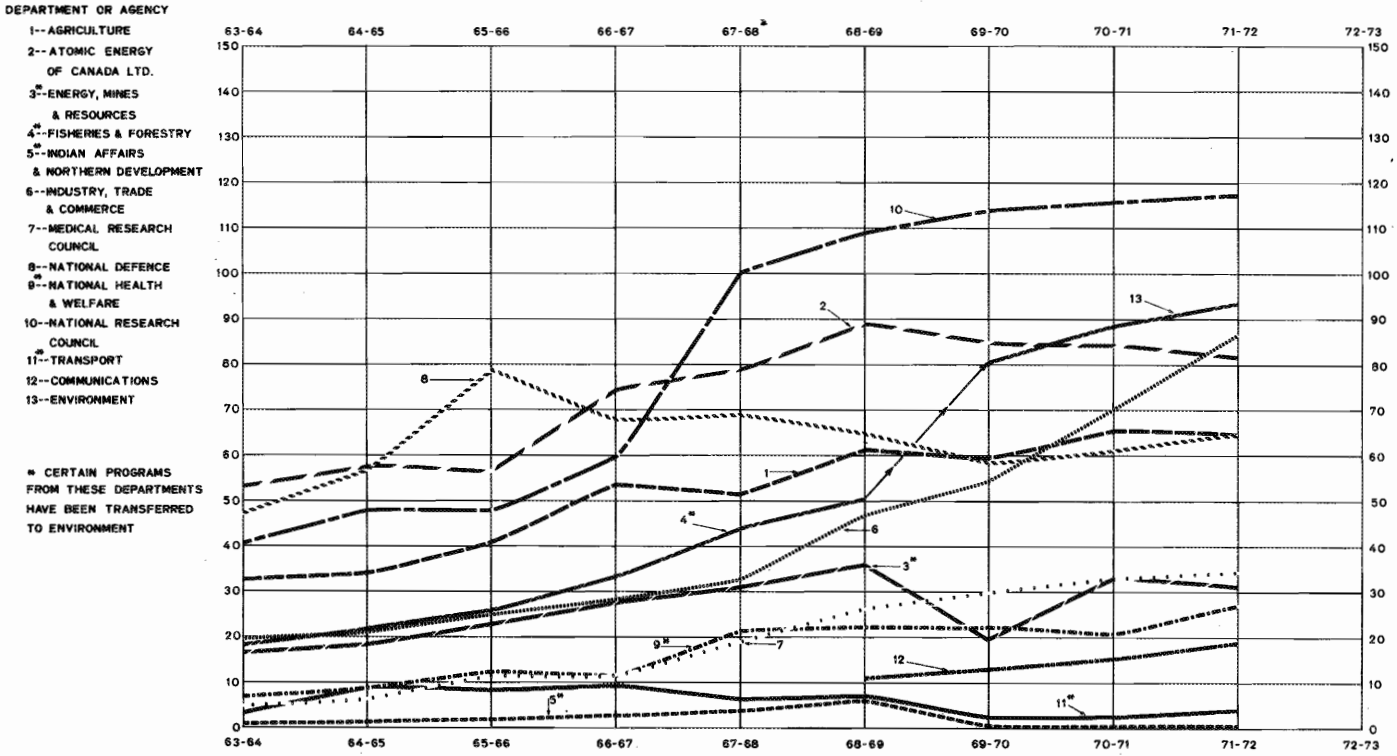
DOE - Department of the Environment
DND - Department of National Defence
NRC - National Research Council
AGR - Department of Agriculture
EMR - Department of Energy, Mines and Resources
AECL - Atomic Energy of Canada Limited
DOC - Department of Communications
NHW - Department of National Health and Welfare
CCA - Department of Consumer and Corporate Affairs
MOT - Ministry of Transport
NM - National Museums of Canada
DPW - Department of Public Works
ITC - Department of Industry, Trade and Commerce
IDRC - International Development Research Centre
MRC - Medical Research Council
INA - Department of Indian Affairs and Northern Development
CPDL - Canadian Patents and Development Limited
SLSA - St. Lawrence Seaway Authority
NFB - National Film Board
EA - Department of External Affairs
VA - Department of Veterans Affairs
DREE - Department of Regional Economic Expansion
CBC - Canadian Broadcasting Corporation
CAL - Canadian Arsenals Limited
CMHC - Central Mortgage and Housing Corporation
AECB - Atomic Energy Control Board
CIDA - Canadian International Development Agency

Figure A.1 - Total Costs of Scientific Activities, 1963-64 to 1971-72, by Department or Agency



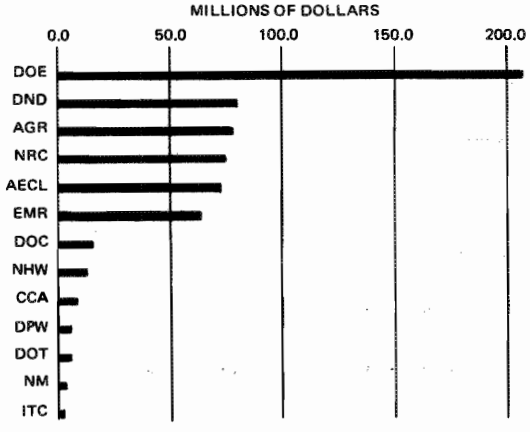
Source: Ministry of State for Science and Technology, Scientific Activities, Federal Government Costs, 1958-59 to 1971-72, Information Canada, Ottawa, November 1971, p.7.

Figure A.2 - Total Costs of Research Development by Department or Agency, 1963-64 to 1971-72



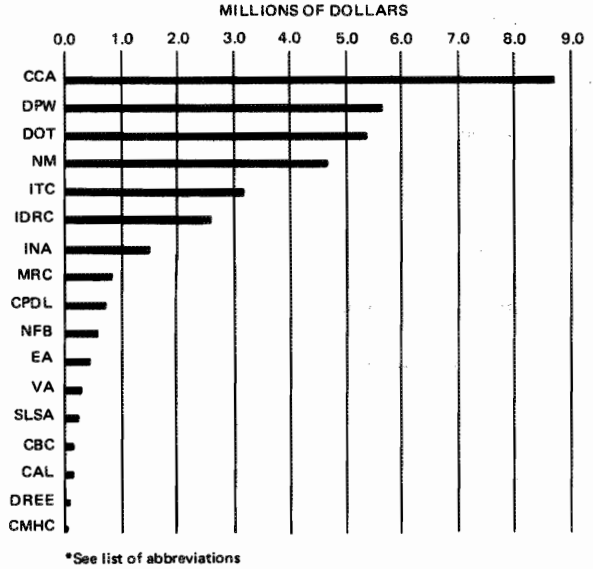
Source: Ministry of State for Science and Technology, Scientific Activities, Federal Government Costs, 1958-59 to 1971-72, Information Canada, Ottawa, November 1971, p. 8.

FIGURE A.3
FEDERAL INTRAMURAL AND ADMINISTRATIVE EXTRAMURAL EXPENDITURES ON SCIENTIFIC ACTIVITIES, 1973-74 BY DEPARTMENT OR AGENCY*



*See list of abbreviations.

FIGURE A.4
FEDERAL INTRAMURA AND ADMINISTRATIVE EXTRAMURAL EXPENDITURES ON SCIENTIFIC ACTIVITIES, 1973-74 BY DEPARTMENT OR AGENCY*. NOTE CHANGE IN SCALE FROM FIGURE A-3



*See list of abbreviations

FIGURE A.5
TOTAL REGIONAL FEDERAL INTRAMURAL
EXPENDITURES ON SCIENTIFIC ACTIVITIES, 1973-74

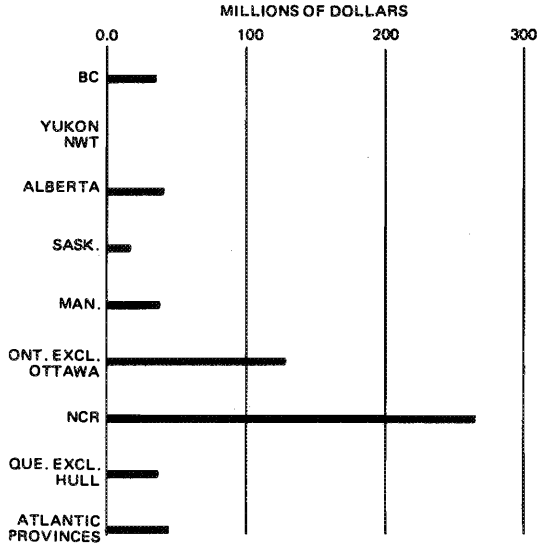


FIGURE A.6
TOTAL REGIONAL FEDERAL INTRAMURAL
EXPENDITURES ON SCIENTIFIC ACTIVITIES, 1972-73
(MARITIMES DISAGGREGATED)

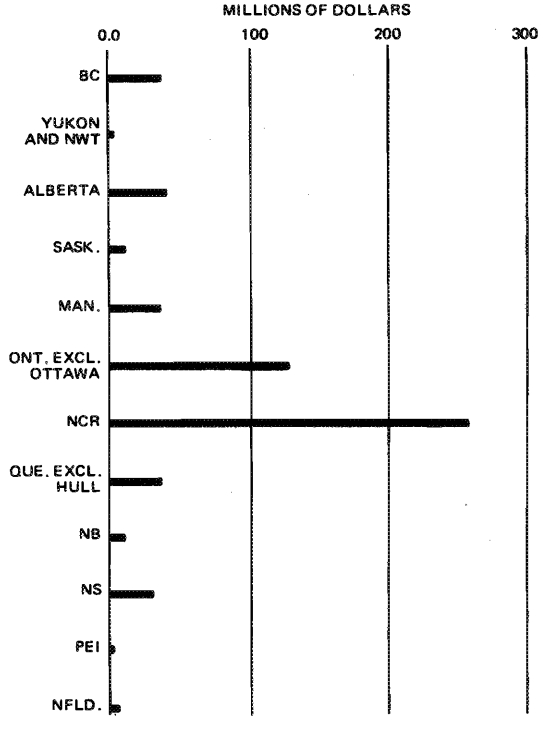


FIGURE A.7
FEDERAL INTRAMURAL EXPENDITURES ON SCIENTIFIC ACTIVITIES: A REGIONAL BREAKDOWN FOR NATURAL SCIENCES, 1973-74
DEPARTMENT OF AGRICULTURE

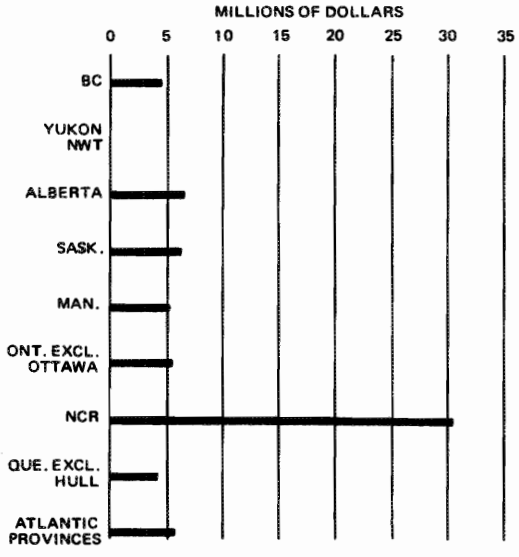


FIGURE A.8
FEDERAL INTRAMURAL EXPENDITURES ON SCIENTIFIC ACTIVITIES: A REGIONAL BREAKDOWN FOR NATURAL SCIENCES, 1972-73
DEPARTMENT OF AGRICULTURE
(MARITIMES DISAGGREGATED)

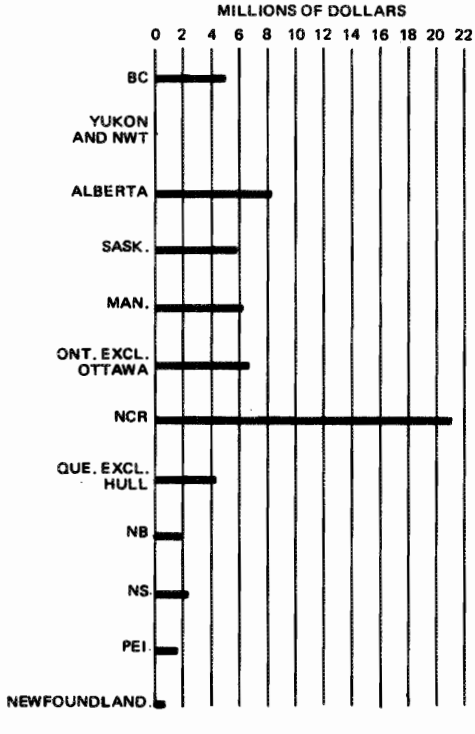


FIGURE A.9
FEDERAL INTRAMURAL EXPENDITURES ON SCIENTIFIC ACTIVITIES: A REGIONAL BREAKDOWN FOR NATURAL SCIENCE, 1973-74
DEPARTMENT OF ENERGY, MINES AND RESOURCES

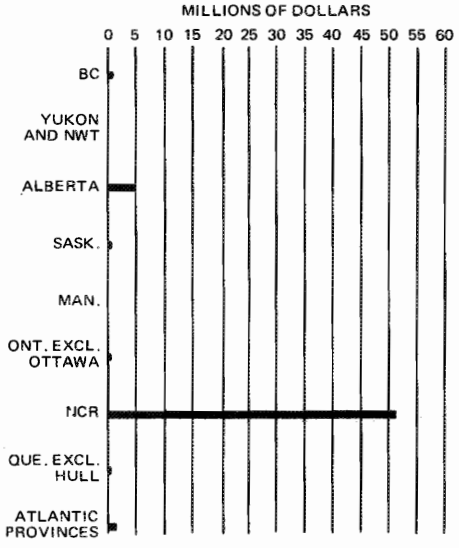


FIGURE A.10
FEDERAL INTRAMURAL EXPENDITURES ON SCIENTIFIC ACTIVITIES: A REGIONAL BREAKDOWN FOR NATURAL SCIENCE, 1972-73
DEPARTMENT OF ENERGY, MINES AND RESOURCES
(MARITIMES DISAGGREGATED)

