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SCIENCE INDICATOR PROJECT

REPORT #2

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SCIENCE INDICATOR PROJECT

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Program Assessment
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Abbreviations

CPDL	-	Canadian Patent and Development Ltd.
FBE	-	Federal Budgetary Expenditures
FGERD	-	Federal Gross Expenditures on Research and Development
GDP	-	Gross Domestic Product
GERD	-	Gross Expenditure on Research and Development (Domestic)
GNP	-	Gross National Product
GPE	-	Gross Provincial Product
PNP	-	Private Non-Profit

I. Introduction

An interim report on the science indicator project was reviewed by the Project Management Committee in January of this year. The definition of a science indicator provided in that report was:

> " Science indicators are measures describing the science and technology system and, from the Ministry's point of view, describing the impact of policy on the science and technology system."

This definition was narrowed to some extent by imposing additional criteria on the indicators to be chosen for examination - "... availability of data, relevance of the indicators to policy evaluation or analysis, significance of the phenomenon measured and adequacy of the set of indicators to resolve the issues".

The broad nature of the definition made it clear from the outset that the problem of science indicators is one of too much information as opposed to too little, and that this, in itself, dictated, to some extent, the approach one must take toward the subject. One must be able to select out the pertinent information, organize it into some meaningful framework, and manage it in a timely fashion. The interim report provided a conceptual framework which takes into account these three major aspects of the science indicator problem. Christened the 'profile matrix' approach it provided an ordered structure of indicator 'type' vs. policy objectives and mechanisms which at once provided a useful format for the organization of indicators and a demonstration of their relevance. It is this organizational framework which places science related data in the context of purpose and reduces it to useful information, and the characteristic which differentiates the science indicator project from the 'Black Book' exercise which is essentially a cataloguing of data. The management of the information, the third major aspect of the science indicator project is concerned with updating, revising, and the distribution of the information from a centralized data base. It is understood that this aspect of the problem may be left to the MOSST Data Base Management Committee.

The general direction resulting from the Project Management Committee's deliberation on the report was that the project should be reduced in scope and that the methodology proposed be applied. Reduction in scope related to giving priority to measures of the government sector and concentrating on measures describing the scientific system's resource inputs, stock variables and outputs. This report is an attempt to comply with the wishes of the committee.

II. Summary

The indicators examined in this report are described in Table 1. Table 1 is a policy profile matrix for Government Branch. It relates, in summary, the indicators discussed in the report to the objectives which they propose to monitor. Because of the interdependence of performance sectors and the dual role of the federal government as performer and funder, which focusses in Government Branch, it was not possible to consider the government sector in isolation from other sectors or the national picture. For this reason the national objectives which have been made explicit through various announcements by the federal government in 1978 have been included. For the same reason, extramural payments have been included in the discussions relating to priorities or national concerns, the 'health' of intramural science and a balanced regional distribution of research performed.

The problem of the taxonomy of indicator type is carried forward into this report. Namely, there is still the ambiguity as to what is to be considered as input and output depending on whether you are referring to science policy or the actual research. In general, government expenditures on research are considered to be inputs (policy and research). National expenditures on research and development are considered to be policy outputs. Research outputs, characterised as 'direct outputs' of research and development are also included in the output column, and include patent proposals, royalties, publications, citations and innovations. National performance and funding distributions have been included in the inventory/structure column as they are indicative of some aspects of the structure of the nations research system. The policy impact column

Table 1
Policy Profile Matrix
Government Branch
Ministry of State for Science
and Technology

Indicators

Science Objective	Policy Mechanisms	Input	Output	Inventory/Structure	Policy Impact	Socio-Economic Objective	Performance/Normalizing Factors
i) To increase the national science and technology effort.		- FGERD (current dollars/yr.) - FGERD (constant dollars/yr.)	- GERD (current dollars/yr.) - GERD (constant dollars/yr.)		- GERD (current dollars/yr, growth, index) over time. - FGERD (current dollars/yr, growth, index) over time. - GERD (constant dollars/yr, growth, index) over time - FGERD (constant dollars/yr, growth, index) over time. - GERD/GNP (%) over time. - GERD/GNP (%) vs. 1.5% goal. - GERD/GNP (%) vs. international norm. - FGERD/FBE (%) over time.		GNP (current dollars/yr.) FBE (current dollars/yr.) GNP (constant dollars/yr.) FBE (constant dollars/yr.)
ii) To increase industries share of the performance of research in Canada.		- FGERD by sector of performance (current dollars) - FGERD by sector of performance (%)		GERD by sector of performance (%).	- Performance distribution of GERD over time (%). - Performance distribution of GERD vs. international norm (%).		
iii) To increase industries share of the funding of research in Canada		- Federal government payments to industry for science and technology		- GERD by sector of funding (%)	- GERD by sector of funding over time (%) - GERD by sector of funding vs. international norm (%).		
iv) To maintain the 'health' of federal government intramural science.		- Federal government expenditures on current intramural R&D (current and constant dollars) - Extramural R&D contracts (current and constant dollars) - Federal government payments to industry for science and technology by type of expenditure (current dollars, %) - Federal government extramural expenditures on R&D (current and constant dollars)	- Patent proposals received by CPDL from government departments and agencies. - innovations* - publications* - citations*		- Proposals received by CPDL from government departments and agencies over time. - federal government expenditures on current intramural R&D over time (current and constant dollars, growth, %) - innovations over time* - publications over time* - citations over time* - Intramural vs. extramural funding (growth, %)		
v) To promote the transfer of technology from government laboratories to industry			- patent proposals received by CPDL by department - CPDL summary of royalties (dollars) - CPDL summary of royalties by department (dollars).		- patent proposals received by CPDL by department over time. - CPDL summary of royalties over time.		
vi) To direct the research in government laboratories to areas of national concern and/or opportunity (priorities)		- Federal government expenditures by application (current dollars) - Federal government expenditures by application (%)			- Federal government expenditures by application over time (%)		
vii) To promote a balanced regional distribution of research performed in government laboratories		- Regional expenditure of the federal government on natural science activities (current dollars) - Regional expenditures of the federal government on natural science activities (%)			- Regional Science expenditures/population - Regional Science expenditures/GPE (%)		- Population (by province). - Gross Provincial Expenditure

* Discussed but data not included.

contains various types of indicators measured over time, in relation to normalizing factors, international norms, and goals. It also includes indicators which are related through the text but not directly in a numerical fashion, GERD as a percent of GNP and FGERD as a percent of FBE, for example. The indicators examined which facilitate international and regional comparisons as well as providing, in some way, a standard of measurement are contained in the performance/normalizing factor column.

The level of the real value of the nation's performance of research and development has stagnated over the 1970's after a decade of relatively healthy expansion (see table 2, page 18). The 1978 value of research and development was $2,178 million. However, because of inflation this represents an insignificant increase over the real value of expenditures in 1971, 2.6%. The real value of the federal government's funding of research has exacerbated the national situation by declining by more than 10% in the 1970's, after the expansion of the 60's (see table 12, page 38). The value of federal government expenditures in 1979/80 is $1,054.0 million. However, in real terms there has been a reduction of the value of funding vis â vis the level in 1971/72, of over $60 million dollars.

While the national performance of research stagnated in the 1970's, the value of GNP continued to expand. As a result, the measure of national effort, GERD as a percent of GNP declines over the period from 1.23% in 1971 to .94% in 1978 (see table 4, page 22). The same is true (but more so) of the federal government's research and development effort. Federal Budgetary Expenditures (FBE) grew at an average rate of nearly 8% in real terms while R&D funding declined. As a result the federal funding of research and development (FGERD) as a percentage of FBE has declined almost 2%, from 3.94% in 1971/72 to 2.08% in 1979/80 (see table 14, page 45). Not only is this a further indication that the federal government has contributed to and aggravated the national problem, but it also indicates a reduction of the priority of science in relation to other federal government activity, a contradiction of stated policy. This conclusion must be softened to the extent that initiatives on the tax side have compensated for the reduced expenditure effort.

Over the sixteen year period between 1963 and 1978 the sectoral performance of research and development has shifted, a certain amount, in the direction that is suggested by the norm set by international comparison (see table 8, page 28). (As indicated in Part V,ii), the international norm is not necessarily the distribution to which Canada should aspire). The federal government has decreased its proportion of R&D performed by 10.6% to 31.2% in 1978. Industry has increased its share of performance by 3.8% to 42.6% of the research performed in Canada in 1978. The university sector has increased its share or performance by 7% to 25.5%. Most of this shift in the distribution of performance took place in the 1960's, the period of significant growth of the nation's research and development. Government's performance share decreased by 9.1% between 1965 and 1971, while the university sector offset most of this decrease with an increase of 8.1%. In contrast, the greatest part of industry's increase in performance (2.6%) took place in the 1970's as it was the only sector to have a positive real growth rate. In general, the distribution of the federal government's funding of research and development has supported the change in structure of the nation's performance of research. Discounting the Canadian nonprofit, foreign and other sectors as they are proportionally insignificant, the shifts in government funding were directly related to the proportional shift in the nation's sectoral performance (see table 16, page 48). During the early growth period the government proportional decrease in intramural funding (14.7%) was offset for the most part by an increase in the proportion of funding (11.8%) going to universities. Industry's proportional increase in federal funding between 1963-64 and 1971-72 was only 2.2%. During the 1970's, when the government's real funding declined by $62.5 million, industry suffered, proportionally, the least of this decrease, so that its proportional share of government funding declined by only -0.2%. The distribution of government's funding of research in 1979-80 is: intramural, 52.5%; industry, 21.1%; and universities, 19.2%.

The structure of the funding of national research has been relatively stable over the sixteen year period between 1963 and 1978(see table 9, page 31). Shifts in federal government funding have not had a significant effect on the nation's funding structure. Government was the source of 61.8% of national funding either directly or indirectly through the university sector in 1978. Industry was the source of funding of 34.0% of the nation's research and development. By international standards government's contribution is far too high and industry's too low (see table 11, page 34).

The volatility of nominal growth and negative real growth of the federal government's funding of intramural research and development during the 1970's provide preliminary evidence that the 'health' of intramural science is threatened(see table 18, page 53). In 1979/80 the real value of research performed intramurally is only 81.5% of its 1971/72 level. In current dollars the value of intramural R&D in the natural sciences was $460.2 million. As a measure of output, the patent proposals received by Canadian Patent and Development Ltd. from departments between 1972/73 and 1977/78 tentatively support the expenditure evidence, that the 'health' of intramural science is beginning to suffer. Because international norms ignore basic characteristics such as industrial structure it may be to the nation's disadvantage to support a mixture of policies which would see a continued decline of research performed in house in the hope that sufficient research can be stimulated in other sectors to compensate. In addition to the direct costs, in terms of funding of the 'health' of intramural research, some conflicting policies may result in unaccounted costs in terms of the breaking up of research teams and the loss of the knowledge embodied in members of these teams which decide not to continue as the result of changes in employment conditions.

An emphasis on technology transfer from government laboratories to industry should be one of the policy directions taken in an effort to reduce the conflict between policies which support a shift towards extramural funding and those which require a reversal in the trend of the funding of intramural research. The evidence examined as to whether technology transfer from government laboratories is increasing or decreasing is ambiguous(see table 24, page 71). The other policy mechanism whose emphasis would reduce conflict between intramural and extramural funding would be tax policy.

The examination of government priorities and application data indicate that 56% of the total of federal science expenditures are associated with the government's science priorities (see table 28, page 77). Inconsistency in the terminology relating to the application data, and the lack of benchmark policy statements make it difficult to extend the analysis relating to research on national concerns.

A preliminary analysis indicates that the federal government has had some success at equitably distributing the research which it both performs and funds regionally (see table 31, page 84). Quebec would have to be identified as the exception. This, however, is probably the result of the pattern of development of the provinces academic community. Inconsistency in the collection of regional data does not permit a trend analysis.

