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1989–90

Strategic Overview of Science and Technology Activities in the Federal Government

Canada

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STRATEGIC OVERVIEW OF SCIENCE AND TECHNOLOGY ACTIVITIES IN THE FEDERAL GOVERNMENT

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NOTE: For all charts in this publication, numbers have been rounded to the nearest $100 000.

Contributors

Agriculture Canada

Atlantic Canada Opportunities Agency

Atomic Energy of Canada Limited

Canadian International Development Agency

Communications Canada

Energy, Mines and Resources Canada

Environment Canada

Fisheries and Oceans

Forestry Canada

Health and Welfare Canada

Indian and Northern Affairs Canada

Industry, Science and Technology Canada

Medical Research Council

National Defence

National Library of Canada

National Research Council

Natural Sciences and Engineering Research Council

Social Sciences and Humanities Research Council

Statistics Canada

Transport Canada

Western Economic Diversification Canada

Executive Summary

- The purpose of the strategic overview is to provide an account of science and technology (S&T) activities in science-based departments and agencies in the Government of Canada.

- In 1989, the federal government spent \$5.05 billion on S&T activities. Of this amount, \$2.95 billion (58%) was performed intramurally and \$2.10 billion (42%) was performed extramurally. Intramural and extramural activities supporting industry represent more than one-third (37%) of total federal S&T expenditures.

- Scientific excellence and competitiveness have been chosen as the themes for the 1989 overview as they reflect the key thrusts of current government S&T policy. Within this context, three sub-themes are examined: technology transfer, scientific personnel requirements and sustainable development.

- With respect to technology transfer, departments and agencies report a high level of activity in federal laboratories. The general trend in these laboratories is to promote: shared project funding in partnership with industry and universities; research and development (R&D) collaboration with the provinces and private organizations; directed procurement for regional and economic development; formal S&T agreements with other industrialized countries; support of business opportunities in developing countries; the provision of specialized facilities and infrastructure; as well as national technology networks. More specifically, there is an increasing number of new technologies arising from federal laboratory activities. For example, Agriculture Canada files about 50 new patent applications each year, and Energy, Mines and Resources Canada's (EMR's) Canada Centre for Mineral and Energy Technology (CANMET) negotiated 12 new licences with industry in the past 15 months. In addition, the National Research Council's (NRC's) Biotechnology Research Institute has initiated 22 collaborative projects with industry over the past year.

- With respect to scientific personnel requirements, almost 34 000 people work in federal S&T. Of these, approximately 11 000 are in scientific and professional categories. Work force demographic statistics compiled by the Natural Sciences and Engineering Research Council (NSERC) show an aging work force with promotion stagnation and potential shortages of university graduates in mathematics, computer science, geology, health sciences, and civil, chemical and electrical engineering. There is a need for researchers, capable of working in multi-disciplinary teams, who are not only experts in their own fields, but also able to understand and deal with issues in other fields of the natural and social sciences and engineering.

- With respect to sustainable development, many program initiatives are in place or under way. New legislation governing the Environmental Assessment and Review Process (EARP) will oblige departments to review all policies and programs, including those involving S&T, and to integrate sustainable development principles with operational objectives.

Broad conclusions drawn from the contributions of federal departments and agencies include:

- Collaborative R&D among the federal government, universities and industry will be key to enhancing the effectiveness of federal resources. Many of these collaborative efforts are under way and effects have been felt. But there are still a lot of opportunities to be seized before the full potential of all federal government S&T programs can be realized.
- Not all departments identify economic or industrial development as an objective of their S&T mandate. For those that do, technology transfer is a key activity. Departments with missions such as health and safety, national security and protection, or basic research are recognizing more and more that technology transfer is an important component of program activity.
- In light of the demographic profile of the public service generally and the scientific community in particular, training and development initiatives to improve the management of our existing human resources and special recruitment efforts must be fully exploited.
- Federal S&T for sustainable development will change the formulation of public policy and government support to industry. The implementation of EARP will have a resource impact on the development of new polices and programs and the delivery of existing and future programs.
- S&T are critical to our economic and social well-being. Federal S&T activities are an important part of the national effort, given the weak performance of the private sector. In the current climate of fiscal restraint, it is important that the contributions made by federal S&T are recognized and that the level of support is adequate to generate the results needed.

Introduction

Today, as never before, S&T issues rank prominently on the national agenda. Public demand for scientific and technical information is at an historical high. Conferences on S&T subjects attract thousands of participants. Interest on the part of the news media has reached unprecedented heights.