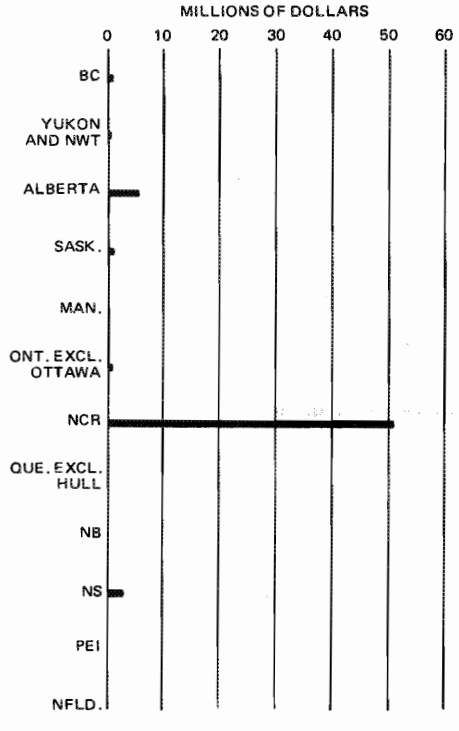


FIGURE A.11
FEDERAL INTRAMURAL EXPENDITURES ON SCIENTIFIC ACTIVITIES: A REGIONAL BREAKDOWN FOR NATURAL SCIENCE, 1973-74
DEPARTMENT OF ENVIRONMENT

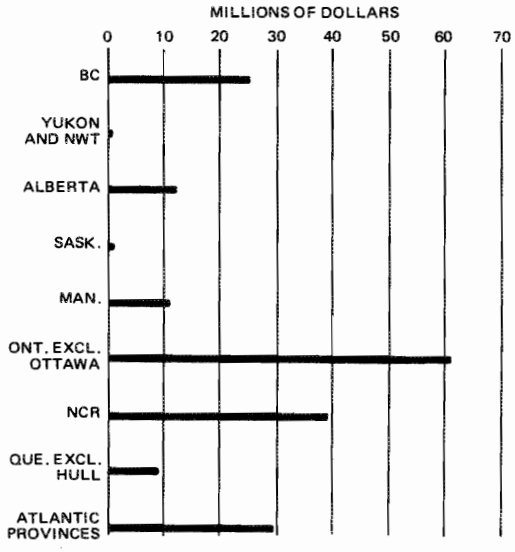


FIGURE A.12
FEDERAL INTRAMURAL EXPENDITURES ON SCIENTIFIC ACTIVITIES: A REGIONAL BREAKDOWN FOR NATURAL SCIENCE, 1972-73
DEPARTMENT OF ENVIRONMENT
(MARITIMES DISAGGREGATED)

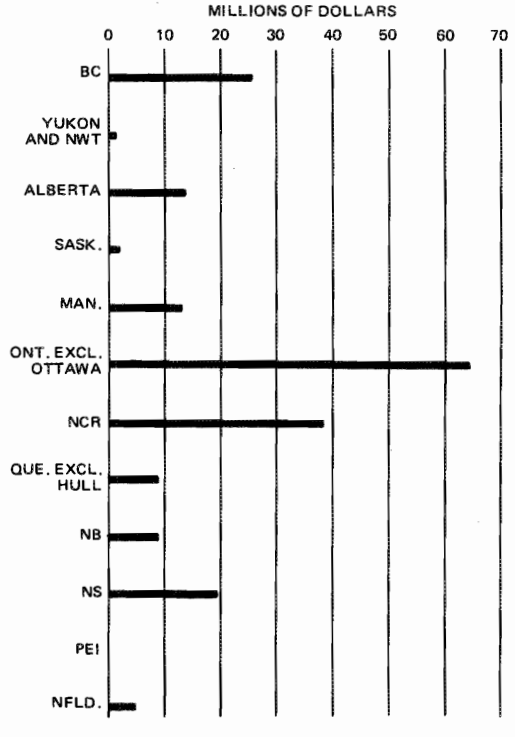


FIGURE A.13
FEDERAL INTRAMURAL EXPENDITURES ON SCIENTIFIC ACTIVITIES: A REGIONAL BREAKDOWN FOR NATURAL SCIENCES, 1973-74 DEPARTMENT OF NATIONAL DEFENCE

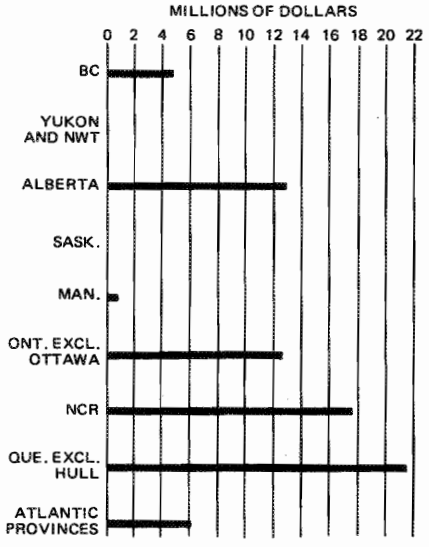


FIGURE A.14
FEDERAL INTRAMURAL EXPENDITURES ON SCIENTIFIC ACTIVITIES: A REGIONAL BREAKDOWN FOR NATURAL SCIENCES, 1972-73 DEPARTMENT OF NATIONAL DEFENCE (MARITIMES DISAGGREGATED)

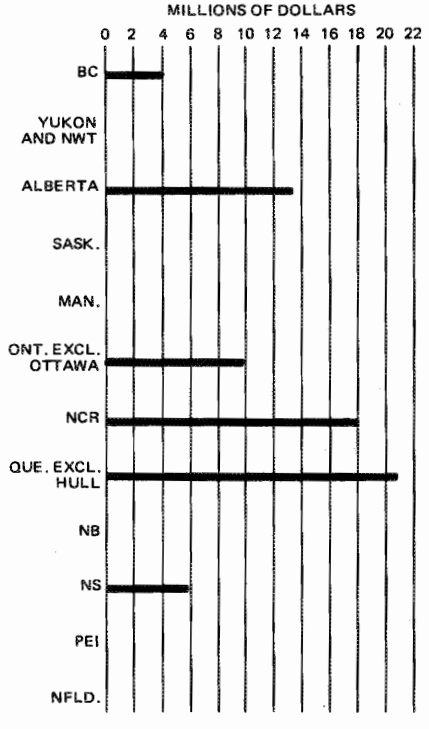


FIGURE A.15
REGIONAL PER CAPITA EXPENDITURES ON SCIENTIFIC ACTIVITIES BY THE FEDERAL GOVERNMENT, 1973-74
(INTRAMURAL & ADMIN. EXTRAMURAL)

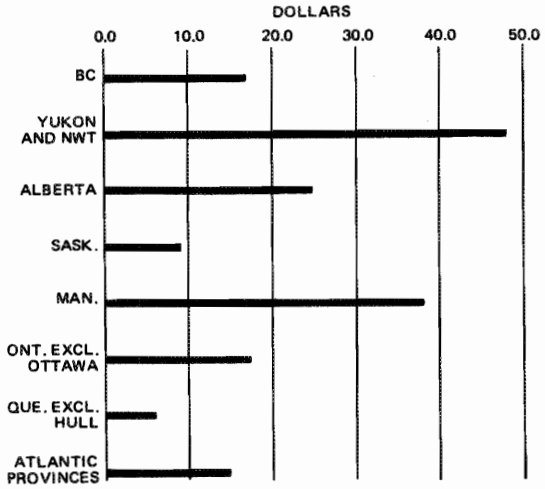


FIGURE A.16
REGIONAL PER CAPITA EXPENDITURES ON SCIENTIFIC ACTIVITIES BY THE FEDERAL GOVERNMENT, 1972-73
(INTRAMURAL AND ADMIN. EXTRAMURAL)
(MARITIMES DISAGGREGATED)

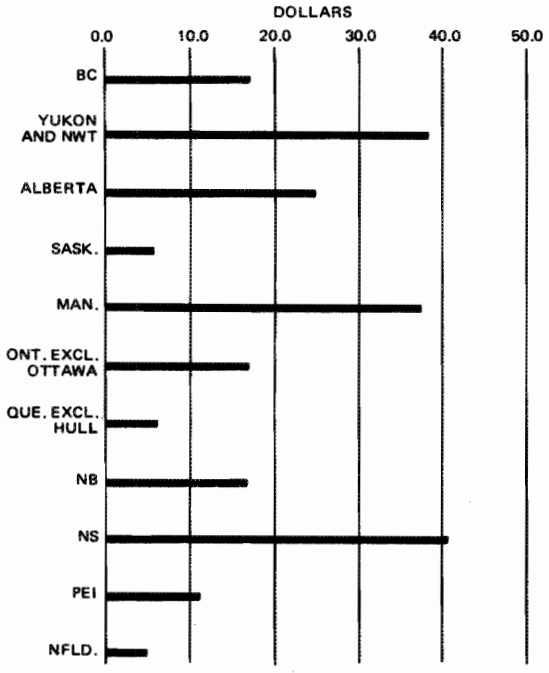


Table A.1 - Federal Intramural Expenditures on Scientific Activities in the Natural Sciences, 1972-73, By Department or Agency ($'000s)

Department or Agency[1]	British Columbia	Yukon & NWT	Alberta	Sask.	Man.	Ont.[2]	National Capital Region	Quebec[3]	NB	NS	PEI	Newfoundland	Unallocated	Total	Percentage of Grand Total
AGR	4 845	-	8 105	5 632	6 201	6 569	20 894	4 211	2,064	2 206	1 260	536	7 511	70 034	(11.4)
AECL	-	-	-	-	15 731	45 192	5 418	-	-	-	-	-	-	66 341	(10.8)
CAL	-	-	-	-	-	-	-	106	-	-	-	-	-	106	(-)
CBC	-	-	-	-	-	-	-	115	-	-	-	-	-	115	(-)
CPDL	-	-	-	-	-	-	612	-	-	-	-	-	-	612	(0.1)
CMHC	-	-	-	-	-	-	6	-	-	-	-	-	-	6	(-)
DOC	-	-	-	-	-	-	23 362	-	-	-	-	-	-	23 362	(3.8)
CCA	-	-	-	-	-	-	8 816	-	-	-	-	-	-	8 816	(1.4)
EMR	1 117	539	5 325	768	32	590	51 009	116	6	2 451	-	20	5 311	67 284	(11.0)
DOE	25 706	928	13 497	1 380	13 248	64 168	38 452	8 847	8,643	19 684	-	4 598	2 600	201 751	(33.0)
EA	-	-	-	-	-	-	225	-	-	-	-	-	-	225	(-)
NHW	34	350	33	33	17	-	11 057	-	-	-	-	-	-	11 524	(1.9)
DINA	-	206	-	-	-	-	432	-	-	-	-	-	-	638	(0.1)
ITC	-	-	-	-	-	-	2 237	-	-	-	-	-	-	2 237	(0.4)
IDRC	-	-	-	-	-	-	1 503	-	-	-	-	-	-	1 503	(0.2)
MRC	-	-	-	-	-	-	735	-	-	-	-	-	-	735	(0.1)
DND	4 100	-	13 435	-	-	9 870	18 040	20 796	-	5 824	-	-	-	72 065	(11.8)
NFB	-	-	-	-	-	-	-	369	-	-	-	-	-	369	(0.1)
NM	-	-	-	-	-	-	3 013	-	-	-	-	-	-	3 013	(0.5)
NRC	1 669	-	-	1 868	1 410	506	64 330	206	-	1 727	-	-	-	71 716	(11.7)
Post Office	-	-	-	-	-	-	767	-	-	-	-	-	-	767	(0.1)
DPW	-	-	-	-	-	25	1 765	536	-	-	-	-	-	2 326	(0.4)
DREE	-	-	-	152	-	-	-	-	-	-	-	-	-	152	(-)
SLSA	-	-	-	-	-	190	-	354	-	-	-	-	-	544	(0.1)
MOT	-	-	-	-	-	-	4 407	1 127	4	-	-	-	-	5 538	(0.9)
VA	59	-	-	-	37	8	-	85	-	23	-	-	19	231	(-)
Total	37 530	2 023	40 395	9 883	36 676	127 118	257 080	36 868	10 717	31 915	1 260	5 154	15 441	612 010	(100.0)

[1] See list of abbreviations.
[2] Excluding Ottawa.
[3] Excluding Hull.

Source: The authors gratefully acknowledge the assistance provided by MOSST in providing data and information related to the scientific activities of the Federal Government.