III. Conclusions

A number of conclusions have fallen out of the work relating to science indicators as opposed to the analysis of the indicators examined in this report. These are discussed below. They relate to the extension of the work on science indicators along the lines of the policy profile matrix developed here, consideration of parallel approaches which should prove to be valuable to the ministry, future considerations relating to the use or application of the research on science indicators, and housekeeping considerations relating to the ongoing operations of data collection and management.

i) Extension of the Science Indicator Project

- Project Report #2 fulfills the commitments of the Science Indicator project proposal. It is recommended for a number of reasons, however, that the project be extended. The project has been wide ranging in nature and there is work in process which has not been documented or reported on in this paper. This report has emphasized the system approach outlined in the first progress report. As a result, some of the technical documentation should be tightened. There are a number of areas which have not been examined. The whole area of manpower in the scientific system has not been dealt with here. The Science Council of Canada will eventually publish its ongoing work on science indicators. The ministry should be in a position to influence this work, if possible, and/or respond to published material. The Organization for Economic Cooperation and Development has also committed itself to a work plan related to science indicators, and plans to hold an international conference on the subject in the fall of 1980. The ministry should be prepared to contribute to and attend this conference in order to take advantage of the work and knowledge developed by other nations interested in the subject.

- It is proposed that Government Branch continue the work on science indicators related to the government sector, both extending and refining the profile matrix so far developed. As a first step, assuming the concurrence of the committee, a detailed project proposal describing the work to be undertaken will be submitted to PMC.

- It is further proposed that the other branches develop policy profile matrices for their respective sectors with a view to developing a global ministry perspective at a future date.

ii) Related Considerations

- Consideration should be given to developing a number of case studies relating to successful outcomes of the research and development undertaken in government departments. By virtue of data availability, the reduced input side of the research picture is continuously being stressed. It is also necessary to demonstrate the output generated by that research. Case studies of this type could be used as special topics for the 'Federal Science Activities' publication. A good starting point for investigation would be the data on royalties and patents collected by CPDL. Of course, it would be necessary to have the support and concurrence of departments and CPDL for such an exercise.

- In its future efforts related to science indicators the ministry should give substantial consideration to the dynamics of the scientific system and the interdependence of the various sectors of the system. Some preliminary work has been carried out in this area by the Science Council. A simple model has been developed in relation to the university sector which is driven by population and government funding. The dynamic nature of the supply and demand for highly qualified manpower and resources and the output of research itself are of considerable importance to a policy generating ministry such as MOSST.

- There should be a re-examination and documentation of the use of international norms in the determination of science policy in Canada. Although they have been used as guidelines in the past, it may be that the exceptions to the rule are the important considerations with respect to Canada's situation.

- It is possible to infer from the aggregate data available that the 'health' of intramural science is not good particularly with respect to the real level of resources available for that research. However, a detailed diagnosis of the problem of intramural science would require a much more disaggregated, program evaluation type of approach. Further work on the 'health' of intramural science should take this path. (Except for further refinement of descriptive aggregates which are useful in illustrating and monitoring the broader parameters of the situation). The support of departments and their participation and commitment of resources to the generation of the necessary data and other information will be necessary in this approach.

iii) Future Considerations

- The ministry should consider developing a management reporting system based on an extended and refined version of the framework proposed and demonstrated in this report and the previous project progress report. Such a report would provide management with some of the necessary basic information on which policy and management decisions can be based.

- The ministry should consider the strategy of publication of its own perspective on science indicators and the scientific system. This would have the advantage of providing an alternative perspective for public consumption if the need should arise. A substantial amount of additional ground work should be done prior to going public in this fashion. One possible approach would be to incorporate a chapter on science indicators into the 'Federal Science Activities' publication as a prelude to a separate publication.

iv) Housekeeping Considerations

- The data series which form an integral part of the science indicator project should be included as a package in the 'Black Book'. Many of these series could simply be cross referenced for technical description. This would provide a solution to the data management aspects of the science indicator 'problem', tracking, updating and dissemination.

- A significant effort should be made to ensure consistent definition and collection of data. Two specific examples where this has been lacking are regional data and application data. Regional data definitions are inconsistent with the definitions used in the federal government survey and the collection of data has been erratic. The definition of application areas, the categories, have been in a constant state of flux. No concordance exists between the application data and the priority categories presently being used by the ministry.

- A mechanism should be put in place to ensure that revisions to the data base be incorporated consistently into the historical data series, and a sufficient record of such revisions be maintained. An examination of some of the disaggregate data in the historical series suggest spurious discontinuities in the time series. It is possible that the creation of software linkages relating the current and historical data bases with suitable capability for generating historical revisions would be a useful approach to a solution to this problem.

- The historical series should be incorporated into the program review methodology for purposes of review at program forecast and main estimates. The three years of data collected are usually internally consistent. However, discontinuities between currently collected and historical series data can slip by unnoticed. This would not only serve as a benchmark by which to measure new data but would provide a useful review and check on the historical series and recent revisions which had been incorporated into them.

- Efforts to isolate and quantify the foregone revenue due to research related tax policy should be continued. A total picture of the federal government's support of science and technology is not available at this time. A quantitative evaluation of that support is limited by the absence of data in the areas of foregone revenue. No analysis of the relative merits of direct and indirect funding can be undertaken in the absence of tax data.

IV. National Objectives

In June, 1978 the federal government came forward with a clearly articulated policy statement with respect to science and technology in Canada.[1] The general thrust of the policy statement was to recognize the importance of science and technology to the nation and to provide the following broad guidelines:

- to increase the national effort in science and technology. (An explicit goal for this policy objective is to increase the national research and development effort to 1.5% of the gross national product by 1983).
- to increase industry's share of the performance of R&D in Canada.
- to encourage an increase in industry's share of the funding of research in Canada.

Section IV describes some of the indicators which may be used to measure and evaluate the progress towards these objectives.

The policy objective of an increased national R&D effort is usually measured in terms of Gross Expenditure on Research and Development (GERD) and its ratio to Gross National Product (GNP). GERD describes the total research and development performed by a nation. More rigorously, it is defined by the "Frascati Manual" as the 'total intramural expenditure for R&D performed on national territory during a

[1] Buchanan, J., Measures to Strengthen and Encourage Research and Development in Canada. Policy Statement, House of Commons, June 1978.

given period'.[2] Although the formal definition of GERD does not stipulate the natural sciences only, it has generally come to be recognized as a measure of expenditure on the natural sciences by convention, as most countries, including Canada, do not collect statistics on human science R&D across all sectors.

Table 2 describes the behaviour of GERD for Canada between 1963 and 1978.[3] In current dollars, it has grown at an average rate of 11.0% per annum to more than four and a half times the 1963 level of $465 million. However, the real value of GERD, has only doubled between 1963 and 1978. Almost all of that growth took place prior to the 1970's.[4] In other words, the real value of research performed in Canada has remained relatively stagnant since 1971.

GERD takes on an added significance if compared to some standard. The normalizing measures conventionally used are gross national product (GNP) or gross domestic product (GDP). Both are measures of the total output of the nation. The resulting ratio can be loosely interpreted as the percentage

2 OECD, The Measurement of Scientific and Technical Activities, Paris 1976.

3 Statistics Canada, R&D Expenditures in Canada 1963-78, Science Statistics Centre, internal report.

4 The Gross National Expenditure implicit price index (GNE-IPI) is used throughout to deflate Science Expenditures. A number of attempts have been undertaken to derive a science expenditure specific deflator. See Science Council of Canada, Federal Funding of Science in Canada: Apparent and Effective Levels, Working Paper, June 1978. However, it has never been demonstrated satisfactorally that any of the proposed deflators are more appropriate than the GNE-IPI in their application to science expenditures. It has thus been decided to retain a deflator which has some acceptance in general usage.

Table 2

Gross Domestic Expenditure on R&D, Canada (GERD)

	Millions of Current Dollars	Growth (%)	Index 1971=100.0	Millions of Constant 1971 Dollars	Growth (%)	Index 1971=100.0
1963	465		40.0	622		53.5
1964	556	19.6	47.8	726	16.7	62.5
1965	667	20.0	57.4	843	16.1	72.5
1966	757	13.5	65.2	917	11.1	78.9
1967	858	13.3	73.8	999	8.9	86.0
1968	914	6.5	78.7	1030	3.1	88.6
1969	1006	10.1	86.6	1086	5.4	93.5
1970	1066	5.9	91.7	1100	1.3	94.7
1971	1162	9.0	100.0	1162	5.6	100.0
1972	1184	2.0	101.9	1128	-2.9	97.1
1973	1280	8.1	110.2	1117	-1.0	96.1
1974	1472	15.0	126.7	1114	-0.3	95.9
1975	1666	13.2	143.4	1140	2.3	98.1
1976	1776	6.6	152.8	1107	-2.9	95.3
1977	1998	12.5	171.9	1165	5.2	100.3
1978	2178	9.0	187.4	1192	2.3	102.6
Average		11.0			4.7	

of the nation's resources devoted to the research and development function. Technically speaking, the preferable normalizing factor would be GDP. GDP is the analogous economic measure. That is to say, both statistics are geographically defined in that they both relate to performance or production by factors within the geographic boundaries of the nation. GERD, for example, includes research funded by the foreign sector and performed in Canada, but does not include payments for research performed abroad. Likewise, GDP includes the product generated by foreign investment in Canada and excludes the product generated by Canadian investment outside Canada. GNP, by contrast, is defined in terms of nationality of the productive factor. For example, product generated by Canadian investment abroad is included, while product generated by foreign investment in Canada is excluded. However, pragmatic considerations come into play which result in the use of GNP as the normalizing factor generally used in Canada. The Canadian method of calculation measures GDP at factor cost. The OECD method measures GDP at market prices. The methodological difference results in a significant numerical discrepancy. The Canadian measure of GNP, on the other hand, is measured at market prices which makes the domestic GNP statistic roughly comparable to the international GDP statistic.

Table 3 quantitatively describes GNP for the period 1963 to 1978, over which time it has grown by an average of 11.5% and increased by approximately five fold.[5] In real terms, on the other hand, GNP has only doubled over the 16 year

[5] Bank of Canada, Bank of Canada Review, December 1978

Table 3

Gross National Product (GNP)

	Millions of Current Dollars	Growth (%)	Index 1971 = 100.0	Millions of Constant Dollars	Growth (%)	Index 1971 = 100.0
1963	45,978	-	48.7	61,468	-	65.1
1964	50,280	9.4	53.2	65,640	6.8	69.5
1965	55,364	10.1	58.6	69,992	6.6	74.1
1966	61,828	11.7	65.5	74,852	6.9	79.2
1967	66,409	7.4	70.3	77,310	3.3	81.8
1968	72,586	9.3	76.8	81,833	5.9	86.6
1969	79,815	10.0	84.5	86,193	5.3	91.2
1970	85,685	7.4	90.7	88,426	2.6	93.6
1971	94,450	10.2	100.0	94,450	6.8	100.0
1972	105,234	11.4	111.4	100,223	6.1	106.1
1973	123,560	17.4	130.8	107,818	7.6	114.1
1974	147,528	19.4	156.2	111,679	3.6	118.2
1975	165,428	12.1	175.1	113,152	1.3	119.8
1976	191,492	15.8	202.7	119,384	5.5	126.4
1977	210,132	9.7	222.5	122,526	2.6	129.7
1978	232,800	10.8	246.5	127,492	4.1	135.0
Average		11.5			5.0	

period and real growth has averaged about 5%.

GERD as a percentage of GNP is described in Table 4.[6] The proportion of national resources devoted to research and development peaked in 1967 at 1.29%. Between 1967 and 1978 there was a consistent decline to .93%. There is some indication that this downward trend corrected itself in the last two years.

Expressing GERD as a percentage of GNP or GDP normalizes for currency differences and the size of the economic unit. On this basis it is possible to make international comparisons.[7] Table 5 describes GERD as a percentage of GNP for selected OECD countries and selected years 1969-1975. Canada is at the bottom end of the scale in terms of the proportion of domestic product devoted to research and development. Of the countries below the international average of 1.8% it is the only one which exhibits a decidedly negative trend. Other countries whose GERD/GDP declines over the period, the United States, the United Kingdom and the Netherlands, are all substantially above the international average.