In part, this interest reflects the burgeoning role of S&T in everyday life, from the automated workplace to home electronics, satellite systems, health care, test tube babies and space-age materials. In part, it is an acknowledgement that success in addressing pressing social and economic concerns — including the environment, human health, and economic and regional development — will depend on our ability to deal with their scientific and technological dimensions. And, in part, it arises from a growing recognition that our S&T performance is closely linked to our ability to innovate, to compete in demanding international markets, to generate national wealth and to maintain our standard of living.

But science itself raises complex legal, ethical, and human issues. How do people adapt to rapid technological change? What social and institutional support do they need? What kinds of education and training facilitate adaptation? While these questions are not the subject of this report, it is important to recognize the human and social dimensions and the need to reconcile economic and competitive goals with them.

Purpose of this Overview

As a significant funder and performer of S&T activities, the federal government recognizes the central role they play in the future social and economic well-being of the country. As the Prime Minister stated on August 25, 1989:

> The goal is an economy that can compete with the best in the world, producing stimulating new jobs and new opportunities for future generations of Canadians. ... Our national unity, as well as our standard of living, scientific and artistic excellence, social welfare, the environment, foreign policy — all depend upon the strength and dynamism of our economy. ... Science and technology are the keys to a modern competitive economy.

The priority attached to S&T has been translated into action through a number of initiatives:

- the National Science and Technology Policy, endorsed by federal, provincial and territorial governments;
- InnovAction, the Canadian Strategy for Science and Technology;
- the National Advisory Board on Science and Technology, chaired by the Prime Minister;
- the Council of Science and Technology Ministers; and

- the *Decision Framework for Science and Technology*, a set of principles and guidelines established in 1987 to co-ordinate and direct the government's $5.05–billion annual investment in S&T.

The *Decision Framework for Science and Technology* calls for an annual overview of S&T activities in the federal government. The process involves the participation of 20 science-based departments and agencies. This 1989 overview, which is based on submissions from those departments and agencies, has been prepared to inform ministers about the current state of federal S&T activities, together with the challenges and opportunities inherent in them. At the same time, the document is intended to inform the public of the continuing role of S&T in the Government of Canada. A companion document is the statistical publication entitled *Science and Technology Resource Allocation Statistics*.

This overview has six sections. In the remainder of this first section, federal S&T activities and expenditures are reviewed briefly. In the second section, two central themes are introduced: scientific excellence and competitiveness. In the third, fourth and fifth sections, examples of departmental and agency activities illustrate how three aspects of S&T — technology transfer, scientific personnel requirements and sustainable development — can contribute to excellence and competitiveness. The sixth and final section offers conclusions about priorities and directions for federal S&T activities. An annex deals with S&T statistics.

Federal S&T Activities and Expenditures

The context for the strategic overview process is provided by the *Decision Framework for Science and Technology*. It provides four principles for the management, co-ordination and direction of the federal government's S&T activities:

- S&T are vital means to support the social and economic goals of the government.

- Federally funded S&T should be performed in the private sector and universities where appropriate and feasible.

- Federal support levers increased contributions by industry and the provinces to raise the national level of R&D performance.

- Federal S&T activities are grouped into three broad categories: economic and regional development; government missions; and advancement of knowledge.

During the eighties, federal S&T expenditures more than doubled, from $2.40 billion to $5.05 billion (a 35% increase in real terms). However, the ratio of federal S&T expenditures to gross domestic product (GDP) remained fairly static for this period. The ratio of S&T expenditures to program expenditures (total government expenditures minus interest payments) has increased somewhat. But, as a percentage of program expenditures minus interest payments and statutory transfers to provinces and individuals, S&T expenditures increased from 8.0% to 11.8% during this period.

There were some 290 federal scientific establishments located in all regions of Canada, with the majority located in the National Capital Region. These establishments range in size from one person-year (PY) to over 2 000 PYs and represent more than 20 departments and agencies. NRC, Environment Canada and Agriculture Canada account for the majority of the facilities. In 1989-90 total federal S&T expenditures were $5.05 billion, a 4% increase over 1988-89 in current terms, or no increase in real terms. There were 33 988 PYs allocated to federal S&T activities across all departments and agencies, a 0.1% decrease from the 1988-89 level.