Table A.2 - Federal Manpower[1] Engaged in Scientific Activities in the Natural Sciences, 1972-73, By Department or Agency

Department or Agency[2]	British Columbia	Yukon & NWT	Alberta	Sask.	Man.	Ont.[3]	National Capital Region	Quebec[4]	NB	NS	PEI	Newfoundland	Unallocated	Total	Percentage of Grand Total
AGR	299.0	-	495.0	393.0	334.0	373.5	1 452.0	300.0	145.5	154.0	94.0	38.8	-	4 078.0	(15.6)
AECL	-	-	-	-	511.0	1 894.0	104.0	-	-	-	-	-	-	2 509.0	(9.6)
CAL	-	-	-	-	-	-	-	5.5	-	-	-	-	-	5.5	(-)
CBC	-	-	-	-	-	-	-	6.0	-	-	-	-	-	6.0	(-)
CPDL	-	-	-	-	-	-	25.0	-	-	-	-	-	-	25.0	(0.1)
CMHC	-	-	-	-	-	-	0.7	-	-	-	-	-	-	0.7	(-)
DOC	-	-	-	-	-	-	531.0	-	-	-	-	-	-	531.0	(2.0)
CCA	-	-	-	-	-	-	449.5	-	-	-	-	-	-	449.5	(1.7)
EMR	45.0	10.0	175.0	-	-	26.0	2 090.0	3.0	-	80.0	-	-	257.0	2 686.0	(10.3)
DOE	1 214.0	26.0	655.0	59.0	514.0	2 083.0	1 394.0	412.0	600.5	868.7	-	184.0	25.0	8 035.2	(30.7)
EA	-	-	-	-	-	-	4.0	-	-	-	-	-	-	4.0	(-)
NHW	-	3.0	-	-	-	-	527.9	-	-	-	-	-	2.0	532.9	(2.0)
DINA	-	11.0	-	-	-	-	7.0	-	-	-	-	-	-	18.0	(0.1)
ITC	-	-	-	-	-	-	131.0	-	-	-	-	-	-	131.0	(0.5)
IDRC	-	-	-	-	-	-	63.0	-	-	-	-	-	-	63.0	(0.2)
MRC	-	-	-	-	-	-	27.0	-	-	-	-	-	-	27.0	(0.1)
DND	142.0	-	626.0	-	-	433.0	773.0	1 278.0	-	248.0	-	-	-	3 500.0	(13.4)
NFB	-	-	-	-	-	-	-	12.0	-	-	-	-	-	12.0	(-)
NM	-	-	-	-	-	-	112.0	-	-	-	-	-	-	112.0	(0.4)
NRC	73.4	-	-	99.9	9.5	29.9	2 682.7	7.6	-	76.8	-	-	-	2 979.8	(11.4)
Post Office	-	-	-	-	-	-	25.3	-	-	-	-	-	-	25.3	(0.1)
DPW	-	-	-	-	-	1.5	96.0	118.0	-	-	-	-	-	215.5	(0.8)
DREE	-	-	-	13.0	-	-	-	-	-	-	-	-	-	13.0	(-)
SLSA	-	-	-	-	-	2.0	10.0	8.5	-	-	-	-	-	20.5	(0.1)
MOT	-	-	-	-	-	-	134.9	43.0	-	-	-	-	-	177.9	(0.7)
VA	9.5	-	-	-	3.3	1.2	-	7.3	-	2.7	-	-	-	24.0	(0.1)
Total	1 782.9	50.0	1 951.0	564.9	1 371.8	4 844.1	10 640.0	2 200.9	746.0	1 430.2	94.0	222.0	284.0	26 181.8	(100.0)

1 Expressed in full-time equivalent. The total includes continuing employees on strength as of September 30, 1972, as well as term, casual and seasonal employees for 1972-73.
2 See list of abbreviations.
3 Excluding Ottawa.
4 Excluding Hull.

Source: See Table A.1.

Table A.3 - Federal Government Expenditures on Intramural Activities in the Natural Sciences, by Province, 1973-74 ($'000s)

Department or Agency[1]	Atlantic Provinces			Quebec (excl. Hull)			National Capital Region			Ontario (excl. Ottawa)			Manitoba		
	Current	Capital	Total	Current	Capital	Total	Current	Capital	Total	Current	Capital	Total	Current	Capital	Total
AGR	5 630	236	5 866	4 228	191	4 419	27 864	2 681	30 545	5 262	257	5 519	5 064	324	5 388
AECL	-	-	-	-	-	-	5 685	-	5 685	45 585	3 237	48 822	17 528	1 086	18 614
CAL	-	-	-	153	4	157	-	-	-	-	-	-	-	-	-
CBC	-	-	-	172	3	175	-	-	-	-	-	-	-	-	-
CPDL	-	-	-	-	-	-	731	-	731	-	-	-	-	-	-
CMHC	-	-	-	-	-	-	7	-	7	-	-	-	-	-	-
DOC	-	-	-	-	-	-	7 303	7 915	15 218	-	-	-	-	-	-
CCA	-	-	-	-	-	-	7 719	126	7 845	-	-	-	-	-	-
EMR	1 735	270	2 005	111	5	116	47 464	4 322	51 786	455	25	480	15	-	15
DOE[2]	27 446	2 379	29 825	8 072	1 012	9 084	30 203	9 060	39 263	53 148	8 247	61 395	9 892	1 386	11 278
EA	-	-	-	-	-	-	209	-	209	-	-	-	-	-	-
INA	-	-	-	-	-	-	256	-	256	-	-	-	-	-	-
ITC	-	-	-	-	-	-	3 089	-	3 089	-	-	-	-	-	-
IDRC	-	-	-	-	-	-	2 633	-	2 633	-	-	-	-	-	-
MRC	-	-	-	-	-	-	769	-	769	-	-	-	-	-	-
DND	5 730	351	6 081	20 722	948	21 670	16 982	770	17 752	12 338	320	12 658	776	-	776
NFB	-	-	-	481	25	506	-	-	-	-	-	-	-	-	-
NHW	-	-	-	-	-	-	9 994	599	10 593	30	55	85	-	-	-
NM[3]	-	-	-	-	-	-	3 203	407	3 610	-	-	-	-	-	-
NRC	1 603	50	1 653	226	-	226	60 190	8 152	68 342	581	-	581	1 398	26	1 424
DPW	-	-	-	-	-	-	1 569	422	2 018	-	-	-	75	-	75
DREE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SLSA	-	-	-	114	-	114	83	-	83	39	-	39	-	-	-
MOT	-	-	-	730	10	740	1 924	2 500	4 424	-	-	-	-	-	-
VA	26	-	26	106	-	106	-	-	-	8	-	8	104	-	104
Total	42 170	3 286	45 456	35 115	2 198	37 313	227 904	36 954	264 858	117 446	12 141	129 587	34 852	2 822	37 674

Table A.3 (cont'd) Federal Government Expenditures on Intramural Activities in the Natural Sciences, by Province, 1973-74 ($000s)

Department or Agency	Saskatchewan			Alberta			British Columbia			NWT and Yukon			Non-program costs	Unallocated			Total
	Current	Capital	Total	Current	Capital	Total	Current	Capital	Total	Current	Capital	Total		Current	Capital	Total	
AGR	5 088	246	5 334	6 528	261	6 789	4 531	154	4 685	-	-	-	9 352	-	-	-	77 897
AECL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	73 121
CAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	157
CBC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	175
CPDL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	731
CMHC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7
DOC	-	-	-	-	-	-	-	-	-	-	-	-	706	-	-	-	15 924
CCA	-	-	-	-	-	-	-	-	-	-	-	-	930	-	-	-	8 775
EMR	-	75	75	3 827	1 240	5 067	919	49	968	240	200	440	9 601	-	-	-	70 553
DOE	729	151	880	11 538	764	12 302	21 969	3 025	24 994	742	98	840	17 296	-	-	-	207 157
EA	-	-	-	-	-	-	-	-	-	-	-	-	22	-	-	-	231
INA	-	-	-	-	-	-	-	-	-	496	576	1 072	203	-	-	-	1 531
ITC	-	-	-	-	-	-	-	-	-	-	-	-	175	-	-	-	3 264
IDRC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2 633
MRC	-	-	-	-	-	-	-	-	-	-	-	-	93	-	-	-	862
DND	-	-	-	12 893	150	13 043	4 807	229	5 036	-	-	-	3 386	-	348	348	80 750
NFB	-	-	-	-	-	-	-	-	-	-	-	-	97	-	-	-	603
NHW	-	-	-	77	-	77	-	-	-	-	-	-	2 367	-	-	-	13 122
NM	-	-	-	-	-	-	28	-	28	-	-	-	1 037	-	-	-	4 675
NRC	1 895	40	1 935	-	-	-	1 345	198	1 543	-	-	-	-	48	-	48	75 752
DPW	-	-	-	2 758	385	3 143	-	-	-	-	-	-	415	-	-	-	5 651
DREE	83	-	83	-	-	-	-	-	-	-	-	-	17	-	-	-	100
SLSA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	236
MOT	-	-	-	-	-	-	-	-	-	-	-	-	225	-	-	-	5 389
VA	-	-	-	-	-	-	56	-	56	-	-	-	14	-	-	-	314
Total	7 795	512	8 307	37 621	2 800	40 421	33 655	3 655	37 310	1 478	874	2 352	45 936	48	348	496	649 610

1. See list of abbreviations.
2. $225 thousand spent abroad.
3. NRC non-program costs included in National Capital Region.

Source: Science Statistics Section; Education, Science and Culture Division; Institutions and Public Finance Branch, Statistics Canada, 1974.

Table A.4 - Regional Intramural Manpower, 1974 Natural Science Survey, Continuing, Term, Casual and Seasonal Employees (continuing as of 30 September 1973) (man-years)

Department or Agency*	Atlantic Provinces				Quebec (excluding Hull)				Ontario (excluding Ottawa)			
	Sc. & Prof.	Tech.	Other	Total	Sc. & Prof.	Tech.	Other	Total	Sc. & Prof.	Tech.	Other	Total
AGR:												
Administration	-	-	-	-	-	-	-	-	-	-	-	-
Cdn. Grain Commission	-	-	-	-	-	-	-	-	-	-	-	-
Health of Animals	3	2	1.5	6.5	1	1	1	3	2	2.5	1	5.5
Research	97	96	249	442	65	53	205	323	93	110	188	391
AECL	-	-	-	-	-	-	-	-	478	634	653	1 765
CAL	-	-	-	-	4.5	2.2	1.2	7.9	-	-	-	-
CBC	-	-	-	-	7	-	2	9	-	-	-	-
CPDL	-	-	-	-	-	-	-	-	-	-	-	-
CMHC	-	-	-	-	-	-	-	-	-	-	-	-
DOC	-	-	-	-	-	-	-	-	-	-	-	-
CCA:												
Consumer Affairs	-	-	-	-	-	-	-	-	-	-	-	-
Intel. Property	-	-	-	-	-	-	-	-	-	-	-	-
EMR:												
Earth Sciences	-	-	-	-	-	1	-	1	3	1	-	4
Min. & Energy Res.	51	27	10	88	2	2	1	5	10	8	3	21
DOE:												
Atmos. Env. Serv.	51	166	65	282	27	136	46	209	454	407	457.1	1 318.1
Env. Mgt. Serv.	92	143	98	333	43	74	46	163	231	320	213	764
Env. Prot. Serv.	-	-	-	-	-	-	-	-	3	4	1	8
Fisheries	151	135	147	433	-	-	-	-	16	7	2	25
Marine Sciences	62	216	275	553	-	-	-	-	7	84	74	165
EA[1]	-	-	-	-	-	-	-	-	-	-	-	-
INA	-	-	-	-	-	-	-	-	-	-	-	-
Industry, Trade & Commerce	-	-	-	-	-	-	-	-	-	-	-	-
IDRC	-	-	-	-	-	-	-	-	-	-	-	-
MRC	-	-	-	-	-	-	-	-	-	-	-	-
DND:												
Defence Research[1,2]	63	101	52	216	121	302	300	723	35	54	63	152
Defence Services[1]	-	8	47	55	6	229	170	405	-	231	207	438
NFB	-	-	-	-	3	6	1	10	-	-	-	-
NHW:												
Health Care	-	-	-	-	-	-	-	-	-	-	-	-
Health Protection	-	-	-	-	-	-	-	-	-	-	-	-
Med. Services	-	-	-	-	-	-	-	-	-	.5	1	1.5
Non-Med. Use of Drugs	-	-	-	-	-	-	-	-	-	-	-	-
NM[1]	-	-	-	-	-	-	-	-	-	-	-	-
NRC[1]	33.5	28.5	17.5	79.5	8	-	2	10	6.5	19	5	30.5
DPW	-	-	-	-	-	-	-	-	-	-	-	-
DREE	-	-	-	-	-	-	-	-	-	-	-	-
SLSA	-	-	-	-	10.3	-	1.2	11.5	1	-	-	1
MOT:												
Air Transport	-	-	-	-	-	-	-	-	-	-	-	-
Marine	-	-	-	-	.5	9.5	.8	10.8	-	-	-	-
Surface Transport	-	-	-	-	-	-	-	-	-	-	-	-
TDA	-	-	-	-	13	-	3	16	-	-	-	-
VA[1]	.2	4	.5	4.7	1.5	2	.7	4.2	-	-	-	-
Total	603.7	926.5	962.5	2 492.7	312.8	817.7	780.9	1 911.4	1 339.5	1 882	1 868.1	5 089.6

Table A.4 (cont'd)

Department or Agency	National Capital Region				Manitoba				Saskatchewan			
	Sc. & Prof.	Tech.	Other	Total	Sc. & Prof.	Tech.	Other	Total	Sc. & Prof.	Tech.	Other	Total
AGR:												
Administration	34	10	60	104	-	-	-	-	-	-	-	-
Cdn. Grain Commission	-	-	-	-	13.8	50.4	12.3	76.5	-	-	-	-
Health of Animals	30.5	53.5	19.5	103.5	.5	1	.5	2	1	1	.5	2.5
Research	316	295	695	1 306	77	76	143	296	103	108	208	419
AECL	45	57	11	113	157	221	215	593	-	-	-	-
CAL	-	-	-	-	-	-	-	-	-	-	-	-
CBC	-	-	-	-	-	-	-	-	-	-	-	-
CPDL	11	-	12	23	-	-	-	-	-	-	-	-
CMHC	.2	-	.5	.7	-	-	-	-	-	-	-	-
DOC	149	159	213.5	521.5	-	-	-	-	-	-	-	-
CCA:												
Consumer Affairs	20	50	14	84	-	-	-	-	-	-	-	-
Intel. Property	199	-	206	405	-	-	-	-	-	-	-	-
EMR:												
Earth Sciences	270	582	491	1 343	-	1	-	1	-	1	1	2
Min. & Energy Res	445	322	333	1 100	-	-	-	-	-	-	-	-
DOE:												
Atmos. Env. Serv	-	-	-	-	44	204	62	310	-	-	-	-
Env. Mgt. Serv	325	259	261.1	845.1	13	31	10	54	15	22	21	58
Env. Prot. Serv	25.5	8	4	37.5	-	-	-	-	-	-	-	-
Fisheries	10	-	4	14	78	48	46	172	-	-	-	-
Marine Sciences	28	139	126	293	-	-	-	-	-	-	-	-
EA[1]	-	-	14	14	-	-	-	-	-	-	-	-
INA	6	-	5.2	11.2	-	-	-	-	-	-	-	-
ITC	32	5.3	92	129.3	-	-	-	-	-	-	-	-
IDRC	17.5	-	61.4	78.9	-	-	-	-	-	-	-	-
MRC	5	-	24	29	-	-	-	-	-	-	-	-
DND:												
Defence Research[1,2]	125.9	92	241.9	459.8	-	-	-	-	-	-	-	-
Defence Services[2]	39	154	253	446	-	13	24	37	-	-	-	-
NFB	-	-	-	-	-	-	-	-	-	-	-	-
NHW:												
Health Care	6.9	4.1	12.3	23.3	-	-	-	-	-	-	-	-
Health Protection	199	219	171.1	589.1	-	-	-	-	-	-	-	-
Med. Services	-	-	-	-	-	-	-	-	-	-	-	-
Non-Med. Use of Drugs	-	1	4.5	5.5	-	-	-	-	-	-	-	-
NM[1]	50.7	30	80.1	160.8	-	-	-	-	-	-	-	-
NRC	794	921	971	2 686	5.5	1	3	9.5	38.5	49.5	14.5	102.5
DPW	23.5	58	16	97.5	-	2	-	2	-	-	-	-
DREE	-	-	-	-	-	-	-	-	1	7	-	8
SLSA	2	-	2.1	4.1	-	-	-	-	-	-	-	-
MOT:												
Air Transport	25.7	37.1	9	71.8	-	-	-	-	-	-	-	-
Marine	7.3	3.2	5	15.5	-	-	-	-	-	-	-	-
Surface Transport	2.5	.6	1.2	4.3	-	-	-	-	-	-	-	-
TDA	-	-	-	-	-	-	-	-	-	-	-	-
VA[1]	-	-	-	-	2.5	4	1.3	7.8	-	-	-	-
Total [3]	245.2	3 459.8	4 414.4	11 119.4	391.3	652.4	517.1	1 560.8	158.5	188.5	245	592