Another indicator of interest associated with GERD is its sectoral distribution, both from the perspective of performance and the perspective of funding. Intuitively, the sector of performance implies a position in the spectrum of types of scientific activity; pure research, applied research, development, innovation. Most university research is considered to be basic research, industrial research is generally

6 Statistics Canada, Annual Review of Science Statistics, Catalogue 13-212 Forthcoming May 1979.

7 A number of caveats, usually dealing with different aspects of industrial structure, are associated with this statement. These caveats are critical to policy definition as discussed later in the paper. See page 64.

Table 4

GERD as a Per Cent of GNP

(%)

1963	1.01
1964	1.11
1965	1.21
1966	1.23
1967	1.29
1968	1.26
1969	1.26
1970	1.24
1971	1.23
1972	1.13
1973	1.04
1974	1.00
1975	1.01
1976	0.93
1977	0.95
1978	0.94

Table 5

GERD as a Percentage of GDP
Selected OECD Countries

(%)

	1969	1971	1973	1975
Canada[1]	1.3	1.2	1.0	1.0
Belgium	1.1	1.2	1.3	1.2
France	1.9	1.8	1.7	1.8
Germany	1.7	2.1	2.0	2.1
Italy	0.8	0.9	-	0.9
Japan	1.5	1.6	1.7	1.7
Netherlands	2.1	2.0	1.9	1.9
Sweden	1.3	1.6	1.6	1.8
Switzerland	2.1	1.9	-	2.2
United Kingdon	2.4	2.3	2.1	2.1
United States	2.8	2.6	2.4	2.3
Other Country Average	1.8	1.8	1.8	1.8

[1] GNP is used as the normalizing factor

considered to be applied research or development, while government research is seen as a mixture of mission oriented, applied and basic research.[8] Industrial research is closer to the innovation end of the spectrum, the point in the process at which the economic benefits of the research are most apparent and begin to be realized. For this reason, it is considered important that a significant percentage of the nation's research be performed in industry. This is coincident with the government's desire to reduce, if not reverse, the expansion of the public service.

Table 6 describes the distribution of the performance of research and development in Canada between 1963 and 1978.[9] In 1978 the distribution is government 31.2%, industry 42.6%, university 25.5% and private nonprofit 0.7%. This represents a substantial change from the performance distribution in 1963 which was 41.8, 38.8, 18.5 and 0.9% respectively. Government, as a performer, declined by 10.6% while industry and university increased their shares by 3.8 and 7%.

It is useful to divide the performance distribution into two periods for analysis. Table 7 provides a growth analysis corresponding to the periods 1963-71 and 1971-78. About 95% of the real growth in national science expenditures between 1963 and 1978 took place in the 1960's. All sectors benefited by this growth, some more than others. As a result of the disproportionate participation in growth, the performance distribution shifted in favour of the industry and

[8] At best, this is an over simplification. See H. Whitehead, The Functions of the Federal Scientific Establishment, Internal Report, 1979.

[9] Statistics Canada, Annual Review of Science Statistics, 1978, Catalogue 13-212, May 1979.

Table 6

Total Expenditure on R&D in Canada
by Performing Sector

(%)

	Government	Industry	University	Private Non Profit
1963	41.8	38.8	18.5	0.9
1964	38.8	40.8	19.6	0.8
1965	36.7	43.1	19.4	0.7
1966	35.3	41.9	22.1	0.7
1967	36.2	39.1	24.0	0.7
1968	36.7	37.4	25.2	0.7
1969	33.7	39.1	26.5	0.7
1970	33.0	38.8	27.5	0.7
1971	32.7	40.0	26.6	0.7
1972	34.3	38.8	26.1	0.8
1973	34.7	39.2	25.3	0.8
1974	33.2	41.0	25.1	0.7
1975	31.3	41.8	26.2	0.7
1976	31.4	41.1	26.8	0.7
1977	30.8	42.8	25.7	0.7
1978	31.2	42.6	25.5	0.7
(First difference, %)				
1963–71	-9.1	1.2	8.1	-0.2
1971–78	-1.5	2.6	-1.1	0.0
1963–78	-10.6	3.8	7.0	-0.2

Table 7

Performer Growth Analysis

1963-71

	Government	Industry	University	PNP	Total
Millions of 1971 dollars	120.0	223.3	194.5	2.6	540.4
%	22.2	41.3	35.9	0.5	100.0

1971-78

	Government	Industry	University	PNP	Total
Millions of 1971 dollars	-7.1	43.4	-5.4	-0.2	30.7
%	-23.1	141.4	-17.6	-0.7	100.0

1963-78

	Government	Industry	University	PNP	Total
Millions of 1971 dollars	112.9	266.7	189.1	2.4	571.1
%	19.8	46.7	33.1	0.4	100.0

and university sectors.

Real growth in the 1970's amounted to $30.7 million dollars, only 5% of the total growth of the 1963-1978 period. Industry was the only sector to participate in this growth, however sluggish. In fact, in all other sectors the real value of research performed declined. As a result, industry continued to increase its share of research performed, but the trend was reversed slightly in the university sector. Perhaps it might be expected, but it is interesting to note, that in the earlier period of relatively rapid growth in expenditure, a substantial shift in the distribution of performance was more readily achieved than in the later period of restricted growth. When research expenditures are expanding rapidly shifts in distribution may be accomplished through differential growth, while in times of constrained growth a shift in the distribution involves a real loss to one or more sectors. This is an important observation in the context of the current situation with respect to general government restraint and the desire to facilitate a further increase in the share of industry performance.

Again it is interesting to examine the distribution of the performance of research in Canada in the perspective of the situation in other countries. Table 8 provides this comparison.[10] The average performance distribution for eleven selected OECD countries is: government 22%, industry 59%, university 18% and private nonprofit 2%. In the same year (1975), Canada's performance distribution is: government 31%, industry 42%, university 26% and private nonprofit 1%.

[10] Statistics Canada, Science Statistics, International R&D Statistics, Catalogue 13-003, Vol. 2, No. 2, March 1978

Table 8

Expenditure by Sector of Performance
for Selected OECD Countries

1975
(%)

	Government	Industry	University	Private Non Profit
Canada	31	42	26	1
Denmark	26	41	31	1
Finland	24	57	18	1
France	23	61	15	1
Germany	16	66	18	-
Ireland	50	33	15	2
Japan	13	64	20	3
Norway	20	51	28	-
Spain	36	60	4	1
Sweden	8	69	23	-
Switzerland	7	77	16	-
United States	16	68	13	4
Average	22	59	18	2

Canada's performance distribution is substantially out of balance in comparison to the international norm; both the universities and government sectors are substantially above the international average, while industry is well below. Therefore, although the distribution of GERD in Canada has been adjusting towards increased performance in industry and reduced performance by government, there is still a substantial discrepancy between Canada's distribution and the international norm.

The other indicator related to the distribution of GERD is the source of funding. It is generally understood that industry cannot internalize all the benefits that result from research and development. As a result, it will not finance a socially optimal amount. Ergo, the interest of governments in research and development. Although this is the fundamental rationale for government support of research it is not the only argument. Other reasons are the associated risk, and substantial time frame involved between expenditure and receipt of associated revenues or other benefits. A further interesting observation is that economic theory does not distinguish between support, in the sense of funding research and support, in the sense of performing research. This point will be referred to later in the discussion relating to the government sector. Getting back to the main stream of the discussion, although it is realized that industry in Canada is not in a position to support an optimal amount of research from society's point of view, it is generally felt that it should undertake a greater share of the burden than it has done in the past.

Table 9 describes the behaviour of the distribution of GERD by source of funds for the period 1963 to 1978.[11] In contrast to the distribution of performance by sector, the distribution of funding has remained relatively stable over the sixteen year period. The proportional distribution of funding in 1978 is: government 48.4%, industry 34%, university 13.4%, private nonprofit 1.4% and foreign 2.7%. Although relatively stable, there has been a modest but consistent shift towards an increased proportion of the total research being funded by industry (2.7% over its share in 1963). There are marginal increases in proportional support by the university and foreign sectors of 1.7% and 0.7% respectively, as well. These increases are matched by a decrease in the government's share by 4.8%. Therefore, although the distribution is relatively constant over time, there has been some shift in the desired direction of less government and more support by other sectors, principally industry.

Again, it is useful to analyze the trend in the distribution by dividing the period in two, examining the sector share of real growth as described in Table 10. During the rapid growth phase, 1963-71, all sectors contributed to the incremental funding in roughly the same proportion that they contributed to the base year level of funding. Therefore, the relative stability of the distribution of research support between 1963 and 1971.

Probably, because of the rapid expansion of universities, more than any other reason, there is a marginal increase in

[11] Statistics Canada, <u>Annual Review of Science Statistics, 1978</u>, Catalogue 13-212, Forthcoming, May 1979.

Table 9

Total Expenditure on R&D in Canada
by Funding Sector

(%)

	Government	Industry	University	Private Nonprofit	Foreign
1963	53.2	31.3	11.7	1.8	2.0
1964	52.0	31.6	11.9	1.6	2.8
1965	51.7	31.6	11.1	1.4	4.1
1966	50.7	32.5	12.3	1.3	3.2
1967	53.5	31.8	11.3	1.3	2.1
1968	55.9	30.7	10.3	1.2	1.8
1969	53.4	32.3	11.4	1.2	1.6
1970	52.5	31.3	13.2	1.2	1.9
1971	51.5	31.5	13.5	1.2	2.3
1972	53.2	30.4	12.6	1.2	2.5
1973	53.6	30.6	11.9	1.2	2.7
1974	50.2	33.2	12.7	1.4	2.5
1975	47.2	34.3	14.4	1.4	2.7
1976	47.7	33.2	14.9	1.5	2.7
1977	47.5	34.7	13.6	1.4	2.7
1978	48.4	34.0	13.4	1.4	2.7

(First difference, %)

1963-71	-1.7	0.2	1.8	-0.6	0.6
1971-78	-3.1	2.5	-0.1	0.2	0.4
1963-78	-4.8	2.7	1.7	-0.4	0.7

Table 10

Growth Analysis Funder

1963-71

	Government	Industry	University	PNP	Foreign	Total
Millions of 1971 dollars	267.7	171.2	84.7	2.3	14.6	540.0
%	49.5	31.7	15.7	0.4	2.7	100.0

1971-78

	Government	Industry	University	PNP	Foreign	Total
Millions of 1971 dollars	-20.8	40.4	2.9	3.5	4.7	30.7
%	-67.8	131.6	9.4	11.4	15.3	100.0

1963-78

	Government	Industry	University	PNP	Foreign	Total
Millions of 1971 dollars	246.8	211.6	87.6	5.8	19.3	571.1
%	43.2	37.1	15.3	1.0	3.4	100.0

the support of research by that sector matched by a nearly identical decrease in the proportion of government support, 1.8 and 1.7% respectively. Proportional participation in the growth of research funding between 1971 and 1978 was not the case. However, the amount of real growth, was so small as to minimize the shift in sectoral proportions of support. In the period 1971 to 1978 the real value of government support actually declined by $20.8 million.[12] This was compensated for by increases in support by other sectors, principally industry. As a result, the shift that did occur in the distribution of funding, occurred for the most part in the later, slow growth period, 1971-78. This is also in contrast to the behaviour of the performance distribution which shifted, for the most part, during the earlier, rapid growth period.

Table 11 describes the international perspective relating to the distribution of research support by sector.[13] Government support of research, either directly or indirectly through general university funding, contributes on average to 43% of national research funding. In Canada, the government share, on this basis, is 61%. Industry, on average, supports 52%. In Canada the corresponding proportion is 34%. The imbalance is striking and suggests that although there has been some shift over the past decade, it is dwarfed by the magnitude of the difference which still remains.

[12] See page 39 for a discussion of the leakage problem.

[13] Statistics Canada, Science Statistics, International R&D Statistics, Catalogue 13-003, Vol. 2, No. 2, March 1978.