Table A.4 (cont'd)

Department or Agency	Alberta				British Columbia				Yukon and NWT			
	Sc. & Prof.	Tech.	Other	Total	Sc. & Prof.	Tech.	Other	Total	Sc. & Prof.	Tech.	Other	Total
AGR:												
Administration	-	-	-	-	-	-	-	-	-	-	-	-
Cdn. Grain Commission	-	-	-	-	-	-	-	-	-	-	-	-
Health of Animals	3	12	7.5	22.5	2	2	1	5	-	-	-	-
Research	94	126	259	479	72	86	166	324	-	-	-	-
AECL	-	-	-	-	-	-	-	-	-	-	-	-
CAL	-	-	-	-	-	-	-	-	-	-	-	-
CBC	-	-	-	-	-	-	-	-	-	-	-	-
CPDL	-	-	-	-	-	-	-	-	-	-	-	-
CMHC	-	-	-	-	-	-	-	-	-	-	-	-
DOC	-	-	-	-	-	-	-	-	-	-	-	-
CCA:												
Consumer Affairs	-	-	-	-	-	-	-	-	-	-	-	-
Intel. Property	-	-	-	-	-	-	-	-	-	-	-	-
EMR:												
Earth Sciences	8	4	3	15	7	6	2	15	1	8	13	22
Min. & Energy Res	74	43	39	156	25	4	6	35	-	-	-	-
DOE:												
Atmos. Env. Serv	42	199	45	286	30	130	32	192	-	-	-	-
Env. Mgt. Serv	103	160	86	349	137	189	98	424	4	18	2	24
Env. Prot. Serv	-	-	-	-	-	-	-	-	-	-	-	-
Fisheries	-	-	-	-	91	94	101	286	13	20	8	41
Marine Sciences	-	-	-	-	27	111	134	272	-	-	-	-
EA[1]	-	-	-	-	-	-	-	-	-	-	-	-
INA	-	-	-	-	-	-	-	-	12	4	7	23
ITC	-	-	-	-	-	-	-	-	-	-	-	-
IDRC	-	-	-	-	-	-	-	-	-	-	-	-
MRC	-	-	-	-	-	-	-	-	-	-	-	-
DND:												
Defence Research[1]	33	91	74	198	41	51	37	129	-	-	-	-
Defence Services[2]	4	21	358	383	7	6	90	103	-	-	-	-
NFB	-	-	-	-	-	-	-	-	-	-	-	-
NHW:												
Health Care	-	-	-	-	-	-	-	-	-	-	-	-
Health Protection	-	-	-	-	-	-	-	-	-	-	-	-
Med. Services	2	-	2	4	-	-	-	-	-	-	-	-
Non-Med. Use of Drugs	-	-	-	-	-	-	-	-	-	-	-	-
NM	-	-	-	-	-	2	-	2	-	-	-	-
NRC[1]	-	-	-	-	35	27	12	74	-	-	-	-
DPW	14	45	57.1	116.1	-	-	-	-	-	-	-	-
DREE	-	-	-	-	-	-	-	-	-	-	-	-
SLSA	-	-	-	-	-	-	-	-	-	-	-	-
MOT:												
Air Transport	-	-	-	-	-	-	-	-	-	-	-	-
Marine	-	-	-	-	-	-	-	-	-	-	-	-
Surface Transport	-	-	-	-	-	-	-	-	-	-	-	-
TDA	-	-	-	-	-	-	-	-	-	-	-	-
VA[1]	-	-	-	-	.5	1	3	4.5	-	-	-	-
Total	377	701	930.6	2 008.6	474.5	709.0	682.0	1 865.5	30	50	30	110

Table A.4 (cont'd)

Department or Agency*	Sc. & Prof.	Tech.	Other	Total
AGR:				
Administration	34	10	60	104
Cdn. Grain Commission	13.8	50.4	12.3	76.5
Health of Animals	43	75	32.5	150.5
Research	917	950	2 113	3 980
AECL	680	912	879	2 471
CAL	4.5	2.2	1.2	7.9
CBC	7	-	2	9
CPDL	11	-	12	23
CMHC	.2	-	.5	.7
DOC	149	159	213.5	521.5
CCA:				
Consumer Affairs	20	50	14	84
Intel. Property	199	-	206	405
EMR:				
Earth Sciences	289	604	510	1,403
Min. & Energy Res	607	406	392	1,405
DOE:				
Atmos. Env. Serv	648	1 242	707.1	2 597.1
Env. Mgt. Serv	963	1 216	835.1	3 014.1
Env. Prot. Serv	28.5	12	5	45.5
Fisheries	359	304	308	971
Marine Sciences	124	550	609	1 283
EA[1]	-	-	14	14
IBA	18	4	12.2	34.2
ITC	32	5.3	92	129.3
IDRC	17.5	-	61.4	78.9
MRC	5	-	24	29
DND:				
Defence Research[1,2]	418.9	691	767.9	1 877.8
Defence Services[2]	56	662	1 149	1 867
NFB	3	6	1	10
NHW:				
Health Care	6.9	4.1	12.3	23.3
Health Protection	199	219	171.1	589.1
Med. Services	2	-	2	4
Non-Med. Use of Drugs	-	1.5	5.5	7
NM[1]	50.7	32	80.1	162.8
NRC	921	1 046	1 025	2 992
DPW	37.5	105	73.1	215.6
DREE	1	7	-	8
SLSA	13.3	-	3.3	16.6
MOT:				
Air Transport	25.7	37.1	9	71.8
Marine	7.8	12.7	5.8	26.3
Surface Transport	2.5	.6	1.2	4.3
TDA	13	-	3	16
VA[1]	4.7	11.0	5.5	21.2
Total	6 932.5	9 386.9	10 430.6	26 750.0

[1] Excludes manpower outside Canada.

[2] Includes military personnel.

* See list of abbreviations.

Table A.5 - Total Expenditures on Activities in the Natural Sciences, 1972-73, Includes Non-Program Costs

DEPT OR AGENCY	CURRENT R & D	CAPITAL R & D	DATA COLL	SCI INFO	TEST & STAND	FEASI STUDIES	SCHLRSHP PROGS	TOTAL CURR RSA	CAPITAL RSA	TOTAL EXPEND
					($'000)					
AGRICULTURE:	66,336	3,329	393	2,297	38	0	0	2,728	184	72,577
ADMINISTRATION	0	0	0	1,336	0	0	0	1,336	5	1,341
CDN GRAIN COMM	514	180	393	119	38	0	0	550	179	1,423
HLTH OF ANIMALS	2,067	85	0	12	0	0	0	12	0	2,164
RESEARCH	63,755	3,064	0	830	0	0	0	830	0	67,649
A.E.C.B.	7,928	0	0	0	0	0	0	0	0	7,928
A.E.C.L.	76,962	4,704	1,126	2,193	773	92	0	4,184	0	85,850
CDN ARSENALS LTD	119	1	0	0	0	0	0	0	0	120
C.B.C.	49	6	0	0	0	0	0	0	0	55
C.I.D.A.	1,450	0	3,700	0	0	10,400	2,650	16,750	0	18,200
CDN PAT & DEV LTD	30	0	0	823	0	0	0	823	0	853
C.M.H.C.	650	0	0	0	0	0	0	0	0	650
COMMUNICATIONS	21,466	3,927	0	341	0	216	0	557	0	25,950
CONS & CORP AFFAIRS:	0	0	0	6,833	770	0	0	7,603	39	7,642
CONSUMER AFFAIRS	0	0	0	0	770	0	0	770	39	809
INTEL PROPERTY	0	0	0	6,833	0	0	0	6,833	0	6,833
E.M.R.:	33,794	4,470	22,214	9,379	870	592	0	33,055	1,615	72,934
EARTH SCIENCES	8,186	2,534	15,509	7,061	33	0	0	22,603	834	34,157
MIN & ENERGY RES	25,608	1,936	6,705	2,318	837	592	0	10,452	781	38,777
ENVIRONMENT:	68,794	19,517	61,573	31,924	1,453	4,378	46	99,374	10,700	198,385
ATMOS ENV SERV	4,766	1,337	31,428	23,161	252	0	36	54,877	3,873	64,853
ENV MGT SERVICE	38,752	9,793	13,679	3,959	1,089	4,286	10	23,023	3,315	74,883
ENV PROT SERV	202	54	462	196	112	92	0	862	392	1,510
FISHERIES	15,262	5,780	3,916	783	0	0	0	4,699	0	25,741
MARINE SCIENCES	9,812	2,553	12,088	3,825	0	0	0	15,913	3,120	31,398
EXTERNAL AFFAIRS	1,835	0	0	453	0	0	55	508	0	2,343
I.A.N.D.	1,506	15	224	119	0	64	0	407	82	2,010
IND TRADE & COMMERCE	91,280	0	0	0	0	0	486	486	0	91,766
I.D.R.C.	2,881	0	0	1,257	38	0	0	1,295	0	4,176
M.R.C.	36,471	0	174	169	0	0	1,354	1,697	0	38,168
NATIONAL DEFENCE:	49,572	3,258	0	1,494	38,295	0	8	39,797	159	92,786
DEFENCE RESEARCH	40,485	3,258	0	1,494	0	0	8	1,502	39	45,284
DEFENCE SERVICES	9,087	0	0	0	38,295	0	0	38,295	120	47,502
NATL FILM BOARD	329	25	0	32	0	70	0	102	0	456
NATL HLTH & WELFARE:	22,514	837	1,254	219	2,025	8	575	4,081	44	27,476
HEALTH CARE	13,652	0	42	16	7	8	393	466	0	14,118
HEALTH PROTECTION	8,234	611	1,212	203	2,018	0	0	3,433	44	12,322
MED SERVICES	81	0	0	0	0	0	0	0	0	81
NMED USE DRUGS	547	226	0	0	0	0	182	182	0	955
NATL MUSEUMS	1,881	38	816	486	0	0	0	1,302	26	3,247
N.R.C.	118,527	2,389	486	9,096	5,267	830	7,293	22,972	6,763	150,651
PUBLIC WORKS	1,020	30	1,329	11	446	4,435	0	6,221	713	7,984
REG ECON EXPANSION	2,041	0	0	0	0	0	0	0	0	2,041
S.L.S.A.	233	0	0	0	0	0	0	0	0	233
TRANSPORT:	3,886	873	363	13	80	28	0	484	0	5,243
AIR TRANSPORT	1,308	868	9	13	74	28	0	124	0	2,300
MARINE	479	5	354	0	6	0	0	360	0	844
SURFACE TRANSPORT	119	0	0	0	0	0	0	0	0	119
T.D.A.	1,980	0	0	0	0	0	0	0	0	1,980
VETERANS AFFAIRS	259	0	0	0	0	0	0	0	0	259
TOTAL	611,813	43,419	93,652	67,139	50,055	21,113	12,467	244,426	20,325	919,983

Source: Statistics Canada, Science Statistics Section, Federal Government Activities in the Natural Sciences, Fiscal Years 1972-73, 1973-74, 1974-75, (1974 Survey Results), 15 May 1974, p. 61.

Table A.6 - Total Expenditures on Activities in the Natural Sciences, 1973-74, Includes Non-program Costs

DEPT OR AGENCY	CURRENT R & D	CAPITAL R & D	DATA COLL	SCI INFO	TEST & STAND	FEASI STUDIES	SCHLRSHP PROGS	TOTAL CURR RSA	CAPITAL RSA	TOTAL EXPEND
					($'000)					
AGRICULTURE:	71,047	4,202	608	2,620	72	0	0	3,300	148	78,697
ADMINISTRATION	0	0	0	1,507	0	0	0	1,507	48	1,555
CDN GRAIN COMM	661	90	608	216	72	0	0	896	100	1,747
HLTH OF ANIMALS	2,316	189	0	11	0	0	0	11	0	2,516
RESEARCH	68,070	3,923	0	886	0	0	0	886	0	72,879
A.E.C.B.	7,287	0	0	0	0	0	0	0	0	7,287
A.E.C.L.	89,243	4,323	1,123	2,338	783	55	0	4,299	0	97,865
CDN ARSENALS LTD	153	4	0	0	0	0	0	0	0	157
C.B.C.	172	3	0	0	0	0	0	0	0	175
C.I.D.A.	3,400	0	3,600	0	0	8,900	5,000	17,500	0	20,900
CDN PAT & DEV LTD	58	0	0	831	0	0	0	831	0	889
C.M.H.C.	297	0	0	0	0	0	0	0	0	297
COMMUNICATIONS	24,581	6,010	0	327	0	344	0	671	0	31,262
CONS & CORP AFFAIRS:	0	0	0	7,434	1,215	0	0	8,649	126	8,775
CONSUMER AFFAIRS	0	0	0	0	1,215	0	0	1,215	126	1,341
INTEL PROPERTY	0	0	0	7,434	0	0	0	7,434	0	7,434
E.M.R.:	37,405	4,302	22,940	10,566	947	686	0	35,139	1,884	78,730
EARTH SCIENCES	9,779	2,367	15,699	7,912	55	0	0	23,666	1,255	37,067
MIN & ENERGY RES	27,626	1,935	7,241	2,654	892	686	0	11,473	629	41,663
ENVIRONMENT:	81,078	14,560	69,337	34,763	3,334	4,664	49	112,147	11,562	219,347
ATMOS ENV SERV	6,303	1,780	36,119	25,619	206	0	39	61,983	3,616	73,682
ENV MGT SERVICE	46,053	7,229	15,424	3,532	3,002	4,559	10	26,527	2,703	82,512
ENV PROT SERV	226	60	520	221	125	103	0	969	435	1,690
FISHERIES	17,384	1,683	4,310	862	0	0	0	5,172	0	24,239
MARINE SCIENCES	11,112	3,808	12,964	4,529	1	2	0	17,496	4,808	37,224
EXTERNAL AFFAIRS	1,990	0	0	480	0	0	61	541	0	2,531
I.A.N.D.	1,624	451	354	228	0	31	0	613	125	2,813
IND TRADE & COMMERCE	102,730	0	0	0	0	0	539	539	0	103,269
I.D.R.C.	4,403	0	0	2,211	56	0	0	2,267	0	6,670
M.R.C.	39,571	0	177	171	0	0	1,303	1,651	0	41,222
NATIONAL DEFENCE:	50,479	2,708	0	1,852	38,322	0	12	40,186	408	93,781
DEFENCE RESEARCH	42,915	2,708	0	1,852	0	0	12	1,864	60	47,547
DEFENCE SERVICES	7,564	0	0	0	38,322	0	0	38,322	348	46,234
NATL FILM BOARD	290	25	0	30	30	228	0	288	0	603
NATL HLTH & WELFARE:	27,241	560	1,049	279	3,068	7	568	4,971	94	32,866
HEALTH CARE	18,496	0	20	15	10	7	397	449	0	18,945
HEALTH PROTECTION	7,691	505	1,029	218	3,058	0	0	4,305	94	12,595
MED SERVICES	87	0	0	0	0	0	0	0	0	87
NMED USE DRUGS	967	55	0	46	0	0	171	217	0	1,239
NATL MUSEUMS	2,346	244	1,202	720	0	0	0	1,922	163	4,675
N.R.C.	124,938	3,190	506	10,399	5,490	932	7,251	24,578	5,276	157,982
PUBLIC WORKS	1,257	98	302	27	450	5,271	0	6,050	709	8,114
REG ECON EXPANSION	2,049	0	0	0	0	0	0	0	0	2,049
S.L.S.A.	287	0	0	0	0	0	0	0	0	287
TRANSPORT:	4,665	2,510	1,049	60	301	73	0	1,483	0	8,658
AIR TRANSPORT	1,572	2,500	29	26	46	63	0	164	0	4,236
MARINE	569	10	384	34	0	10	0	428	0	1,007
SURFACE TRANSPORT	197	0	52	0	5	0	0	57	0	254
T.D.A.	2,327	0	584	0	250	0	0	834	0	3,161
VETERANS AFFAIRS	314	0	0	0	0	0	0	0	0	314
TOTAL	678,905	43,190	102,247	75,336	54,068	21,191	14,783	267,625	20,495	1,010,215

Source: Statistics Canada, Science Statistics Section, Federal Government Activities in the Natural Sciences, Fiscal Years 1972-73, 1973-74, 1974-75, (1974 Survey Results), 15 May 1974, p. 62.

Table A.7 - Total Expenditures on Activities in the Natural Sciences, by Performer, 1972-73, Includes Non-Program Costs

DEPT OR AGENCY	IN-HOUSE	ADMIN EXTRAMURAL PROGRAMS	CANADIAN INDUSTRY	CDN UNIV & NON-PROFIT INST	OTHER CANADIAN	FOREIGN	TOTAL
			($ '000)				
AGRICULTURE:	71,766	0	0	799	12	0	72,577
ADMINISTRATION	1,341	0	0	0	0	0	1,341
CDN GRAIN COMM	1,423	0	0	0	0	0	1,423
HLTH OF ANIMALS	2,152	0	0	12	0	0	2,164
RESEARCH	66,850	0	0	787	12	0	67,649
A.E.C.B.	0	0	33	7,895	0	0	7,928
A.E.C.L.	64,438	0	20,326	830	89	167	85,850
CDN ARSENALS LTD	120	0	0	0	0	0	120
C.B.C.	55	0	0	0	0	0	55
C.I.D.A.	0	0	14,100	2,650	0	1,450	18,200
CDN PAT & DEV LTD	716	0	107	0	30	0	853
C.M.H.C.	0	6	152	0	492	0	650
COMMUNICATIONS	13,496	0	10,738	573	21	1,122	25,950
CONS & CORP AFFAIRS:	7,642	0	0	0	0	0	7,642
CONSUMER AFFAIRS	809	0	0	0	0	0	809
INTEL PROPERTY	6,833	0	0	0	0	0	6,833
E.M.R.:	65,465	52	5,571	1,353	373	120	72,934
EARTH SCIENCES	32,696	0	869	416	164	12	34,157
MIN & ENERGY RES	32,769	52	4,702	937	209	108	38,777
ENVIRONMENT:	191,531	142	1,096	2,959	2,637	20	198,385
ATMOS ENV SERV	64,197	56	111	489	0	0	64,853
ENV MGT SERVICE	69,261	80	871	2,082	2,582	7	74,883
ENV PROT SERV	1,468	6	29	7	0	0	1,510
FISHERIES	25,395	0	0	346	0	0	25,741
MARINE SCIENCES	31,210	0	85	35	55	13	31,398
EXTERNAL AFFAIRS	230	213	0	0	0	1,900	2,343
I.A.N.D.	646	128	231	1,005	0	0	2,010
IND TRADE & COMMERCE	0	2,360	88,484	809	113	0	91,766
I.D.R.C.	693	810	0	120	0	2,553	4,176
M.R.C.	14	694	0	35,378	32	2,050	38,168
NATIONAL DEFENCE:	76,181	1,849	10,779	3,146	0	831	92,786
DEFENCE RESEARCH	37,056	245	4,837	3,146	0	0	45,284
DEFENCE SERVICES	39,125	1,604	5,942	0	0	831	47,502
NATL FILM BOARD	456	0	0	0	0	0	456
NATL HLTH & WELFARE:	12,781	194	72	14,350	71	8	27,476
HEALTH CARE	111	170	10	13,802	25	0	14,118
HEALTH PROTECTION	12,217	0	45	6	46	8	12,322
MED SERVICES	81	0	0	0	0	0	81
NMED USE DRUGS	372	24	17	542	0	0	955
NATL MUSEUMS	3,247	0	0	0	0	0	3,247
N.R.C.	71,431	1,124	11,014	65,369	529	1,184	150,651
PUBLIC WORKS	4,589	157	1,241	17	1,980	0	7,984
REG ECON EXPANSION	146	0	0	709	1,186	0	2,041
S.L.S.A.	217	1	5	10	0	0	233
TRANSPORT:	3,235	430	777	781	20	0	5,243
AIR TRANSPORT	2,244	0	40	16	0	0	2,300
MARINE	537	13	294	0	0	0	844
SURFACE TRANSPORT	26	22	68	3	0	0	119
T.D.A.	428	395	375	762	20	0	1,980
VETERANS AFFAIRS	259	0	0	0	0	0	259
TOTAL	589,354	8,160	164,726	138,753	7,585	11,405	919,983

Source: Statistics Canada, Science Statistics Section, Federal Government Activities in the Natural Sciences, Fiscal Years 1972-73, 1973-74, 1974-75, (1974 Survey Results), 15 May 1974, p. 4.

Table A.8 - Total Expenditures on Activities in the Natural Sciences, by Performer, 1973-74, Includes Non-Program Costs

DEPT OR AGENCY	IN-HOUSE	ADMIN EXTRAMURAL PROGRAMS	CANADIAN INDUSTRY	CDN UNIV & NON-PROFIT INST	OTHER CANADIAN	FOREIGN	TOTAL
				($ '000)			
AGRICULTURE:	77,897	0	0	788	12	0	78,697
ADMINISTRATION	1,555	0	0	0	0	0	1,555
CDN GRAIN COMM	1,747	0	0	0	0	0	1,747
HLTH OF ANIMALS	2,516	0	0	0	0	0	2,516
RESEARCH	72,079	0	0	788	12	0	72,879
A.E.C.B.	0	0	42	7,245	0	0	7,287
A.E.C.L.	73,121	0	23,541	756	320	127	97,865
CDN ARSENALS LTD	157	0	0	0	0	0	157
C.B.C.	175	0	0	0	0	0	175
C.I.D.A.	0	0	12,500	5,000	0	3,400	20,900
CDN PAT & DEV LTD	731	0	118	0	40	0	889
C.M.H.C.	0	7	170	0	120	0	297
COMMUNICATIONS	15,924	0	13,902	557	0	879	31,262
CONS & CORP AFFAIRS:	8,775	0	0	0	0	0	8,775
CONSUMER AFFAIRS	1,341	0	0	0	0	0	1,341
INTEL PROPERTY	7,434	0	0	0	0	0	7,434
E.M.R.:	70,479	74	5,915	1,546	529	187	78,730
EARTH SCIENCES	35,662	0	766	383	239	17	37,067
MIN & ENERGY RES	34,817	74	5,149	1,163	290	170	41,663
ENVIRONMENT:	206,973	184	4,777	3,670	3,668	75	219,347
ATMOS ENV SERV	72,875	96	118	585	8	0	73,682
ENV MGT SERVICE	72,731	82	3,627	2,460	3,537	75	82,512
ENV PROT SERV	1,643	6	33	8	0	0	1,690
FISHERIES	23,269	0	550	420	0	0	24,239
MARINE SCIENCES	36,455	0	449	197	123	0	37,224
EXTERNAL AFFAIRS	237	219	0	0	0	2,075	2,531
I.A.N.D.	1,412	119	195	1,021	66	0	2,813
IND TRADE & COMMERCE	0	3,264	97,702	1,256	1,047	0	103,269
I.D.R.C.	1,348	1,285	0	180	0	3,857	6,670
M.R.C.	17	845	0	38,329	17	2,014	41,222
NATIONAL DEFENCE:	78,911	1,839	9,250	3,237	10	534	93,781
DEFENCE RESEARCH	39,169	257	4,818	3,237	10	56	47,547
DEFENCE SERVICES	39,742	1,582	4,432	0	0	478	46,234
NATL FILM BOARD	603	0	0	0	0	0	603
NATL HLTH & WELFARE:	12,807	315	181	19,550	9	4	32,866
HEALTH CARE	217	257	3	18,464	4	0	18,945
HEALTH PROTECTION	12,377	0	178	31	5	4	12,595
MED SERVICES	87	0	0	0	0	0	87
NMED USE DRUGS	126	58	0	1,055	0	0	1,239
NATL MUSEUMS	4,675	0	0	0	0	0	4,675
N.R.C.	74,375	1,377	12,868	66,836	481	2,045	157,982
PUBLIC WORKS	5,506	145	699	5	1,759	0	8,114
REG ECON EXPANSION	100	0	0	0	1,949	0	2,049
S.L.S.A.	235	1	45	0	6	0	287
TRANSPORT:	5,167	222	2,609	660	0	0	8,658
AIR TRANSPORT	4,195	0	36	5	0	0	4,236
MARINE	707	29	271	0	0	0	1,007
SURFACE TRANSPORT	24	26	155	49	0	0	254
T.D.A.	241	167	2,147	606	0	0	3,161
VETERANS AFFAIRS	314	0	0	0	0	0	314
TOTAL	639,939	9,896	184,514	150,636	10,033	15,197	1,010,215

Source: Statistics Canada, Science Statistics Section, Federal Government Activities in the Natural Sciences, Fiscal Years 1972-73, 1973-74, 1974-75, (1974 Survey Results), 15 May 1974, p. 5.