Table 11

Expenditures by Sector of Funding
for Selected OECD Countries

1975
(%)

	Government		Industry	Other	Foreign
	Direct	General Univ. Funding			
Canada	47	14	34	1	3
Finland	29	15	54	1	1
France	41		40	15	4
Germany	45		53	–	2
Ireland	51	8	34	3	4
Japan	16	11	65	8	–
Norway	34	24	40	1	2
Spain	38		59	1	2
Sweden	39		57	2	2
Switzerland	23		76	–	–
United States	53		43	3	–
Average	43		52	4	2

V. Government Objectives

i) The Federal Government as a Funder of Research and Development and National Objectives

The general national objectives for research in Canada referred to in section IV of this report were an expanded national research effort, increased performance in industry and increased funding by industry. There are two ways in which the federal government can affect the national research and development picture. First, because federal government funding represents such a large portion (41.6%, 1978) of the nation's research effort, the direction of national expenditures on R&D over time quite naturally reflect the trend in federal government funding.[14] Secondly, expenditures by the federal government can also induce additional expenditures on research by other sectors, particularly industry.[15] Of course, the direct funding of research and development is not the only avenue by which the federal government impacts on the national R&D picture. Other mechanisms include regulation and administration, and indirect funding in the form of tax deductions and credits.

The picture of federal government activity in support of national scientific activity is understated, most particularly with respect to foregone revenue. As Canadian tax law is most liberal in this regard, this understatement is significant relative to other countries.[16] A general, underlying principle of taxation in Canada is that expenses may be written off in the year in which the associated revenue is

[14] Statistics Canada, R&D Expenditures in Canada, 1963-78, Science Centre, Internal Report.

[15] McFetridge, D.G., Government Support of Scientific Research and Development: An Economic Analysis. Economic Council of Ontario.

[16] a) MOSST, Tax Incentives for Industrial Research and Development, Federal-Provincial Conference of Officials on Industrial Research and Development, Oct. 5, 1978.
b) Finance, Budget Papers, Notice of Ways and Means Motions and Supplementary Information on the Budget. Nov. 16, 1978

realized. Research and development is one of those types of expenditures which is not easily linked to revenues of any specific period. As a result, prior to 1944, R&D expenses were not allowed as a write-off except in the unusual situation where it could be shown that they were directly linked to the revenues of the period. However, the situation with respect to taxation and research and development has been progressively liberalized up to and including the latest budget speech (November 16, 1978). The situation is now 100% deductability of current and capital expenditures plus an additional 50% for those R&D expenditures which exceed the past three year average. The latter is to be in effect for a 10 year period. The deduction of current R&D expenditures simply renders the treatment of all current expenditures the same. The deduction of capital expenditures is basically accelerated depreciation which increases a firm's cash flow. The additional 50% deduction also differentiates R&D expenditures in a preferential way. Research and development is also eligible for the graduated investment tax credit which was increased to a minimum of 10% and whose termination date was repealed. Unfortunately revenue foregone by the government in deference to the support of research and development is not available. Because the hundred percent write-off of current R&D expenditures is not differentiable from other current expenses, data on these deductions will probably never be captured. This is probably not as important as is obtaining a measure of the foregone revenue due to the differential treatment of R&D, although a total support figure would be ideal. Negotiations to obtain tax data relating to research and development have been underway for some time. It is expected that a limited amount of data with respect to the investment tax credit will soon be available. In the mean time, it is necessary to proceed with the best picture of federal support of national scientific activity as possible, direct funding.

The indicator of direct funding by the federal government which is analogous to GERD is total government expenditure on R&D in the natural sciences. This measure includes capital expenditures and administration of extramural program costs (AEP). Table 12 exhibits federal government expenditures on research and development for the years 1963/64 through 1979/80.[17] Expenditures in current dollars have grown at an average annual rate of 9.6%, from $246.0 million in 1963/64 to $1,054.0 million in 1979/80.[18,19] In constant dollars, however, the average annual growth has only been 3.4%. The real growth rate over the 70's has been negative. The value of government's funding of research in 1971 dollars is $541.9 million in 1979/80, representing 89.7% of the 1971/72 value of research funded. The growth rates in the most recent years do not indicate a recovery of the trend of negative real growth in science funding by the federal government.

A comparison of the federal government expenditures on R&D and the GERD series discussed in section IV indicate that both avenues by which federal expenditures can affect the national R&D picture are operative. During the 1960's real federal government expenditures on R&D grew at an

17 Statistics Canada, Annual Review of Science Statistics, 1978, Catalogue 13-212, Forthcoming, May 1979.

18 The years 1977/78 through 1979/80 were taken from the current survey of Federal Government Scientific Activity. Estimates of nonprogram costs have not been included.

19 Total Government expenditure on R&D in the natural sciences also understates government involvement in scientific activity. Total government expenditure on science in 1979/80 is estimated to be $1,853.4 million. See appendix A for additional data on government expenditures.

Table 12

Total Federal Government Expenditures
on Research and Development
(FGERD)

	Millions of Current Dollars	Growth (%)	Index (1971/72=100.0)	Millions of Constant 1971 Dollars	Growth (%)	Index (1971/72=100.0)
1963-64	246.0	-	40.7	328.9	-	54.4
1964-65	282.0	14.6	46.7	368.1	11.9	60.9
1965-66	339.9	20.5	56.2	429.7	16.7	71.1
1966-67	382.0	12.4	63.2	462.5	7.6	76.5
1967-68	446.0	16.8	73.8	519.2	12.3	85.9
1968-69	515.3	15.5	85.3	580.9	11.9	96.1
1969-70	530.0	2.9	87.7	572.4	-1.5	94.7
1970-71	573.0	8.1	94.8	591.3	3.3	97.8
1971-72	604.4	5.5	100.0	604.4	2.2	100.0
1972-73	636.4	5.3	105.3	606.1	0.3	100.3
1973-74	700.9	10.1	116.0	611.6	0.9	101.2
1974-75	749.4	6.9	124.0	567.3	-7.2	93.9
1975-76	803.1	7.2	132.9	549.3	-3.2	90.9
1976-77	889.8	10.8	147.2	554.7	1.0	91.8
1977-78	918.0	3.2	151.9	535.3	-3.5	88.6
1978-79	1,009.6	10.0	167.0	552.9	3.2	91.5
1979-80	1,054.0	4.4	174.4	541.9	-2.0	89.7
Average		9.6			3.4	

average annual rate of 8.1%. This was matched by a national rate of 8.1%. The negative growth of federal science in the 1970's is reflected in a 0.4% growth in national R&D for the same period. Although the analysis is more dramatic when done in real terms, the relatively slower nominal growth of government funding impacts on the trend of GERD in the same way.

In view of the fact that the trend in government expenditures exhibits no indication of correcting itself and the demonstrated interdependence of federal government funding and GERD, the data tend to contradict stated objectives with respect to giving priority consideration to science and technology and expanding the national research effort. However, 1979/80 will be the first fiscal year in which the full scope of government policy, including tax policy, will be in effect. It is not known to what extent increased tax incentives will offset the slow growth of federally funded research. New estimates for GERD in 1979 will provide evidence as to whether tax incentives have stimulated industrial R&D expenditure sufficiently to offset the decrease in real government funding (or the slowness of the growth of current dollar funding).

It is appropriate, when comparing GERD and federal funding of R&D, to insert a note relating to the 'leakage' problem. GERD data is a combination of the results of several different surveys. In the compilation of GERD, the convention when reconciling these surveys, is to use the performer's response. 'Leakage' refers to the differential that chronically exists between the federal funding which industry reports receiving and the funding which the government survey indicates as being directed to industry. Government contracts to industry are always larger than those reported as being received by industry. According to the convention then, government expenditures, for the purpose of GERD, must be adjusted downward. Thus, when the GERD government funding series and the federal survey government funding series are compared, the latter is always larger. Besides the normal errors of observation on both sides, there is a more fundamental definitional problem. Partial contracts of government research to industry may not be perceived to be related to R&D. Clearing a landsite for a laboratory may be considered a scientific expenditure by the government, but not by the contractor. As a result, there is a discrepancy in what government and industry report as contracted research and development. Some attempts have been made to rectify the problem in terms of having the larger science based federal government agencies report such expenditures as intramural expenditures. In addition the most recent survey of industrial R&D has also taken steps to rectify the problem by requesting the source department of the contracts which firms receive from government. This will allow a detailed comparison of the two surveys and more specific identification of the discrepancies.

As is the case with the GERD/GNP indicator, federal government total expenditures on R&D take on an added significance when compared to some standard. A measure of the total budgetary expenditure of the federal government is the direct analogy to GNP. It is a measure of the total resources government has at its disposal. Table 13 describes the behaviour of total federal budgetary expenditure for the period 1971/72 to 1979/80.[20] The use of budgetary expenditures is a step in the direction of recognizing the concept of 'discretionary expenditures'.[21] Although the government budgetary process is on an annual cycle, a large portion of the government's expenditures are committed for an indefinite period, because of either statutory, contractual or other relatively permanent arrangements. As a result, the amount of resources which the government can shift between expenditure priorities from year to year is limited. The concept of discretionary expenditures is time dependent. In the short term, especially in a period of general constraint, uncommitted funds are extremely limited. The current budgetary period provides a good example. The growth in government expenditures is virtually equivalent to the increase in program costs. Any new initiatives or the expansion of existing program must be funded through a reallocation of expenditures, a cutting back of services in some other area. This is a painful process at the best of times, and government is limited, in the short term, to extracting funds from areas where it has no legislated or other contractual commitment. In the longer term it can be expected that a larger portion of the federal budget is discretionary, as legislated termination of commitments is possible and other contractual

[20] a)Canada, Public Accounts, for the fiscal years ended March 31, 1973 1977 and 1978
b)Canada, Main Estimates, for the fiscal year ended March 31, 1980.

[21] Budgetary Expenditures, although they exclude nonbudgetary items, substantially overstate discretionary expenditures because of other types of fixed commitments. The use of budgetary expenditures is only a token recognition of the concept of discretionary expenditures. The Treasury Board Secretariat is currently engaged in a project to determine the actual value of government discretionary expenditures.

Table 13

Total Federal Budgetary Expenditures
(FBE)

	Millions of Current Dollars	Growth (%)	Index (1971/72=100.0)	Millions of Constant 1971 Dollars	Growth (%)	Index (1971/72=100.0)
1971/72	15,341.0	-	100.0	15,341.0	-	100.0
1972/73	18,645.0	21.5	121.5	17,757.1	15.7	115.7
1973/74	22,839.0	22.5	148.9	19,929.3	12.2	129.9
1974/75	29,245.0	28.0	190.6	22,138.5	11.1	144.3
1975/76	33,987.0	16.2	221.5	23,246.9	5.0	151.5
1976/77	39,011.0	14.8	254.3	24,321.1	4.6	158.5
1977/78	42,882.0	9.9	279.5	25,004.1	2.8	163.0
1978/79	47,634.3	11.1	310.5	26,086.7	4.3	170.0
1979/80	50,767.7	6.6	330.9	26,101.6	5.7	170.1
Average		16.3			7.7	

arrangements expire. Therefore, it is more likely that shifts in the direction of stated priorities will be observed in the long term. Expenditures on science and technology are not exempt from this fact of life, and can not be expected, under current circumstances, to acquire a significantly greater proportion of the federal budget in the short term. ie. The current fiscal year. (See paragraph 2 page 44).

Federal budgetary expenditures have grown at a significant rate (16.3%) since 1971/72. The 1979/80 value of $50,767.7 million is more than three times the level of 1971/72 expenditures. This compares to a growth of 13.8% for GNP over the same period. The differential in growth has resulted in federal expenditures increasing as a proportion of the nations product from 16.2% in 1971/72 to 22.6% in 1978/79. The real growth in budgetary expenditures has been substantially less than the growth in current dollar terms, 7.7%. In consequence, government expenditures in 1971 dollars have less than doubled over the period.

The trend in real growth in government budgetary expenditures suggest that constraint set in after 1974/75. Budgetary expenditures between 1975/76 and 1979/80 exhibit an average real growth of 4.5% versus double digit real growth in prior years. Federal government expenditures on research and development have an average real growth rate of -0.9% between 1975/76 and the present. This differential growth in the period of general government constraint lends credence to the idea that 'when things get tough research and development is the first to suffer', the rationale, of course, being that the impact of other government services is more immediate and visible. Therefore, managers restrict or pare down R&D in preference to other line oriented activities.