Table A.9 - Total Expenditures on R & D in the Natural Sciences, by Performer, 1972-73, Includes Non-Program Costs

DEPT OR AGENCY	IN-HOUSE	ADMIN EXTRAMURAL PROGRAMS	CANADIAN INDUSTRY	CDN UNIV & NON-PROFIT INST	OTHER CANADIAN	FOREIGN	TOTAL
			($ '000)				
AGRICULTURE:	68,854	0	0	799	12	0	69,665
CDN GRAIN COMM	694	0	0	0	0	0	694
HLTH OF ANIMALS	2,140	0	0	12	0	0	2,152
RESEARCH	66,020	0	0	787	12	0	66,819
A.E.C.B.	0	0	33	7,895	0	0	7,928
A.E.C.L.	60,580	0	20,004	826	89	167	81,666
CDN ARSENALS LTD	120	0	0	0	0	0	120
C.B.C.	55	0	0	0	0	0	55
C.I.D.A.	0	0	0	0	0	1,450	1,450
CDN PAT & DEV LTD	0	0	0	0	30	0	30
C.M.H.C.	0	6	152	0	492	0	650
COMMUNICATIONS	13,052	0	10,625	573	21	1,122	25,393
E.M.R.:	33,578	52	3,274	986	270	104	38,264
EARTH SCIENCES	10,184	0	54	362	119	1	10,720
MIN & ENERGY RES	23,394	52	3,220	624	151	103	27,544
ENVIRONMENT:	83,767	142	934	2,841	607	20	88,311
ATMOS ENV SERV	5,447	56	111	489	0	0	6,103
ENV MGT SERVICE	45,112	80	803	1,971	572	7	48,545
ENV PROT SERV	223	6	20	7	0	0	256
FISHERIES	20,696	0	0	346	0	0	21,042
MARINE SCIENCES	12,289	0	0	28	35	13	12,365
EXTERNAL AFFAIRS	0	185	0	0	0	1,650	1,835
I.A.N.D.	221	128	193	979	0	0	1,521
IND TRADE & COMMERCE	0	2,360	88,484	323	113	0	91,280
I.D.R.C.	0	502	0	100	0	2,279	2,881
M.R.C.	0	665	0	33,811	25	1,970	36,471
NATIONAL DEFENCE:	36,225	1,849	10,779	3,146	0	831	52,830
DEFENCE RESEARCH	35,515	245	4,837	3,146	0	0	43,743
DEFENCE SERVICES	710	1,604	5,942	0	0	831	9,087
NATL FILM BOARD	354	0	0	0	0	0	354
NATL HLTH & WELFARE:	9,267	173	62	13,795	46	8	23,351
HEALTH CARE	74	151	0	13,427	0	0	13,652
HEALTH PROTECTION	8,740	0	45	6	46	8	8,845
MED SERVICES	81	0	0	0	0	0	81
NMED USE DRUGS	372	22	17	362	0	0	773
NATL MUSEUMS	1,919	0	0	0	0	0	1,919
N.R.C.	49,867	831	11,014	58,199	29	976	120,916
PUBLIC WORKS	1,035	0	15	0	0	0	1,050
REG ECON EXPANSION	146	0	0	709	1,186	0	2,041
S.L.S.A.	217	1	5	10	0	0	233
TRANSPORT:	2,775	430	753	781	20	0	4,759
AIR TRANSPORT	2,144	0	16	16	0	0	2,176
MARINE	177	13	294	0	0	0	484
SURFACE TRANSPORT	26	22	68	3	0	0	119
T.D.A.	428	395	375	762	20	0	1,980
VETERANS AFFAIRS	259	0	0	0	0	0	259
TOTAL	362,291	7,324	146,327	125,773	2,940	10,577	655,232

Source: Statistics Canada, Science Statistics Section, Federal Government Activities in the Natural Sciences, Fiscal Years 1972-73, 1973-74, 1974-75, (1974 Survey Results), 15 May 1974, p. 37.

Table A.10 - Total Expenditures on R & D in the Natural Sciences, by Performer, 1973-74, Includes Non-Program Costs

DEPT OR AGENCY	IN-HOUSE	ADMIN EXTRAMURAL PROGRAMS	CANADIAN INDUSTRY	CDN UNIV & NON-PROFIT INST	OTHER CANADIAN	FOREIGN	TOTAL
				($ '000)			
AGRICULTURE:	74,449	0	0	788	12	0	75,249
CDN GRAIN COMM	751	0	0	0	0	0	751
HLTH OF ANIMALS	2,505	0	0	0	0	0	2,505
RESEARCH	71,193	0	0	788	12	0	71,993
A.E.C.B.	0	0	42	7,245	0	0	7,287
A.E.C.L.	69,301	0	23,072	746	320	127	93,566
CDN ARSENALS LTD	157	0	0	0	0	0	157
C.B.C.	175	0	0	0	0	0	175
C.I.D.A.	0	0	0	0	0	3,400	3,400
CDN PAT & DEV LTD	0	0	18	0	40	0	58
C.M.H.C.	0	7	170	0	120	0	297
COMMUNICATIONS	15,478	0	13,677	557	0	879	30,591
E.M.R.:	36,160	74	3,873	1,135	315	150	41,707
EARTH SCIENCES	11,540	0	108	327	165	6	12,146
MIN & ENERGY RES	24,620	74	3,765	808	150	144	29,561
ENVIRONMENT:	86,032	184	4,416	3,417	1,514	75	95,638
ATMOS ENV SERV	7,321	96	118	540	8	0	8,083
ENV MGT SERVICE	45,894	82	3,540	2,264	1,427	75	53,282
ENV PROT SERV	249	6	23	8	0	0	286
FISHERIES	18,097	0	550	420	0	0	19,067
MARINE SCIENCES	14,471	0	185	185	79	0	14,920
EXTERNAL AFFAIRS	0	190	0	0	0	1,800	1,990
I.A.N.D.	727	113	195	974	66	0	2,075
IND TRADE & COMMERCE	0	3,264	97,702	717	1,047	0	102,730
I.D.R.C.	0	814	0	150	0	3,439	4,403
M.R.C.	0	811	0	36,801	15	1,944	39,571
NATIONAL DEFENCE:	38,317	1,839	9,250	3,237	10	534	53,187
DEFENCE RESEARCH	37,245	257	4,818	3,237	10	56	45,623
DEFENCE SERVICES	1,072	1,582	4,432	0	0	478	7,564
NATL FILM BOARD	315	0	0	0	0	0	315
NATL HLTH & WELFARE:	8,361	274	178	18,979	5	4	27,801
HEALTH CARE	175	238	0	18,083	0	0	18,496
HEALTH PROTECTION	7,978	0	178	31	5	4	8,196
MED SERVICES	87	0	0	0	0	0	87
NMED USE DRUGS	121	36	0	865	0	0	1,022
NATL MUSEUMS	2,590	0	0	0	0	0	2,590
N.R.C.	52,769	1,104	12,797	59,621	2	1,835	128,128
PUBLIC WORKS	1,275	22	53	5	0	0	1,355
REG ECON EXPANSION	100	0	0	0	1,949	0	2,049
S.L.S.A.	235	1	45	0	6	0	287
TRANSPORT:	4,598	222	1,695	660	0	0	7,175
AIR TRANSPORT	4,051	0	16	5	0	0	4,072
MARINE	282	29	268	0	0	0	579
SURFACE TRANSPORT	24	26	98	49	0	0	197
T.D.A.	241	167	1,313	606	0	0	2,327
VETERANS AFFAIRS	314	0	0	0	0	0	314
TOTAL	391,353	8,919	167,183	135,032	5,421	14,187	722,095

Source: Statistics Canada, Science Statistics Section, Federal Government Activities in the Natural Sciences, Fiscal Years 1972-73, 1973-74, 1974-75, (1974 Survey Results), 15 May 1974, p. 38.

Table A.11 - Total In-House Expenditures on Activities in the Natural Sciences, 1972-73, Includes Non-Program Costs

DEPT OR AGENCY	CURRENT R & D	CAPITAL R & D	DATA COLL	SCI INFO	TEST & STAND	FEASI STUDIES	SCHLRSHP PROGS	TOTAL CURR RSA	CAPITAL RSA	TOTAL EXPEND
					($'000)					
AGRICULTURE:	65,525	3,329	393	2,297	38	0	0	2,728	184	71,766
ADMINISTRATION	0	0	0	1,336	0	0	0	1,336	5	1,341
CDN GRAIN COMM	514	180	393	119	38	0	0	550	179	1,423
HLTH OF ANIMALS	2,055	85	0	12	0	0	0	12	0	2,152
RESEARCH	62,956	3,064	0	830	0	0	0	830	0	66,850
A.E.C.L.	55,876	4,704	1,122	2,193	543	0	0	3,858	0	64,438
CDN ARSENALS LTD	119	1	0	0	0	0	0	0	0	120
C.B.C.	49	6	0	0	0	0	0	0	0	55
CDN PAT & DEV LTD	0	0	0	716	0	0	0	716	0	716
COMMUNICATIONS	9,125	3,927	0	341	0	103	0	444	0	13,496
CONS & CORP AFFAIRS:	0	0	0	6,833	770	0	0	7,603	39	7,642
CONSUMER AFFAIRS	0	0	0	0	770	0	0	770	39	809
INTEL PROPERTY	0	0	0	6,833	0	0	0	6,833	0	6,833
E.M.R.:	29,108	4,470	19,495	9,315	870	592	0	30,272	1,615	65,465
EARTH SCIENCES	7,650	2,534	14,595	7,050	33	0	0	21,678	834	32,696
MIN & ENERGY RES	21,458	1,936	4,900	2,265	837	592	0	8,594	781	32,769
ENVIRONMENT:	64,250	19,517	61,431	31,826	1,393	2,378	36	97,064	10,700	191,531
ATMOS ENV SERV	4,110	1,337	31,428	23,161	252	0	36	54,877	3,873	64,197
ENV MGT SERVICE	35,319	9,793	13,631	3,888	1,029	2,286	0	20,834	3,315	69,261
ENV PROT SERV	169	54	453	196	112	92	0	853	392	1,468
FISHERIES	14,916	5,780	3,916	783	0	0	0	4,699	0	25,395
MARINE SCIENCES	9,736	2,553	12,003	3,798	0	0	0	15,801	3,120	31,210
EXTERNAL AFFAIRS	0	0	0	230	0	0	0	230	0	230
I.A.N.D.	206	15	224	119	0	0	0	343	82	646
I.D.R.C.	0	0	0	693	0	0	0	693	0	693
M.R.C.	0	0	14	0	0	0	0	14	0	14
NATIONAL DEFENCE:	32,967	3,258	0	1,494	38,295	0	8	39,797	159	76,181
DEFENCE RESEARCH	32,257	3,258	0	1,494	0	0	8	1,502	39	37,056
DEFENCE SERVICES	710	0	0	0	38,295	0	0	38,295	120	39,125
NATL FILM BOARD	329	25	0	32	0	70	0	102	0	456
NATL HLTH & WELFARE:	8,430	837	1,218	219	2,025	8	0	3,470	44	12,781
HEALTH CARE	74	0	6	16	7	8	0	37	0	111
HEALTH PROTECTION	8,129	611	1,212	203	2,018	0	0	3,433	44	12,217
MED SERVICES	81	0	0	0	0	0	0	0	0	81
NMED USE DRUGS	146	226	0	0	0	0	0	0	0	372
NATL MUSEUMS	1,881	38	816	486	0	0	0	1,302	26	3,247
N.R.C.	47,478	2,389	486	8,218	5,267	830	0	14,801	6,763	71,431
PUBLIC WORKS	1,005	30	1,103	11	446	1,304	0	2,864	690	4,589
REG ECON EXPANSION	146	0	0	0	0	0	0	0	0	146
S.L.S.A.	217	0	0	0	0	0	0	0	0	217
TRANSPORT:	1,902	873	363	13	80	4	0	460	0	3,235
AIR TRANSPORT	1,276	868	9	13	74	4	0	100	0	2,244
MARINE	172	5	354	0	6	0	0	360	0	537
SURFACE TRANSPORT	26	0	0	0	0	0	0	0	0	26
T.D.A.	428	0	0	0	0	0	0	0	0	428
VETERANS AFFAIRS	259	0	0	0	0	0	0	0	0	259
TOTAL	318,872	43,419	86,665	65,036	49,727	5,289	44	206,761	20,302	589,354

Source: Statistics Canada, Science Statistics Section, Federal Government Activities in the Natural Sciences, Fiscal Years 1972-73, 1973-74, 1974-75, (1974 Survey Results), 15 May 1974, p. 43.

Table A.12 - Total In-House Expenditures on Activities in the Natural Sciences, 1973-74, Includes Non-Program Costs

DEPT OR AGENCY	CURRENT R & D	CAPITAL R & D	DATA COLL	SCI INFO	TEST & STAND	FEASI STUDIES	SCHLRSHP PROGS	TOTAL CURR RSA	CAPITAL RSA	TOTAL EXPEND
					($'000)					
AGRICULTURE:	70,247	4,202	608	2,620	72	0	0	3,300	148	77,897
ADMINISTRATION	0	0	0	1,507	0	0	0	1,507	48	1,555
CDN GRAIN COMM	661	90	608	216	72	0	0	896	100	1,747
HLTH OF ANIMALS	2,316	189	0	11	0	0	0	11	0	2,516
RESEARCH	67,270	3,923	0	886	0	0	0	886	0	72,079
A.E.C.L.	64,978	4,323	1,111	2,338	371	0	0	3,820	0	73,121
CDN ARSENALS LTD	153	4	0	0	0	0	0	0	0	157
C.B.C.	172	3	0	0	0	0	0	0	0	175
CDN PAT & DEV LTD	0	0	0	731	0	0	0	731	0	731
COMMUNICATIONS	9,468	6,010	0	327	0	119	0	446	0	15,924
CONS & CORP AFFAIRS:	0	0	0	7,434	1,215	0	0	8,649	126	8,775
CONSUMER AFFAIRS	0	0	0	0	1,215	0	0	1,215	126	1,341
INTEL PROPERTY	0	0	0	7,434	0	0	0	7,434	0	7,434
E.M.R.:	31,858	4,302	20,291	10,513	945	686	0	32,435	1,884	70,479
EARTH SCIENCES	9,173	2,367	14,902	7,912	53	0	0	22,867	1,255	35,662
MIN & ENERGY RES	22,685	1,935	5,389	2,601	892	686	0	9,568	629	34,817
ENVIRONMENT:	71,472	14,560	68,908	34,567	3,303	2,562	39	109,379	11,562	206,973
ATMOS ENV SERV	5,541	1,780	36,119	25,574	206	0	39	61,938	3,616	72,875
ENV MGT SERVICE	38,665	7,229	15,256	3,447	2,972	2,459	0	24,134	2,703	72,731
ENV PROT SERV	189	60	510	221	125	103	0	959	435	1,643
FISHERIES	16,414	1,683	4,310	862	0	0	0	5,172	0	23,269
MARINE SCIENCES	10,663	3,808	12,713	4,463	0	0	0	17,176	4,808	36,455
EXTERNAL AFFAIRS	0	0	0	237	0	0	0	237	0	237
I.A.N.D.	276	451	354	206	0	0	0	560	125	1,412
I.D.R.C.	0	0	0	1,348	0	0	0	1,348	0	1,348
M.R.C.	0	0	17	0	0	0	0	17	0	17
NATIONAL DEFENCE:	35,609	2,708	0	1,852	38,322	0	12	40,186	408	78,911
DEFENCE RESEARCH	34,537	2,708	0	1,852	0	0	12	1,864	60	39,169
DEFENCE SERVICES	1,072	0	0	0	38,322	0	0	38,322	348	39,742
NATL FILM BOARD	290	25	0	30	30	228	0	288	0	603
NATL HLTH & WELFARE:	7,801	560	1,045	234	3,067	6	0	4,352	94	12,807
HEALTH CARE	175	0	16	11	9	6	0	42	0	217
HEALTH PROTECTION	7,473	505	1,029	218	3,058	0	0	4,305	94	12,377
MED SERVICES	87	0	0	0	0	0	0	0	0	87
NMED USE DRUGS	66	55	0	5	0	0	0	5	0	126
NATL MUSEUMS	2,346	244	1,202	720	0	0	0	1,922	163	4,675
N.R.C.	49,579	3,190	506	9,470	5,490	864	0	16,330	5,276	74,375
PUBLIC WORKS	1,177	98	302	27	450	2,743	0	3,522	709	5,506
REG ECON EXPANSION	100	0	0	0	0	0	0	0	0	100
S.L.S.A.	235	0	0	0	0	0	0	0	0	235
TRANSPORT:	2,088	2,510	408	60	46	55	0	569	0	5,167
AIR TRANSPORT	1,551	2,500	24	26	46	48	0	144	0	4,195
MARINE	272	10	384	34	0	7	0	425	0	707
SURFACE TRANSPORT	24	0	0	0	0	0	0	0	0	24
T.D.A.	241	0	0	0	0	0	0	0	0	241
VETERANS AFFAIRS	314	0	0	0	0	0	0	0	0	314
TOTAL	348,163	43,190	94,752	72,714	53,311	7,263	51	228,091	20,495	639,939

Source: Statistics Canada, Science Statistics Section, Federal Government Activities in the Natural Sciences, Fiscal Years 1972-73, 1973-74, 1974-75, (1974 Survey Results), 15 May 1974, p. 44.

Notes

I. Background to the Study

1. Barry Carin, A Survey of the Literature of the Economies of R & D, (unpublished); Organisation for Economic Cooperation and Development (OECD), "Report of the Secretary General's Ad Hoc Group on New Concepts of Science Policy", Science, Growth and Society: A New Perspective, OECD, Paris, 13 April 1971, C(71)71.

2. N.H. Lithwick, Canada's Science Policy and the Economy, Methuen, Toronto, 1969, p. 5.

3. Canada, Report of the Senate Special Committee on Science Policy, Chairman, the Honourable Maurice Lamontagne, A Science Policy for Canada, vol. 2, Targets and Strategies for the Seventies, Information Canada, Ottawa, 1972, p. 488.

4. M. Fores, "Technology and Innovation: Some Comments on the Literature", Technology and Society, October 1973, vol. 8, no. 3, p. 94.

5. F. Ronald Hayes, The Chaining of Prometheus: Evolution of a Power Structure for Canadian Science, University of Toronto, Toronto, 1973, pp. 23-24.

6. Mel Thistle, The Inner Ring: The Early History of the National Research Council of Canada, University of Toronto Press, Toronto, 1966, pp. 299-300. Facts from this book are used in various places in this section.

7. G. Bruce Doern, Science and Politics in Canada, McGill- Queen's University Press, Montreal, 1972. This interesting book contains a thorough discussion of major governmental science decisions such as: the creation of the NRC; the Royal Commission on Government Organization (the Glassco Commission); the Senate Special Committee on Science Policy; the cancellation of the Queen Elizabeth II telescope; Intense Neutron Generator controversy and the 1969 reorganization of the Science Council and Science Secretariat.

8. Ibid., p. 4.

9. F. Ronald Hayes, op. cit., p. 174.

10. Ibid., p. 145.

11. Canada, Royal Commission on Government Organization, Chairman, the Honourable J. Grant Glassco, vol. 4, Special Areas of Administration, Queen's Printer, Ottawa, 1963, p. 196.

12. G. Bruce Doern, op. cit., p. 46.

13. J. Grant Glassco, op. cit., p. 226.

14. The NRC "has not been successful in its role as a promoter of industrial research". Ibid., p. 231.

15. G. Bruce Doern, op. cit., p. 22.

16. J. Grant Glassco, op. cit., p. 230.

17. F. Ronald Hayes, op. cit., p. 27.

18. Cf. G. Bruce Doern, op. cit., p. 39, where it is noted that "The scholarship program (of the NRC) was really a response to the Research Council's early facilities and manpower which indicated overwhelmingly the poverty and scarcity of Canada's science resources. While the major public and legislative rationale for the NRC's creation had been the utilitarian one of using science to assist industry, the NRC's first policies expressed the realization that Canada had to develop scientists first."

19. Arthur J. Cordell, The Multinational Firm, Foreign Direct Investment and Canadian Science Policy, Science Council of Canada Background Study No. 22, Information Canada, Ottawa, December 1971; Pierre L. Bourgault, Innovation and the Structure of Canadian Industry, Science Council of Canada Background Study No. 23, Information Canada, Ottawa, October 1972.

20. Herbert Marshall, Frank A. Southard, Jr., and Kenneth W. Taylor, Canadian American Investment: A Study in International Investment, Ryerson Press, Toronto, 1936.

21. G. Bruce Doern, op. cit., p. 52 and Arthur J. Cordell, op. cit.

22. A.E. Safarian, Foreign Ownership of Canadian Industry, McGraw-Hill, Scarborough, Ontario, 1966, pp. 280-286; A.E. Safarian, The Performance of Foreign-Owned Firms in Canada, Private Planning Association, Montreal, 1969, pp. 49-53; Organisation for Economic Cooperation and Development (OECD), National Science Policy: Canada, OECD, Paris, 1969, p. 251.

23. Herb Gray, Foreign Direct Investment in Canada, (The Gray Report), Information Canada, Ottawa, 1972, especially pp. 120-127; Arthur J. Cordell, op. cit.; Pierre L. Bourgault, op. cit.; Science Council of Canada Report No. 15, Innovation in a Cold Climate: The Dilemma of Canadian Manufacturing, Information Canada, Ottawa, 1971, pp. 32-35; O.M. Solandt, "Science Policy and Canadian Manufacturing Industries", Nature, 1971, vol. 234, no. 5326, pp. 183-185; Michael Z. Brooke and H. Remmes, The Strategy of Multinational Enterprises, Longman, London, 1970, pp. 40-42; J.B. Quinn, "Technology Transfer by Multinational Companies", Harvard Business Review, 1969, vol. 47,

pp. 147-161; for a thorough discussion of international organizational structure, see Endel J. Kolde, International Business Enterprise, Prentice-Hall, 1968, pp. 240-258; Business International, "Organizing for Worldwide Operations: Structuring and Implementing the Plan", New York, 1965; NICB Report, R & D in the Multinational Company, NICB series on Managing International Business, 1970, no. 8, pp. 65-74; see also, Foreign Investment Review Agency, the Foreign Investment Division and Research Analysis Branch, The International Enterprise: Addendum #1, 1973, A Selected Bibliography to July 1972 Addendum #2, Foreign Investment Review Agency, Ottawa.

24. See A.J. Cordell, "Innovation, The Multinational Corporation: Some Implications for National Science Policy", Long Range Planning, September 1973, pp. 22-28. See also "Mr. IBM Europe Comes Home", New Scientist, 18 April 1974, vol. 62, no. 894, pp. 116-118.

25. Pierre L. Bourgault, op. cit., pp. 110-114, where the phenomenon of market fragmentation is fully explored.

26. The Minister of Industry, Trade and Commerce is reported to have said the following in regard to the operations of de Havilland and Canadair in Canada "In the past the growth and development of the two companies were impaired by the fact that they were foreign-owned and controlled, and that they had no independent authority to make decisions or to enter into inter-company arrangements for meaningful rationalization." Globe and Mail, 28 May 1974, p. B1. "Ottawa is to purchase de Havilland - Will seek option to buy Canadair."

27. Organisation for Economic Cooperation and Developement, The Conditions for Success in Technological Innovation, OECD, Paris, 1971.

28. Herb Gray, op. cit., p. 118. It should be noted that some innovations developed in Canada have been registered in the name of the foreign parent firm; while such cases exist, the exact number is unknown. See Andrew H. Wilson, Background to Invention, Science Council of Canada Background Study No. 11, Information Canada, Ottawa, 1970, for a complete discussion of the problems and pitfalls of the Canadian patent system.

29. N.H. Lithwick, op. cit., p. 112.

30. Canada, Report of the Senate Special Committee on Science Policy, Chairman, the Honourable

Maurice Lamontagne, A Science Policy for Canada, vol. 1, A Critical Review: Past and Present, Queen's Printer, Ottawa, 1970, pp. 146-147.

II. The Scientific Activities of the Federal Government: Expenditure Trends, Regional Distribution of Activities

1. Canada, Parliament, Senate, First Session, Twenty-eighth Parliament 1968-1969, The Senate of Canada, Proceedings of the Special Committee on Science Policy, Chairman, the Honourable Maurice Lamontagne, No. 26, Thursday, 6 February 1969 and No. 36, Thursday, 6 March 1969.

2. For further elaboration on these categories, the reader is referred to Ministry of State for Science and Technology, Federal Scientific Resources 1972 to 1974: Natural and Human Sciences, Information Canada, Ottawa, December 1973, pp. 92-95.

3. Ibid., p. 94.

4. F. Ronald Hayes, The Chaining of Prometheus: Evolution of a Power Structure for Canadian Science, University of Toronto, Toronto, 1973, p. 27.

5. The authors gratefully acknowledge the assistance provided by the Ministry of State for Science and Technology in providing data and information related to the scientific activities of the Federal Government.

6. Government of Canada, Organization of the Government of Canada, Information Canada, Ottawa, 1974, item 5153.

7. Ibid., p. 69.

8. Ibid., p. 17.

9. Ibid., p. 78.

10. Ibid., p. 17.

11. Ibid., p. 28.

12. Ibid., p. 46.

13. Ibid., p. 46.

14. Ibid., p. 67.

15. Ibid., p. 82.

16. Ibid., p. 83.

17. Defence Research Board, Department of National Defence, The First Twenty-Five Years, Information Canda, Ottawa, 1972, pp. 9-10.

18. Ibid., p. 20.

19. Ibid., p. 20.

20. Defence Research Board, Review '73, Department of National Defence, Report No. DR222,

p. 12.

21. Government of Canada, Organization of the Government of Canada, Information Canada, Ottawa, 1974.

22. See note 5, Chapter II.

23. Government of Canada, Organization of the Government of Canada, Information Canada, Ottawa, 1974, items 1846-54. Water survey units are located in Guelph, Ontario; Montreal, Quebec; Victoria, British Columbia; Halifax, Nova Scotia; Whitehorse and Fort Smith, Yukon; NWT.

24. Government of Canada, op. cit., items 1950-52.

25. See note 5, Chapter II.

26. Government of Canada, op. cit., item 542.

27. Organisation for Economic Cooperation and Development, Reviews of National Science Policy: Canada, OECD, Paris, 1969. For more detail on the categories by OECD, see Chapter III.

28. The high per capita level of expenditure in the Yukon and Northwest Territories can be accounted for by the exceedingly small population of the area and the increasing concern of the federal government, particularly in NHW and INA, for the North. The new medical research program of NHW in the North has already been mentioned. INA operates the Inuvik Research Laboratory which is generally available to anyone conducting research in the North. The department's research activities are not extensive, but universities often make use of its research facilities. A program of Arctic Land Use Research is presently being carried on, with work in geology, geography, hydrology, etc.

29. Science, Technology and Provincial Governments, a paper prepared for the Science Council of Canada, Ottawa, July 1972, pp. 1-10.

30. Ibid., p. 34.

31. Ibid., p. 35.

32. Ibid., p. 9.

33. "Les Elements d'un Politique Scientifique pour le Quebec", Le Devoir, 30 Decembre 1970.

34. It commissions studies, develops liaison contacts with other sectors, implements the directives of the Committee.

35. It collects and distills opinion from all sectors of society: universities, industry, government, the service sector, etc.

36. And, further, the terms under which federal financial support was made.

37. And what share of the cost of their information system is absorbed by federal agencies such as NRC through the Canada Institute for Scientific and Technical Information?

III. Structure and Functioning of R & D Establishments

1. National Research Council, NRCL - 71: Activities of the Laboratories, National Research Council, Ottawa, 1971, p. 33.

2. Ibid., p. 67.

3. Research Station Winnipeg, Canada Department of Agriculture, Information Brochure, p. 4.

4. M.P. Bachynski, "Science Policy in Canada: Study and Debate Must Now Be Replaced by Action", Science Forum, vol. 6, no. 1, 1973, p. 23.

5. Sir John Cockcroft, ed., The Organization of Research Establishments, Cambridge University Press, London, 1965, p. 209, notes that a sophisticated industrial laboratory (he specifically refers to Bell Labs, U.S.A.) often operates in much the same way as a government lab. Publication and attendance at international meetings is encouraged. The research "organization keeps in such intimate contact with the whole scientific world that it will know of new results promptly, and sensing their importance, can mobilize to take advantage of them. But only if the research people are themselves doing scientific work of the highest order, and are known and respected for their contributions by professional society and university people of distinction, can they participate in and profit from these exchanges."

6. Defence Research Board, Defence Science in Canada IV: A General Description of the Defence Research Board, Plans Report 71-7, Defence Research Board, Ottawa, 1971, p. 3.

7. Ibid., p. 4.

8. Organisation for Economic Cooperation and Development, Reviews of National Science Policy: Canada, OECD, Paris, 1969, pp. 94-96.

9. Agriculture Canada, Research Branch Report 1971, Information Canada, Ottawa, 1972, p. 144.

10. Organisation for Economic Cooperation and Development, op. cit., p. 143.

11. Treasury Board, Estimate for the Fiscal Year Ending 31 March 1974, Information Canada, Ottawa, 1973, Section 28-22.

12. P. Meyboom, Science in a Changing

Environment: Proposals for a Departmental Science Policy, Science Policy Branch, Policy, Planning and Research Service, Environment Canada, Ottawa, 1972, p. 55.