Table 14 describes federal government expenditures on R&D in the natural sciences as a percentage of budgetary expenditures between 1971/72 and 1979/80. The proportional significance of science to the federal budget has decreased consistantly over the period, from 3.94% in 1971/72 to 2.08% in 1979/80. The trend indicates a decrease in the priority of science with respect to other government activity, in contrast to recent statements that the S&T activity of the federal government was to be of high priority. It should be recalled at this point, however, that expenditures on science do not represent the total scientific activity of the government. There is the foregone revenue designed to stimulate industrial research as well. Also, the concept of discretionary income enters into the picture and it is understandable that a reverse in the trend of the proportion of science expenditures has not occurred or is not estimated to have occurred in the short term. It may well be significant that the marginal decrease in the proportion of the federal budget devoted to science which appears to be smaller in the most recent years of the series, indicates a slowing down in the rate of change and possible reversal of the trend. The analogous national indicator, GERD/GNP, once again, mirrors the federal government indicator.

Tables 15 and 16 describe the sectoral distribution

Table 14

Federal Government Expenditures
on R&D in the Natural Sciences
as a percentage of
Budgetary Expenditures

%

1971/72	3.94
1972/73	3.41
1973/74	3.07
1974/75	2.56
1975/76	2.36
1976/77	2.28
1977/78	2.14
1978/79	2.12
1979/80	2.08

of the government funding of R&D by performer.[22] In 1979-80 total government expenditures of $1,054.0 million are divided as follows: - intramural, $553.1 million or 52.5%; industry, $222.6 million or 21%, university, $202.5 million or 19.2%; the balance, 7.2% being distributed between nonprofit, foreign and other performers. The distribution of funding has shifted substantially between 1963/64 and 1979/80. Government performance as a proportion of total funding has decreased by 18.8% from 71.3% to 52.5% in 1979/80. Over half of this decrease has been compensated for by a proportional increase in university funding of 10.8%. The balance of the offset of the decrease in government performance, 8% is distributed between industry, foreign and other performers; industry increasing in proportion to the total by 2% over the period.

As in the case of the performance distribution of GERD, it is informative to examine the sources of change in the distribution in the context of analysis of the growth of real expenditures as per table 17. Between 1963 and 1971 federal government expenditures on R&D grew, in real terms, by $275.5 million. All sectors participated in this real increase in research funding. However, this participation was disproportionate in relation to the original distribution. Therefore, although 39.1%, or $107.8 million of the real increase in government funding was absorbed by intramural research, it decreased in proportional importance by 14.7%. The university sector, on the other hand, which starts with a relatively small base, 8.4%, absorbed a

[22] Statistics Canada, Annual Review of Science Statistics, 1978, Catalogue 13-212, Forthcoming, May 1979.

Table 15

Federal Government
Total Expenditures on R&D
in the Natural Sciences,
by Performing Sector,
1963-64 to 1979-80

$'000,000

Performer

Year	Federal Government	Canadian Industry	Canadian Universities	Canadian Non-Profit Institutions	Other Canadian	Foreign	Total
1963-64	175.3	47.0	20.7	2.1	0.6	0.2	246.0
1964-65	195.5	55.8	27.8	2.2	0.6	0.2	282.0
1965-66	221.8	75.5	39.1	2.2	0.9	0.4	339.9
1966-67	241.2	83.6	53.3	2.2	0.9	0.7	382.0
1967-68	282.1	79.4	78.2	3.4	1.6	1.3	446.0
1968-69	304.6	101.3	98.9	3.8	2.6	4.0	515.3
1969-70	305.7	102.3	113.1	3.5	1.3	4.1	530.0
1970-71	318.1	129.9	115.9	3.4	1.5	4.1	573.0
1971-72	342.2	129.0	122.1	3.5	1.7	5.9	604.4
1972-73	364.8	133.7	122.2	3.8	2.9	8.9	636.4
1973-74	397.1	156.8	127.8	3.1	5.1	11.0	700.9
1974-75	440.0	147.5	132.6	3.4	7.1	18.8	749.4
1975-76	466.4	159.1	139.6	4.7	6.0	27.4	803.1
1976-77	495.0	198.4	148.5	8.7	10.5	28.7	889.8
1977-78	506.4	188.4	171.1	7.2	18.3	26.6	918.0
1978-79	561.6	204.9	191.9	8.0	17.1	26.1	1009.6
1979-80	553.1	222.6	202.5	8.0	38.2	29.6	1054.0

Includes AEP and capital expenditures.

Table 16

Federal Government
Total Expenditures on R&D
in the Natural Sciences,
by Performing Sectors,
1963-64 to 1979-80

%

Performer

Year	Federal Government	Canadian Industry	Canadian Universities	Canadian Non-Profit Institutions	Other Canadian	Foreign
1963-64	71.3	19.1	8.4	0.9	0.2	0.1
1964-65	69.3	19.8	9.9	0.8	0.2	0.1
1965-66	65.3	22.2	11.5	0.6	0.3	0.1
1966-67	63.1	21.9	14.0	0.6	0.2	0.2
1967-68	63.3	17.8	17.5	0.8	0.4	0.3
1968-69	59.1	19.7	19.2	0.7	0.5	0.7
1969-70	57.7	19.3	21.3	0.7	0.2	0.8
1970-71	55.5	22.7	20.2	0.6	0.3	0.7
1971-72	56.6	21.3	20.2	0.6	0.3	1.0
1972-73	57.3	21.0	19.2	0.6	0.5	1.4
1973-74	56.7	22.4	18.2	0.4	0.7	1.6
1974-75	58.7	19.7	17.7	0.5	1.0	2.5
1975-76	58.0	19.8	17.4	0.6	0.7	3.4
1976-77	55.6	22.3	16.7	1.0	1.2	3.2
1977-78	55.2	20.5	18.6	0.8	2.0	2.9
1978-79	55.6	20.3	19.0	0.8	1.7	2.6
1979-80	52.5	21.1	19.2	0.8	3.6	2.8

(First Differences, %)

Year	Federal Government	Canadian Industry	Canadian Universities	Canadian Non-Profit Institutions	Other Canadian	Foreign
1963-71	-14.7	2.2	11.8	-0.3	0.1	0.9
1971-80	- 4.1	-0.2	-1.0	0.2	3.3	1.8
1963-80	-18.8	2.0	10.8	-0.1	3.4	2.7

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Table 17

Federal Government Funding of R&D
Growth Analysis

1963-71

	Government	Industry	University	PNP	Other	Foreign	Total
Millions of 1971 dollars	107.8	66.2	94.4	0.7	0.9	5.6	275.5
%	39.1	24.0	34.3	0.3	0.3	2.0	100.0

1971-78

	Government	Industry	University	PNP	Other	Foreign	Total
Millions of 1971 dollars	-57.8	-14.6	-18.0	0.6	17.9	9.3	-62.5
%	92.5	23.4	28.8	-0.9	-28.6	-14.9	100.0

1963-79

	Government	Industry	University	PNP	Other	Foreign	Total
Millions of 1971 dollars	50.0	51.6	76.4	1.3	18.8	14.9	213.0
%	23.5	24.2	35.9	0.6	8.8	7.0	100.0

relatively large proportion of the increase, 34.3% or $94.4 million. This boosts universities proportion of the total by 11.8% over the period. Industry's participation in the growth of government funding, 24.0%, was more or less in proportion to its original share of the total, 19.1%. As a result it expands its share by only 2.2%. All the real growth in government funding of R&D took place in the 60's and this is the period in which the major shift of the distribution of federal funding took place. The growth of federal funding in the 1970's was actually negative, decreasing by $62.5 million dollars in real terms. Intramural science absorbed the greatest proportion of this reduction in funding and as a result lost another 4.1% share of the total funding. The industry and university sectors participated in the decrease in funding in proportion to their original shares and no significant change in their proportions of the total are observed. Other Canadian performers and the foreign sector did not participate in the reduced funding, but received increases and therefore increased their shares of the total during this period.

The evidence provided by the data on the distribution of federal government R&D funding is ambiguous. On the one hand, it appears to deny one of the major thrusts of science policy over the 1970's, the encouragement of increased industrial performance. Contrary to the intention of initiatives such as contracting-out, industry's share of the total of federal R&D expenditures has stagnated. In real dollars it has lost $14.6 million in annual funding. In contrast, industry's share of the performance of national research has increased marginally during the period by 2.6% (see Table 6). This may suggest that other mechanisms of government industrial support have compensated for the reduction of direct funding. On the other hand, on the question of encouraging industrial self funding of research, the real reduction in government support appears to have had a positive impact, industry's share of the funding of the nation's research effort having increased marginally by 2.5% (See Table 9).

ii) The Maintenance of the 'Health' of Federal Government Intramural Science

The maintenance of the 'health' of intramural science is one objective which is directed specifically at the performance of research in the government sector as opposed to relating to broader, national policies and objectives. It is the number of objectives which conflict with that of the 'health' of intramural science which have made it an issue.

The 'health' of intramural science is a particularly difficult concept to define, not withstanding operationalizing it in terms of science indicators. Two significant dimensions of 'health' appear to be: the continuity of competence and good management. The phrase 'continuity of competence' has both quantitative and qualitative implications. The term 'continuity' implies uninterrupted or consistent. 'Competence' implies a certain level and quality of output. One measure of support is the level of funding of intramural scientific activity. Federal government current expenditures on intramural research and development are described in table 18.[23] Intramural R&D funding increases by about 60% between 1971/72 and 1979/80, to a level of $460.2 million in 1979/80. However, the rate of growth in current dollars has been erratic (not uninterrupted, inconsistent). For example, in 1978/79 the rate was 12.8% vs a -5.3% estimate for 1979/80. This discontinuity in the growth of research expenditures tends to suggest interrupted and constrained progress on scientific activity. The discontinuity in the growth of research funding means that

[23] Statistics Canada, Annual Review of Science Statistics, 1978, Catalogue 13-212, Forthcoming, May 1979.

Table 18

Federal Government Expenditures
on Current Intramural R&D
Natural Science

	Millions of Current Dollars	Growth (%)	Index (1971/72=100.0)	Millions of Constant 1971 Dollars	Growth (%)	Index (1971/72=100.0)
1971/72	290.4	-	100.0	290.4	-	100.0
1972/73	314.3	8.2	108.2	299.3	3.1	103.1
1973/74	341.8	8.7	117.7	298.2	-0.3	102.7
1974/75	378.7	10.8	130.4	286.7	-3.9	98.7
1975/76	393.2	3.8	135.4	268.9	-6.2	92.6
1976/77	426.6	8.5	146.9	266.0	-1.1	91.6
1977/78	430.7	1.0	148.3	251.1	-5.6	86.5
1978/79	485.9	12.8	167.3	266.1	6.0	91.6
1979/80	460.2	-5.3	158.5	236.6	-11.1	81.5
Average		6.1			-2.4	

planning takes place in an atmosphere of uncertainty, hampering effective use of a management activity that can be considered to intrinsically imply the long term.

The real growth in government expenditures on intramural R&D has been negative, averaging -2.4% between 1971/72 and 1979/80. Funding in 1979/80 is estimated to be 81.5% of the 1971/72 value. Thus, in 1971 dollars the 1979/80 level of funding is $236.6 million as compared to $290.4 million in 1971/72. This means that either the quality or quantity of goods and services purchased as inputs to research activity has decreased. In either case, this must reflect on the research performed intramurally in a negative manner, either, reduced output (unless there has been a corresponding productivity increase with respect to R&D performance over the period, a phenomenon for which there is no supporting evidence) or reduced quality of output. The evidence provided, therefore, by this aggregate measure of intramural R&D expenditures suggests that the 'health' of intramural science (as defined) is threatened. Inconsistent, nominal growth threatens the 'continuity' of performance of R&D and its 'good management'. The decrease in real funding threatens the level of 'competence' of research performed.