13. Treasury Board, op. cit., Section 3-6.

14. Department of Communications, Research and Development, Ottawa, 1972, p. 3.

15. Organisation for Economic Cooperation and Development, op. cit., p. 159.

16. G.D. Watson, Planning, Estimating and Evaluation for Defence Research, Plans Report 72-7, Defence Research Board, Ottawa, 1972, p. 19.

17. Information provided by Division of Building Research, NRC.

18. A large number of government R & D establishments rely on advisory committees of some type to help in program formation. These committees usually consist of a mix of industry, academic and government people. Generally the committee is selected and/or chaired by the director of the establishment. And this mix is applauded by one writer in the field who somewhat cynically notes, "probably the best balance for management of government research is a board with enough academics to keep the science from getting rotten and enough vocal industry members to question continually the retention of the mission for which the agency exists." F. Ronald Hayes, The Chaining of Prometheus: Evolution of a Power Structure for Canadian Science, University of Toronto Press, Toronto, 1973, p. 34.

19. G.D. Watson, op. cit.

20. Ibid.

21. Ibid.

22. Ibid.

23. Sir John Cockcroft, op. cit., p. 263. (emphasis supplied)

24. F. Ronald Hayes, op. cit., p. 46; Hayes cites Dr. Herzberg's convocation address at York University, Toronto, 7 November 1969.

IV. Technology Transfer from Government R & D Establishments

1. A.K. Chakrabarti, "Some Concepts of Technology Transfer: Adoption of Innovations in Organizational Context", R & D Management, 1973, vol. 3, no. 3, pp. 112-113.

2. Ibid., p. 113.

3. Michael Kenward, "Technology Transferred", New Scientist, 5 July 1973.

4. B.M. Kohler, A.H. Rubenstein, C.F. Douds, "A Behavioural Study of International Technology Transfer Between the United States and West Germany", Research Policy, vol. 2, no. 3, 1973, pp. 161-184.

5. C.F. Douds, "A Brief Survey of the State of the Art in Technology Transfer", R & D Management, June 1971.

6. B.M. Kohler, A.H. Rubenstein, and C.F. Douds, op. cit., p. 165.

7. Ibid., p. 165.

8. Ibid., p. 166.

9. Ibid., p. 166. (emphasis supplied)

10. Pierre L. Bourgault, Innovation and the Structure of Canadian Industry, Science Council of Canada Background Study No. 23, Ottawa, October 1972, p. 17.

11. A.C. Chakrabarti, op. cit., p. 113.

12. B.M. Kohler, A.H. Rubenstein, C.F. Douds, op. cit., p. 162.

13. Samuel Globe, Girard W. Levy, and Charles M. Shwartz, "Key Factors and Events in the Innovation Process", Research Management, July 1973, vol. 16, p. 8.

14. Michael Kenward, op. cit., p. 27.

15. Ibid.

16. A.K. Chakrabarti, op. cit., p. 113.

17. Department of Energy, Mines and Resources, Mines Memo - 1972 - Annual Review of Research of the Mines Branch, Mines Branch Admin. Report ADM72-1, Information Canada, Ottawa, 1972, p. 1.

18. Atomic Energy of Canada Limited, Annual Report 1972-1973, Information Canada, Ottawa, 1973, p. 3.

19. Department of Communications, Research and Development, Ministry of Supply and Services, Ottawa, 1972, p. 3. (emphasis supplied)

20. Treasury Board, Estimates for the Fiscal Year Ending 31 March 1974, Information Canada, Ottawa, 1973, Section 6-12.

21. P. Kruus, Basic Research, Science Council of Canada Background Study No. 21, Information Canada, Ottawa, December 1971.

22. Ibid., p. 10.

23. Ibid., p. 44.

24. Cf. Canada, Report of the Senate Special Committee on Science Policy, Chairman, the Honourable Maurice Lamontagne, A Science Policy for Canada, vol. 3, A Government Organization for the Seventies, Information Canada, Ottawa, 1973, where

Prof. Derik de Solla Price (p. 688) is quoted as follows: "The naive picture of technology as applied science simply will not fit all the facts. Inventions do not hang like fruits on a scientific tree. In those parts of the history of technology where one feels some confidence, it is quite apparent that most technological advances derive immediately from those that precede them." In the same volume, Dr. Keichi Oshima, a member of the advisory committee on technology policy to the Minister of International Trade and Industry in Japan notes (p. 689): "We have to admit that most basic research in universities and public institutions had little direct link with technological innovations in industry, but its most important contribution was to supply general scientific and technological background for them."

25. P. Kruus, op. cit., p. 45.

26. Treasury Board, op. cit., Section 3-6.

27. Peter Meyboom, Science in a Changing Environment: Proposals for a Departmental Science Policy, Environment Canada, Ottawa, 1972, p. 21.

28. Canada, The Senate of Canada, Proceedings of the Special Committee on Science Policy, Chairman, the Honourable Maurice Lamontagne, First Session, Twenty-eighth Parliament, no. 15, Wednesday, 11 December 1968, p. 2213.

29. Atomic Energy of Canada Ltd., op. cit., p. 3.

30. E.C.W. Perryman, "AECL's Interaction with Industry", AECL Research and Development in Engineering, Atomic Energy Commission, Chalk River, 1972, p. 2.

31. Canada, The Senate of Canada, Proceedings of the Special Senate Committee on Science Policy, no. 3, Wednesday 23 October 1968, National Research Council - A Report in Support of the Brief presented to the Senate Special Committee on Science Policy, p. 87.

32. United States, National Science Foundation, Successful Industrial Innovation, National Science Foundation, 69-17. One finding of this NSF sponsored study is that significant transfers of technology which result in innovation are a result of personal contact rather than from printed material alone.

33. "Arrangements for Enabling CPDL to Play the Most Effective Role in Exploiting", CPDL, Ottawa, 1973. (Unpublished Paper)

34. For a more thorough discussion of Canadian

Patents and Development Limited, see Andrew H. Wilson, Background to Invention Science Council of Canada Background Study No. 11, Information Canada, Ottawa, 1970, pp. 33-34.

35. "Arrangements...", CPDL, op. cit., p. 10.

36. CPDL is the Crown corporation charged with the job of licensing firms to exploit government-owned processes and patents. However, businessmen are advised of other ways of learning new developments. "Any smart businessman around Ottawa knows that the best way to transfer technology is to prowl the corridors of government laboratories most directly associated with his business." Financial Post, 9 March 1974, p. 54. (emphasis supplied)

37. E.C.W. Perryman, op. cit.

38. Ibid.

39. A. Vanterpool, Transfer of Technology, Working Paper No. 102, Department of Industry, Trade and Commerce, Ottawa, August 1971. The author notes that technology transfer is a) a very active process requiring much energy and commitment on the part of the transfer agents; b) a very inefficient process where only about 0.1 per cent of "situations of interest" ever reach commercialization; and c) a very people-oriented process. These findings correlate rather well with our entire study. We attempt to show why technology transfer is apparently such "an inefficient business". Part of the answer lies in the roles, mandates, structure, and behaviour of government laboratories.

40. James M. Utterback, "Innovation in Industry and the Diffusion of Technology", Science, vol. 183, 15 February 1974, pp. 620-626. Utterback notes (p. 623) "government-held patents and technical reports are seldom used in a commercially or socially important application other than the specific one from which the patent or information arose. Since application of technology is usually stimulated by a need or market one would not expect the availability per se, of patents or technical information to result in application." (emphasis supplied)

41. Industrial reluctance to become involved with technology transfer is not a uniquely Canadian phenomenon. Cf. Richard L. Lesher and George J. Howick, Assessing Technology Transfer, U.S. National Aeronautics and Space Administration, NASA, 1966, p. 39.

42. E.C.W. Perryman, op. cit., p. 3.

43. Technology transfer from government labs

in other countries is also under some scrutiny. For example, the U.S. National Academy of Engineering recently concluded that although accepting the hypothesis that useful technology does exist in federal laboratories, it recommended that the U.S. National Science Foundation survey the federal labs from time to time to determine whether or not there really is a "substantial" amount of useful federally- funded technology available for secondary application. The Report of the NAE notes that "Technology in the form developed by mission-oriented federal laboratories is almost never quite right for transfer into the market place... This technology gap exists largely because none of the participants wants to assume either the technical or financial risks of production modification, market analysis and start-up of a pilot operation. (However,) where all the steps in the normal process have been fostered by federal agencies in a kind of 'pump-priming' enterprise, there have been payoffs - notwithstanding the debates that often rage about the adequacy of return on the taxpayers dollars." See "Federal Technology Transfer Not Going Well", Chemical and Engineering News, 29 April 1974, pp. 16-17.

44. Bruce Doern of Carleton University explains the "failure" in the following way: "My assessment of the NRC and the causes of its total goal displacement indicates that the Canadian industrial community was not exactly "champing at the bit" to develop its R & D capability, a state of mind encouraged, in my view, by the heady foreign investment-induced expansionist era of the late 1940s and the 1950s." From The Senate Report on Science Policy: A Political Assessment, A background paper prepared for the Conference on Science Policy and Political Science sponsored by the Science Council of Canada, Ottawa, 18-19 March 1971, p. 7.

45. Canada, The Senate of Canada, Proceedings of the Special Senate Committee on Science Policy, op. cit., p. 117.

46. It appears that NRC intends to become more involved with technology transfer to industry in general, and to specific firms in particular. This new direction was outlined in a letter from the President of NRC to all NRC staff. The letter, dated December 3, 1974, notes that "NRC will try to complement and assist research in industry and will encourage, where feasible, R & D projects to be

carried out in industry". More specifically the letter states: "NRC work on a proposed industrial technology, if it continued to be promising, would be pursued to a point where a competent company or group of companies could see its value and was prepared to take over final development and application. Bringing a company or companies to this point will usually require that they participate in the research so as to become knowledgeable. Assignment to a company will depend upon the company's overall capability and on the credibility of its plans and intentions regarding exploitation." It will take a few years to determine if and to what extent this new policy orientation, apparently involving a change in objectives, will prove successful.

47. The results of activities undertaken within the NRC often show up in the private sector. A recent example involves HPL Engineering (Hover-products Ltd.,) of Ottawa which is currently producing an NRC designed windmill which produces energy very efficiently. See "Offering Wind-Powered Machine for Cottage Use", Ottawa Journal, 6 April 1974, p. B9.

48. See also Pierre L. Bourgault, Innovation and the Structure of Canadian Industry, Science Council of Canada Background Study No. 23, Information Canada, Ottawa, 1972.

49. A.J. Cordell, The Multinational Firm, Foreign Direct Investment, and Canadian Science Policy, Science Council of Canada Background Study No. 22, Information Canada, Ottawa, 1971, and Pierre L. Bourgault, op. cit.

50. Richard L. Lesher and George J. Howick, op. cit., p. 6.

51. B. Doern, op. cit., p. 221.

52. Ibid., p. 195. (Authors' emphasis)

53. In addition to the concept of providing a public good, there is yet another reason for government involvement. According to economic theory the government should intervene wherever underinvestment is likely to occur because of external benefits which cannot be captured or exploited by the person who makes the investment. Private firms normally underinvest in R & D and the potential for underinvestment increases the closer one gets to the basic research end of the spectrum. Thus "Government has an appropriate role in R & D even when its results will not be incorporated in Government purchases, because private firms would un-

derinvest in R & D for goods normally purchased by the private sector. Although an investment in R & D may produce benefits exceeding its costs from the viewpoint of society as a whole, a firm considering the investment may not be able to translate enough of these benefits into profits on its own products to justify the investment. This is because the knowledge which is the main part of R & D can usually be readily acquired by others who will compete away at least part of the benefits from the original developer. This is particularly true of basic research, where the output frequently occurs in the first instance not as a marketable product, but rather as an advance in basic knowledge that can be subsequently used in applied research and development by a wide and often unforeseeable range of firms." George Eads, "U.S. Government support for civilian technology: economic theory versus political practice", Research Policy, vol. 3, no. 1, 1974, pp. 2-16. (Quote is taken from p. 2.)

54. "Some Economic Aspects of Science", by Harry Johnson, in Civilization and Science, Ciba Foundation Symposium, North Holland Press, p. 172.

55. The historical development of "Make-or-Buy" and some discussion of the merits and drawbacks of the policy itself can be found in A.H. Wilson, Governments and Innovation, Science Council of Canada Background Study No. 26, Information Canada, Ottawa, 1973, pp. 88-93.

V. Technology Transfer: The Industrial View

1. Pierre L. Bourgault, Innovation and the Structure of Canadian Industry, Science Council of Canada Background Study No. 23, Information Canada, Ottawa, 1972.

2. Especially Arthur J. Cordell, The Multinational Firm Foreign Direct Investment and Canadian Science Policy, Information Canada, Ottawa, 1971.

3. Few conclusions can be drawn about size of the R & D Budget and the innovative potential of the firm. R & D expenditures really measure inputs to the innovative process and may not closely reflect output. Cf. John E. Tilton, International Diffusion of Technology: The Case of Semiconductors, The Brookings Institute, Washington, D.C., 1971, p. 56.

4. The Director of Industrial Research and Development Establishments compiled by the Ministry of State for Science and Technology (MOSST) con-

tains more than 500 manufacturing R & D units. The Department of Supply and Services (DSS) issues an R & D bulletin based partly on its Source Information Systems. The mailing list of the bulletin contains at least one hundred manufacturing firms which are engaged in R & D activities, but which are not listed in the MOSST Directory.

5. Cf. "Factors Affecting Technological Innovation in British Industry", Industrial Marketing Management, vol. 2, 1973, pp. 101-112. The problem of source directed as opposed to need directed technology is stated in a somewhat different way. (p. 104) "Where technological innovation is followed by commercial success, the more important variable is market and management need rather than the scientific of technological discovery itself."

6. Cf. Factors in the Transfer of Technology, edited by William H. Gruber and Donald H. Marquis, MIT Press, Cambridge, Mass., 1969. The authors note that, (p. 12) "the mechanism of technological transfer is one of agents, not agencies; of the movement of people among establishments, rather than routing of information through communication systems."

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Background Study No. 33, **Energy Conservation,** by F.H. Knelman, July 1975 (SS21-1/33, Canada: $1.75, other countries: $2.10)

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