The above paragraph makes the inference that, because the real value of inputs has decreased, the output of the government sector's research must have suffered, either quantitatively or qualitatively. For further evidence it is necessary to go directly to output measures of intramural scientific activity. Some measures of the output of government laboratories are: patents, innovations, publications, and citations. Patents represent not only a measure of the quantity or level of output, but to some extent, a measure of quality as well. Proposals which have successfully survived the screening of the patenting process can (with reservation) be considered to be meaningful advances in technology.[24] As described in section V iii), because of an idiosyncracy in the accounting system, Canadian Patent and Development Ltd. does not have readily accessible data on the number of patents registered on an annual basis. It does, however, have an annual statistic on patent proposals. The patent proposals by government departments and agencies for the years 1972/73 through 1977/78 are described in table 19.[25] As these are only proposals, it is not possible to attribute the statistic with the capacity to indicate quality. It does, however, provide some indication of the quantity or level of output of government laboratories. The series covers a relatively short period of time and is quite volatile as indicated by the index. This being the case, it is difficult to determine a trend in the data. However, there is a suggestion that the quantity of applications has decreased in the more recent years. This suggests that the level of output of government research has fallen off and supports, in a tentative fashion, the inference drawn from the intramural expenditure data that the 'health' of science is threatened.

Other outputs of research in the government sector mentioned above are innovations, publications and citations.

[24] See Section V iii) on technology transfer, for a discussion of the caveats usually associated with patents as a science indicator. Page 67.

[25] Canadian Patent and Development Ltd., Patent Proposals Received, Annual internal statement.

Table 19

Number of Proposals Received by CPDL
from Government Departments and Agencies

	Number	Index (1972/73=100.0)
1972/73	174.5	100.0
1973/74	187.0	107.2
1974/75	191.5	109.7
1975/76	162.0	92.8
1976/77	178.0	102.0
1977/78	152.5	87.4

Measures of these are not provided here. Very little work has been done in the area of innovations in Canada generally, not to mention innovation specific to the government sector.[26] Providing summary evidence on innovations within the government sector or otherwise would require a special survey. Royalty data does provide some evidence that innovation has taken place (See Section V iii) on technology transfer). It may be more tractable to mount a number of case studies using the royalty data as a starting point of investigation.[27] Such an approach would provide evidence on 'success stories', however, and not aggregate indicators with respect to innovative activity.

Publications and citations are also measures which would provide evidence on the level and quality of output of scientific activity. Again, no government sector specific work has been done in this area. The Science Council of Canada has, however, done a substantial amount of ground work in the area of publication and citation counts for Canada.[28] The ground work consisted of the establishment of a Canadian Research File which includes bibliometric data on publications and citations. The work is ongoing and the possibility of extending it to a sectoral analysis is being explored.

26 a) Some work has been carried out by Statistic Canada on innovation in Canadian industry. See Selected Statistics on Technological Innovation in Industry, Catalogue 13-555, Occassional, January 1975

b) For work done in the U.S. see - Gellman Research Associates, Indicators of International Trends in Technological Innovation, Report prepared for the National Science Foundation, April 1976.

27 Canadian Patent and Development Ltd., Summary of Royalties and Payments, Annual Report.

28 a) Science Council of Canada, Science Indicators in a Policy Environment. Paper prepared for the Task Force on Research in Canada. November 1977.

b) Science Council of Canada, Self-Destruct Mechanisms and Centres of Excellence in Canadian University Research, Draft paper, June 1978.

Returning to the definition of 'health', the discussion on intramural expenditures of scientific activity touched on one function of management, planning. There are a number of others including: control, co-ordination and allocation. These functions are not particularly amenable to quantitative description and therefore, are not subjects to which science indicators can be profitably applied. 'Allocation', perhaps, can be analyzed in the context of a posteriori assessment of stated priorities. For an example of this type of analysis see section V iv) on priorities and application data. Otherwise, the 'good management' aspect of the 'health' of science is a subject best suited to detailed program evaluation.

The opening paragraph of this section suggested that the 'health' of intramural science was concerned with the performance of research in the government sector, but that it was the number of conflicting government objectives with respect to science policy which have made the 'health' of science an issue. These conflicting objectives relate to the government's role as both performer and funder. Policies which support these conflicting objectives include: contracting-out, privatization, decentralization and general government restraint.

The contracting-out policy was established in 1972. Its intent was to increase the amount of research and development performed in Canadian industry by purchasing the government's requirements for mission-oriented research from that sector. Historical data with respect to extramural contracts for R&D is available from 1975/76. Table 20 describes total extramural contracts on R&D for the period 1975/76 to 1979/80.[29]

[29] Statistics Canada. Natural Science Historical Data Base.

Table 20

Total Extramural R&D Contracts

	Millions of Current Dollars	Growth (%)	Index (1975/76=100.0)	Millions of Constant Dollars	Growth (%)	Index (1975/76=100.0)
1975/76	64.7	-	100.0	44.3	-	100.0
1976/77	90.4	39.7	139.7	56.4	27.3	127.3
1977/78	103.7	14.7	160.3	60.5	7.3	136.6
1978/79	139.7	34.7	215.9	76.5	20.9	172.7
1979/80	137.2	-1.8	212.1	70.5	-7.8	159.1
Average		21.8			11.9	

The average annual rate of growth of contracted research is 21.8%. Contracts have more than doubled in the five year period, to a value of $137.2 million in 1979/80. The picture in constant dollars, is less dramatic but still impressive. The rapid rate of expansion of contracted research is one of the causes for the concern for the health of intramural science. It is feared that, carried to its logical conclusion, and in view of the rapid growth of research contracts, it will not be too long before most intramural scientific activity has fallen victim to contracting-out. In point of fact, however, there is little substance on which to base this anxiety. Table 21 examines payments by the federal government to industry for S&T.[30] The indication is that a significant portion of the growth of contracted research is contributed to by a corresponding decrease in the proportion of R&D grants and contributions. That is to say, the apparent growth in contracted research has been accomplished, to a large extent, by changing the type of financing of extramural expenditures and not by a reduction in intramural science. A comparison of intramural and extramural expenditures on R&D further substantiates this conclusion. Table 22 describes federal government extramural funding of R&D between 1971/72 and 1979/80.[31] The growth of extramural funding averages 8.5% in current dollar terms, compared to 6.1% (Table 18) for intramural funding, a difference of only 2.4%. Although this differential may be significant over the long term, it will, by no means, result in the dramatic shift in structure suggested by the rapid expansion of contracted research. The real culprit appears to be the

[30] Statistics Canada. <u>Natural Science Historical Data Base</u>.

[31] Statistics Canada. Annual Review of Science Statistics, 1978 Catalogue 13-212. Forthcoming, May 1979.

Table 21

Federal Government Payments to Industry for Science and Technology, Natural Sciences

($ 000,000)

	R&D Contracts	R&D Grants	Research Fellowships	RSA	Total
1975/76	50.3	108.0	0.8	44.4	203.5
1976/77	76.2	121.3	0.9	55.4	253.8
1977/78	85.9	101.2	1.2	56.6	245.0
1978/79	121.1	82.2	1.7	65.5	270.4
1979/80	116.6	104.1	1.8	54.4	276.9
			(%)		
1975/76	24.7	53.1	0.4	21.8	100.0
1976/77	30.0	47.8	0.4	21.8	100.0
1977/78	35.1	41.3	0.5	23.1	100.0
1978/79	44.8	30.4	0.6	24.2	100.0
1979/80	42.1	37.6	0.7	19.6	100.0
			(First Differences, %)		
1975/76–1979/80	17.4	-15.5	0.3	-2.2	0.0

Table 22

Federal Government Extramural Expenditures
on R&D in the Natural Sciences

	Millions of Current Dollars	Growth (%)	Index (1971/72=100.0)	Millions of Constant Dollars	Growth (%)	Index (1971/72=100.0)
1971/72	262.2	-	100.0	262.2	-	100.0
1972/73	271.5	3.5	103.5	258.6	-1.4	98.6
1973/74	303.8	11.9	115.9	265.1	2.5	101.1
1974/75	309.4	1.8	118.0	234.2	-11.7	89.3
1975/76	336.8	8.9	128.5	230.4	-1.6	87.9
1976/77	394.8	17.2	150.6	246.1	6.8	93.9
1977/78	411.6	4.3	157.0	240.0	-2.5	91.5
1978/79	448.0	8.8	170.9	245.3	2.2	93.6
1979/80	500.9	11.8	191.0	257.5	5.0	98.2
Average		8.5			-0.1	

slow rate of growth of total funding over the period 1971/72 to 1979/80 (See Table 12) and general government restraint (See Table 13).

Of the policies in conflict with the objective of the 'health' of intramural science, contracting out is the most notable example. Privatization works towards the same end, the shift of the performance of research to the private sector. General government restraint acts to reduce or constrain the growth of the total science budget so as to increase the impact of sectoral shifts in funding (ie. it becomes less a question of differential growth than a question of a reallocation of real funding dollars from one sector to another). These conflicting policies impose a visible cost on the 'health' of intramural science. There is also an invisible cost associated with these sectoral shifts in research performance which results from the nature of research output. The output of research is 'new knowledge' in various forms, publications, physical technology, but perhaps, most importantly knowledge embodied in the scientists, engineers and technicians who participated in the research. Decentralization provides an example of how this invisible cost may be incurred, in this case as a result of a geographic shift in structure. An undesirable or inconvient geographic reallocation may result in the loss of a significant portion of the research team associated with a specific research effort. The embodied knowledge of that part of the research team which chooses not to move is a real loss to the program but not an accounted cost.

Any consideration of the 'health' of intramural science, especially in the light of the number of conflicting objectives, would be remiss if it did not take, at least, a cursory look at the rationales behind these objectives. Perhaps the conflicts are generated by inappropriate policies. The rationales in support of objectives relating to sectoral shifts in performance and funding are based partly on economic theory, partly on intuition and partly on the observation of the international situation. Price theory provides an economic rationale for the support of research and development by the public sector (See the discussion of distribution of the source of funding. Page 21).[32] It is reasoned intuitively that this support would be in the form of direct or indirect funding and that the research would necessarily be performed by industry. An equally valid alternative to this form of support might be the performance of this research within government facilities (which have developed a significant capacity more as the result of historical accident than anything else) with sufficient attention paid to effective transfer of the technology developed. A case for the standard rationale is made by reference to international statistics relating to the distribution of the performance of research. (See the discussion of the distribution of performance in OECD countries, page 27, Table 8). These international comparisons are taken as the norm and proof of substance of the rationale behind the domestic policy objective of shifting Canadian research into the industrial sector. What these international comparisons do not do is take important considerations, such as industrial structure, into account. The structure of the Canadian economy is unique in terms of its degree of direct foreign control, for example. It has been shown that the subsidiaries of foreign parent companies in any given industrial sector are not as

32 McFetridge, D.G., Government Support of Scientific Research and Development: An Economic Analysis, Economic Council of Ontario.

research intensive as their Canadian owned counterparts. It is possible that it is not science policy which will remedy the industrial performance of research problem, but a more fundamental policy directed at the foreign ownership situation itself. That is to say, it may be that the performance of research problem is a chronic one which should be accepted as a reality of the Canadian situation. Policy effort and resources might be more profitably directed towards the support of intramural research and mechanisms which would facilitate the transfer of the resulting technology to the private sector. A brief discussion of technology transfer from government laboratories is the subject of the next section of this report.

iii) The Promotion of the Transfer of Technology from Government Laboratories to Industry

Most of the discussion and analysis of technology transfer which has taken place in the literature has been in the context of international transfers.[33] However, the problem of the sectoral transfer of technology in Canada was raised to the public's consciousness with the publication of the Science Council report, 'Technology Transfer: Government Laboratories to Manufacturing Industry.'[34] The principle concern of the report is that the output of the vast research facility of the federal government be brought effectively to the innovation stage wherever possible and that there should be an explicit policy with respect to technology transfer from government laboratories. This was in fact accomplished through cabinet decision in April of 1978 and the policy is currently being implemented.

Technology transfer, as defined in report number twenty-four ..." takes place whenever technical knowledge, a technique or a device which emerges from, or is developed by, one group becomes taken up and used or applied by another... This definition is in fact general enough to include the transmission and reception of 'scientific' information and 'know-how' as well as the transfer of 'technology' in the narrow sense."[35] The modes of technology transfer are: person embodied, embodied in goods and services, and direct investment. Measures of technology transfer include: patents, licenses, royalties, publications, attendance at

33 For example see Statistics Canada, Statistics on Technology Transfer Between Canadian and Foreign Firms (Parts 1 and 2). Catalogue 13-003, January, February, 1979.

34 Science Council of Canada, Technology Transfer: Government Laboratories to Manufacturing Industry, Report No. 24, December, 1975.

35 Ibid.

scientific conferences, immigration of scientists and engineers or the movement of scientists and engineers from one sector to another, international or intersectoral joint projects, and term appointments in industry or the reverse. Two government specific indicators are discussed below, patents and royalties.

Canadian Patent and Development Ltd. (CPDL) was created in 1947 by the National Research Council of Canada as a subsidiary Crown Corporation for the purpose of promoting the commercial exploitation of its research. Since that time its services have become available to all federal departments and agencies as well as a number of Canadian Universities, Research Institutes and Provincial Research Organizations. In April, 1978 the responsibility for CPDL was tranferred to the Department of Industry, Trade and Commerce with the intention of strengthening its interface with industry. The data in this section are drawn from summary statements describing patenting and related activities of the corporation.

There are some general caveats relating to patents as an indicator of inventive output (let alone technology transfer). These relate to biases which tend to either over or understate the measure of the number of inventions in a given period. There are many situations where it is felt that the protection offered by a patent will not offset the risk of disclosure and thus the number of patents will understate the level of inventive activity. Alternative means of protection are developed. This is largely the case in the area of micro circuit technology where one example of a solution to the protection problem is embedding the circuit in resin so that the circuit itself would be destroyed if attempts were made to extricate and copy it. On the other extreme, patents may overstate the level of inventive activity as is the case when a number of defensive patents are obtained around what is basically one invention. More specifically, in the context of technology transfer, care should be taken in interpreting patents as an indicator. Certainly, the disclosure of the technology has occurred but there is no evidence that it has been received and put to use. More correctly, patents indicate the potential for technology transfer.

Table 23 describes the patent activity of CPDL with respect to federal government departments and agencies for the years 1972/73 to 1977/78. Due to an idiosyncracy in the book keeping, only the number of proposals received in any given year are available. The inventions accepted and inventions licensed refer to the proposals received in the stated year. There is not a readily available record of the total inventions accepted or licensed in a given year nor the number of patents granted. The number of proposals received does, however, provide a reasonable indication of the levels of output of government laboratories and potential for technology transfer. The data is quite volatile and no particularly trend is discernable.

A more conceptually satisfactory indicator of technology transfer is the royalty payments which accrue as a result of licensed inventions. Royalties are more satisfactory in that they are evidence that the invention or technical know-how has actually been received and is being applied. Once again, however, care in interpretation should be exercised. Royalties are normally paid over the term of a

Table 23

No. of Proposals Received (A)

Government Departments and Agencies	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
Agriculture	5.0	6.0	7.5	8.5	11.5	5.0
Atomic Energy of Canada Ltd.	22.0	45.0	39.0	37.0	14.0	18.0
Communications	10.0	18.0	8.0	7.0	14.0	8.0
Energy Mines and Resources	19.0	14.0	15.0	7.0	18.0	15.0
Environment	33.0	22.0	21.0	18.0	16.0	27.0
National Defence	30.5	40.0	42.0	21.0	45.0	28.0
National Health and Welfare	1.5	4.0	1.0	3.0	4.5	2.0
National Research Council	46.5	37.0	44.0	53.5	43.0	41.5
Transport	3.0	-	4.0	1.0	4.0	5.0
Other	4.0	1.0	10.0	6.0	8.0	3.0
Total Government	174.5	187.0	191.5	162.0	178.0	152.5

No. of A Inventions Accepted (B)

Government Departments and Agencies	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
Agriculture	0 (5)	2.0 (3)	2.5 (2)	2.0 (4)	4.5 (6)	3.0
Atomic Energy of Canada Ltd.	3.0 (16)	0 (42)	3.0 (26)	5.0 (27)	4.0 (7)	1.0 (8)
Communications	1.0 (5)	5.0 (5)	2.0 (4)	1.0 (3)	7.0 (2)	2.0 (2)
Energy Mines and Resources	3.0 (11)	5.0 (4)	5.0 (6)	2.0 (2)	6.0 (9)	5.0 (8[illegible]
Environment	11.0 (18)	2.0 (10)	2.0 (11)	1.0 (7)	3.0 (9)	9.0 (8[illegible]
National Defence	10.5 (3)	12.0 (9)	11.0 (2)	10.0 (3)	16.0 (5)	10.0 (4)
National Health and Welfare	0.5 (1)	1.0 (1)	0	0 (1)	0.5 (2)	1.0
National Research Council	18.5 (14)	15.0 (14)	15.0 (12)	12.0 (34)	15.0 (19.5)	16.5 (1[illegible]5)
Transport	0	-	0 (4)	0	1.0 (2)	0 (2[illegible]
Other	1.0	0 (1)	0	4.0	2.0 (4)	3.0
Total Government	48.5 (73)	42.0 (89)	40.5 (67)	37.0 (81)	59.0 (65.5)	50.5 (5[illegible]5)

No. of B. Inventions Licensed

Government Departments and Agencies	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
Agriculture	0	0	0	0	0	1
Atomic Energy of Canada Ltd.	0	0	-	0	0	1
Communications	0	0	1	0	0	1
Energy Mines and Resources	0	0	0	0	1 (1)	0
Environment	0	1	0	0	0	2
National Defence	0	0	0	2	0	1
National Health and Welfare	0	0	0	0	0	0
National Research Council	0	0	0.5	1	3	1
Transport	0	-	0	0	0	-
Other	0	0	0	0	0	0
Total Government	0	1	1.5	3	4 (1)	7

contract and therefore do not refer to technology transfer in any given period but to transfers in the past as well as the present. Tables 24 and 25 describes the royalties received by CPDL on behalf of federal government departments and agencies for the period 1971/72 to 1977/78, the latest year for which data is available. The current value of royalties received grew at an average rate of 8.5%, however the real value of royalties received is relatively constant with the slight suggestion of a negative trend (-0.8%). The National Research Council is the largest generator of royalties at $226.8 thousand in 1977/78. Other departments which generate significant royalties are Agriculture, Energy Mines and Resources, and National Defence. An interesting, but disturbing perspective is to view the royalties received by CPDL in relation to intramural expenditures on research and development by departments. Royalties represent approximately .001% of expenditures for any given year.

Table 24

Canadian Patents and Development Limited
Summary of Royalties

	Thousands of Current Dollars	Growth (%)	Index (1971/72=100.0)	Thousands of Constant 1971 Dollars	Growth (%)	Index (1971/72=100.0)
1971/72	347.3	-	100.0	347.3	-	100.0
1972/73	405.7	16.8	116.8	386.4	11.3	111.3
1973/74	453.5	11.8	130.6	395.7	2.4	113.9
1974/75	451.1	-0.5	129.9	341.5	-13.7	98.3
1975/76	569.3	26.2	163.9	389.4	14.0	112.1
1976/77	611.4	7.4	176.0	381.2	-2.1	109.8
1977/78	546.8	-10.6	157.4	318.2	-16.4	91.8
Average		8.5			- 0.8	

Table 25

Canadian Patents and Development Limited
Summary of Royalties
($000)

Origin of Invention	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78
Agriculture	28.8	47.3	54.6	51.9	60.1	84.0	79.3
Atomic Energy of Canada Limited	4.4	8.3	10.0	8.5	6.0	3.0	37.7
Central Mortgage and Housing Corporation	-	-	-	-	-	-	15.1
Communications	-	-	.1	.3	1.5	2.4	6.1
Energy, Mines and Resources	12.8	15.3	27.6	35.8	52.0	46.8	72.0
Environment	-	2.3	4.5	19.0	16.8	13.9	24.7
Fisheries Research Board	0.5	0.5	0.5	-	-	-	-
National Defence	149.4	121.6	147.9	112.0	90.3	97.3	55.8
National Health and Welfare	4.5	4.9	4.1	19.0	10.7	15.0	28.3
National Research Council	146.9	205.0	203.2	203.6	330.9	348.0	226.8
Transport	-	0.5	1.0	1.0	1.0	1.0	1.0
Total	347.3	405.7	453.5	451.1	569.3	611.4	546.8

iv) The Direction of Research in Government Laboratories to Areas of National Concern and/or Opportunity (Priorities)

As part of its original mandate the ministry was given the task of setting objectives for science and technology in the context of the national interest

> "... a fundamental perspective on your responsibilities will be to direct the efforts of Canadian scientists in the pursuit of national objectives".[36]

This task was carried forward in the objectives of the organization proposal of 1975.

> "To formulate and develop policies for and to advise on the application of science and technology to national issues".[37]

Through the proposal, 'national objectives' have been translated into 'applications' of science and technology and have been interpreted subsequently as national concerns and opportunities. Operationalizing the objective of 'formulating policies for and advising on applications of science' has led to substantial work related to establishing priorities for science and technology. Recently, the results of this work was put before the Federal-Provincial Conference of Officials on Industrial Research and Development in a paper entitled 'Priorities for Science and Technology'.[38] The paper puts forward a list of ten applications as priorities for S&T:

36 Pierre Elliott Trudeau, a letter to Alastair Gillespie, August 12, 1971.

37 MOSST, An Organization Proposal, June 20, 1975.

38 MOSST, Priorities for Science and Technology, October, 1978.

- Food
- Energy
- Climate
- Oceans
- Materials
- Forestry and Forest Products
- Poisons, Contaminents and Pollutants
- Transportation
- Communications and Space Technology
- Health Care

The paper did not go as far as ranking these priorities, thereby providing a guide for the allocation of support. Work is ongoing with respect to this and further refinement of the list. The priorities, instead, were presented as a package of applications as a guide to the scientific community at large as to what the federal government felt were important areas of national interest to which science and technology could make a significant contribution.

The application data gathered in the survey of government establishments can be used to determine the de facto priorities of the federal government. Using the proportion of a scientific application, or the growth of that proportion, or some combination of the two as criteria for ranking, one can determine to what extent, after the fact, government has adhered to stated priorities in terms of the budgetary process. It has been observed that it is possible that some scientific research may be considered extremely high priority, but not absorb a significant amount of resources nor have the potential for so doing. This is probably quite true but would not generally be the case at larger levels of aggregation as in the application context.

There are other, more pragmatic, constraints to using this type of budgetary analysis in the context of federal government science expenditures. These constraints or problems relate to the inconsistency of the classifications over time and the ambiguity of the classification of some research. Because the application classifications are not of themselves mutually exclusive and because much of the research undertaken is ambigious in its classification it is necessary to be quite arbitrary in allocating expenditures to specific applications. Once having arbitrated the allocation it is then necessary to be consistent in that allocation over time. Research on the combustion properties of a specific fuel is a good example. It may find application in energy, transportation, space or all three. However, the survey respondent is required to arbitrate an allocation and be consistent in that allocation from year to year. A further complicating factor is that the classification system itself has changed from time to time, the result being that trends of the magnitudes of various classifications become unreliable. To add to these difficulties there is in some cases a lack of correspondence between the priorities and application classifications. Presumably, at some point in the future, when the priorities work has progressed to an extent where the definitions have hardened there will be a concordence established.

Keeping these caveats in mind Tables 27 and 28 describe the application data from the current main estimate science survey.[39] No trend analysis is possible but it is interesting to look at the magnitude of various application classifications. The tables are broken out into those applications

[39] MOSST, Main Estimate Science Addenda 1979-80

Table 27

Expenditures on Scientific Applications Natural Sciences Fiscal Years 1977-78 to 1979-80
($000)

	1977-78			1978-79			1979-80		
	Intramural	Extramural	Total	Intramural	Extramural	Total	Intramural	Extramural	Total
Energy	99,459	45,142	144,601	117,986	64,538	182,524	116,711	87,283	203,994
Food	136,957	20,855	157,812	149,929	23,466	173,395	157,010	24,842	181,852
Health	25,972	75,729	101,701	27,340	81,559	108,899	26,116	81,796	107,912
Transportation	69,662	22,358	92,020	73,547	28,640	102,187	69,602	21,582	91,184
Space & Communications	29,620	42,585	72,205	47,073	47,711	94,784	32,940	32,148	65,088
Environmental Issues	38,610	12,750	51,360	38,704	18,744	57,448	37,911	15,605	53,516
Oceans	30,798	7,981	38,779	28,223	8,306	36,529	29,867	6,587	36,454
Resources - Forestry	21,864	2,107	23,971	22,070	2,183	24,253	21,019	3,530	24,549
Sub-total Priorities	452,942	229,507	682,449	504,872	275,147	780,019	491,176	273,373	764,549
Other	119,102	104,600	223,702	128,158	85,694	213,852	140,278	108,173	248,451
Advancement of Science	37,964	109,132	147,096	42,950	121,906	164,856	45,197	132,286	177,483
Security	69,303	16,027	85,330	66,961	24,765	91,726	70,432	32,209	102,641
Resources - Other	52,086	9,870	61,956	53,710	11,620	65,330	55,195	12,385	67,580
Culture and Recreation	14,033	4,250	18,283	16,393	4,796	21,189	14,101	4,035	18,136
Developing Nations	2,571	15,390	17,961	3,776	13,886	17,662	3,012	14,618	17,630
Construction (Exc. Housing)	16,325	1,826	18,151	14,858	2,496	17,354	16,834	2,702	19,536
Northern Development	10,635	3,466	14,101	11,462	2,954	14,416	6,361	3,142	9,503
Housing & Urban Development	2,083	2,114	4,197	2,318	2,359	4,677	2,438	2,654	5,092
Social Development & Welfare	2,389	746	3,135	2,240	649	2,889	2,504	579	3,083
Policy Development	549	1,025	1,574	711	1,272	1,983	738	1,254	1,992
Sub-total	327,040	268,446	595,486	343,537	272,397	615,934	357,090	314,037	671,127
Total	779,982	497,953	1,277,935	848,409	547,544	1,395,953	848,266	587,410	1,435,676

Table 28

Expenditures on Scientific Applications Natural Sciences Fiscal Years 1977-78 to 1979-80
(%)

	1977-78			1978-79			1979-80		
	Intramural	Extramural	Total	Intramural	Extramural	Total	Intramural	Extramural	Total
Energy	12.7	9.1	11.3	13.9	11.8	13.1	13.7	14.8	14.2
Food	17.5	4.2	12.3	17.7	4.3	12.4	18.5	4.2	12.7
Health	3.3	15.2	7.9	3.2	14.9	7.8	3.1	13.9	7.5
Transportation	8.9	4.5	7.2	8.6	5.2	7.3	8.2	3.7	6.3
Space and Communications	3.7	8.5	5.7	5.6	8.7	6.8	3.9	5.5	4.6
Environmental Issues	4.9	2.6	4.0	4.6	3.4	4.1	4.5	2.6	3.7
Oceans	3.9	1.6	3.0	3.3	1.5	2.6	3.5	1.1	2.5
Resources - Forestry	2.8	0.4	1.9	2.6	0.4	1.7	2.5	0.6	1.7
Sub-total Priorities	57.7	46.1	53.3	59.5	50.2	55.8	57.9	46.4	53.2
Other	15.3	21.0	17.5	15.1	15.6	15.3	16.5	18.4	17.3
Advancement of Science	4.9	21.9	11.5	5.1	22.2	11.8	5.3	22.5	12.4
Security	8.9	3.2	6.7	7.9	4.5	6.6	8.3	5.5	7.1
Resources - Other	6.7	2.0	4.8	6.3	2.1	4.7	6.5	2.1	4.7
Culture & Recreation	1.8	0.8	1.4	1.9	0.9	1.5	1.7	0.7	1.3
Developing Nations	0.3	3.1	1.4	0.4	2.5	1.3	0.3	2.5	1.2
Construction (Exc. Housing)	2.1	0.4	1.4	1.7	0.4	1.2	2.0	0.4	1.4
Northern Development	1.4	0.7	1.1	1.3	0.5	1.0	0.7	0.5	0.7
Housing & Urban Development	0.3	0.4	0.3	0.3	0.4	0.3	0.3	0.4	0.3
Social Development & Welfare	0.3	0.1	0.2	0.3	0.1	0.2	0.3	0.1	0.2
Policy Development	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.2	0.1
Sub-total	42.1	53.8	46.4	40.4	49.4	44.0	42.0	53.3	46.7
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

suggested as priorities and 'other', and are ranked according to the size of expenditure for the forecast year, 1978-79. Not all of the priorities can be specifically identified with applications, particularly 'materials'. The priorities 'climate' and 'poisons, contaminants and pollutants' are assumed to be encompassed by the application 'environmental issues'. In 1978-79, under the above assumptions, 56% of the total federal science expenditures were associated with priority areas. Generally, intramural expenditures tend to be higher in relation to priorities than extramural expenditures. In 1978-79, they were 59.5% and 50.2% respectively. It is difficult to carry the analysis further given the state of the art with respect to science priority work. There are no bench mark policy statements related to the magnitude of expenditures associated with science priorities such as the policy pronouncements with respect to GERD/GDP. Nor does there exist, at present, an accepted normative ranking of priorities.

v) The Promotion of a Balanced Regional Distribution of Research Performed in Government Laboratories

One of the operating principles of the federation of Canada has been the equalizing of opportunity and economic well-being across the nation. The distribution of expenditures by the federal government has always been, therefore, a highly political and persistent concern. This has been the case with respect to federal government science expenditures as well. Unfortunately, as a result of pressure from the respondents to the various surveys on science expenditures, the collection of regional data was discontinued in 1974.[40] However, the impending Quebec Green Paper on Science and Technology brought the question of regional distribution to the fore and efforts to collect regional data were reinstituted in 1977/78. The collection of the data was facilitated by an annex to the addenda which regularly surveys federal government science expenditures. Unfortunately the data requested is not consistent, definitionally, with that obtained by the science addenda. For this reason it cannot be considered comparable. At best the regional science expenditure data should be considered to be experimental and a rough approximation to the regional distribution of federal government scientific involvement.

Tables 29 and 30 describe the distribution of intramural and extramural scientific expenditures of the federal government by region. The extramural payments are taken from 'Federal Payments for Science, By Region'.[41] The expenditures are

[40] MOSST, Inventory of Federal Scientific Establishments, April, 1974.

[41] Statistics Canada, Federal Payments for Science, By Region, Service Bulletin, Catalogue 13-003, Vol. 3, No. 2.

Table 29

Regional Expenditure
of the Federal Government on
Natural Science Activities

1977-78

($ 000,000)

	Extramural	Intramural	Total
Atlantic Provinces	24.3	75.2	99.5
Quebec	102.9	39.0	141.9
Ontario	191.1	98.9	290.0
Manitoba	11.6	45.9	57.5
Saskatchewan	11.6	17.9	29.5
Alberta	34.1	39.6	73.7
British Columbia	42.2	54.7	96.9
Canada	417.8	371.2	789.0

Table 30

Regional Expenditure
of the Federal Government on
Natural Science Activities

1977-78

(%)

	Extramural	Intramural	Total
Atlantic Provinces	5.8	20.3	12.6
Quebec	24.5	10.5	18.0
Ontario	45.7	26.6	36.8
Manitoba	2.8	12.4	7.3
Saskatchewan	2.8	4.8	3.7
Alberta	8.2	10.7	9.3
British Columbia	10.1	14.7	12.3
Canada	100.0	100.0	100.0

Atlantic Provinces	24.4	75.6	100.0
Quebec	72.5	27.5	100.0
Ontario	65.9	34.1	100.0
Manitoba	20.2	79.8	100.0
Saskatchewan	39.3	60.7	100.0
Alberta	46.3	53.7	100.0
British Columbia	43.6	56.4	100.0
Canada	52.9	47.1	100.0

attributed to region according to the principle address of the recipient. However, the expenditures could well have been made in another region, by the firm, or a subcontractor to the firm. Intramural expenditures are taken from an 'Experimental Listing of Scientific Establishments Outside the National Capital Region, 1978'.[42] The data are actually operating expenditures of science based establishments which means that they are definitionally inconsistent with other intramural science expenditure data. However, the Science Statistics Centre is satisfied that they represent good approximations to intramural scientific expenditures in the natural sciences. An additional caution is, as the title suggests, that intramural expenditures in the national capital area are excluded. This means that intramural science expenditures for Ontario, principally, but Quebec as well, are understated substantially. At the same time, a scan of the dollar values indicate that Ontario and Quebec are the largest beneficiaries of federal government expenditures, receiving $290.0 and $141.9 million respectively. Percentage-wise, Ontario and Quebec account for 54.8% of all federal government scientific expenditures. As might be expected, extramural expenditures represent the highest proportion of scientific expenditures in the areas of highest industrial concentration, Ontario and Quebec, while intramural government expenditures are of greatest proportional significance in areas of low industrial concentration, especially the Atlantic provinces and Manitoba.

As in the case of international comparisons, comparisons of different geographic regions are best made when normalized

[42] Statistics Canada, Experimental Listing of Federal Scientific Establishments Outside the National Capital Region, 1978, Science Statistics Centre internal report.

in some way for the size of the economic unit. Table 31 provides such a comparison on both a per capita and percentage of gross provincial expenditure (GPE) basis.[43] The GPE was originally derived and released by Statistics Canada on an experimental basis and is "... expected to be revised for methodological and conceptual reasons as well as for more customary errors of observation that accompany most early releases of data."[44]. The normalized data provide an interesting perspective. On both a per capita and percentage of GPE basis the Atlantic Provinces ($45.6, 0.009%) and Manitoba ($56.3, 0.007%) receive the greatest intensity of federal government funding. If the primary objective is the distribution of scientific expenditures to have-not provinces or regions, it would appear that some measure of success has been achieved. Even if it is recognized that Quebec, on the other end of the scale, receives the lowest federal science funding per capita ($22.8) or as a proportion of GPE (0.003%). If, on the other hand, the object is to provide some measure of equal access to scientific activity, the term successful is less appropriate. The standard deviation of the regional per capita science expenditures, for example, is $9.8. Only if it could be shown that the substantial variance from the mean was necessary to correct a discrepancy in the regional scientific infrastructures could the distribution of federal science expenditures be described as successful.

[43] a) Statistics Canada, Estimates of Population and Age for Canada and the Provinces, Catalogue 91-202, June 1977
b) Informetrica, Provincial Economic Accounts, June 1978.

[44] Informetrica, Provincial Economic Accounts.

Table 31

Federal Government Regional Expenditures on the Natural Sciences Per Capita and As a Percent of Gross Provincial Expenditure

	Population[1] (000)	GPE[2] ($000,000)	Federal Expenditures on Natural Sciences[3] ($ 000,000)	Per Capita Science Expenditure ($)	Federal Science Expenditures as a Percent of GPE (%)
Atlantic Provinces	2,181.7	11,446	99.5	45.6	0.009
Quebec	6,234.4	45,842	141.9	22.8	0.003
Ontario	8,264.5	75,611	290.0	35.1	0.004
Manitoba	1,021.5	7,951	57.5	56.3	0.007
Saskatchewan	921.3	7,984	29.5	32.0	0.004
Alberta	1,838.0	20,907	73.7	40.1	0.004
British Columbia	2,531.0	22,647	96.9	38.3	0.004
Canada	22,992.6	192,386	789.0	34.3	0.004

1 For 1976

2 For 1976

3 For 1977/78

Appendix A

Federal Government Expenditures
on the Natural & Social Science

	Millions of Current Dollars	Growth (%)	Index (1971/72=100.0)	Millions of Constant 1971 Dollars	Growth (%)	Index (1971/72=100.0)
1971/72	993.6	-	100.0	993.6	-	100.0
1972/73	1,068.8	7.6	107.6	1,017.9	2.4	102.4
1973/74	1,186.7	11.0	119.4	1,035.5	1.7	104.2
1974/75	1,330.9	12.2	133.9	1,007.5	-2.7	101.4
1975/76	1,470.0	10.5	147.9	1,005.5	-0.2	101.2
1976/77	1,669.9	13.6	168.0	1,041.1	3.5	104.8
1977/78	1,673.0	0.2	168.4	975.5	-6.3	98.2
1978/79	1,835.2	9.7	184.7	1,005.0	3.0	101.1
1979/80	1,853.4	1.0	186.5	952.9	-5.2	95.9
Average		8.2			-0.5	