TABLE 1
Federal S&T Expenditures

	1980-81	1984-85	1989-90
S&T (Actual $ Billions)	2.40	4.08	5.05
R&D (Actual $ Billions)	1.36	2.45	2.95
S&T (1981 $ Billions)	2.66	3.47	3.60
S&T as a % of Gross Domestic Product	0.8	0.9	0.8
S&T as a % of Program Expenditures	4.7	4.7	4.9
S&T as a % of Non-Statutory Expenditures	8.0	9.1	11.8

Source: Statistics Canada, special tabulation, July 1989; Receiver General, *Public Accounts of Canada*, Volume I, 1980-81 to 1989-90; Treasury Board, *1989-90 Estimates*, Part 1, "The Government Expenditure Plan," Table 2.2; and S&T Statistics and Analysis Division, ISTC.

Federal S&T activities are divided into two categories: R&D and related scientific activities (RSAs). R&D consists of basic research, technology development and applications development. RSA refers to activities that complement or extend R&D by contributing to the generation, dissemination and application of S&T. Federal R&D activities range from support for environmental, health and safety, and transportation regulations to support for national defence and security, and national facilities used by government, universities and industry.

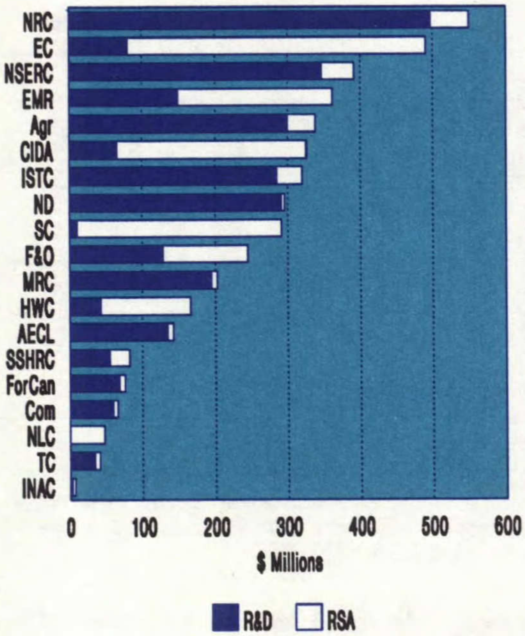
Figure 1 shows the distribution of federal S&T expenditures by departments and agencies, and by R&D and RSA in 1989-90. R&D expenditures for 1989-90 were $2.95 billion, an increase of 6% over 1988-89 in current terms (a slight increase in real terms). The main supporters of R&D were NRC, NSERC, Agriculture Canada, National Defence, and Industry, Science and Technology Canada (ISTC).

RSA expenditures in 1989-90 accounted for $2.10 billion, an increase of 2% over 1988-89 in current terms (a slight reduction in real terms). The main performers of RSA were Environment Canada, Statistics Canada, the Canadian International Development Agency, EMR, and Health and Welfare Canada.

Intramural and Extramural Performance

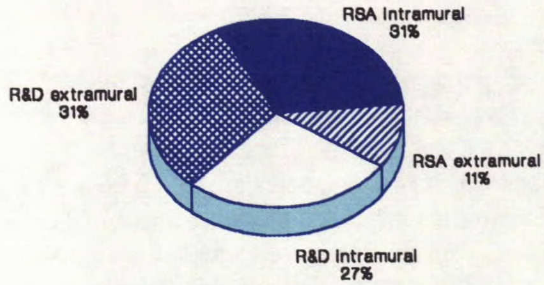
Intramural expenditures consist of costs incurred for scientific activities carried out by in-house personnel; the related acquisition of land, buildings, machinery and equipment; the administration of scientific activities by

FIGURE 1
S&T Expenditures, 1989-90



Source: Statistics Canada, *Federal Science Expenditures and Personnel, 1989-90*, Cat. Nos. ST-89-01 and ST-90-01.

FIGURE 2
Federal S&T Expenditures, 1989-90



Source: Statistics Canada, *Federal Science Expenditures and Personnel, 1989-90*, Cat. Nos. ST-89-01 and ST-90-01.

program employees; and the purchase of goods and services to support in-house scientific activities.

Of the $5.05 billion spent on federal S&T activities in 1989-90, $2.95 billion (58%) was performed intramurally. The major performers of intramural S&T were Environment Canada, NRC, Agriculture Canada, Statistics Canada and EMR.

The remaining $2.10 billion (42%) of federal S&T was performed extramurally. The main funders of extramural activities were NSERC, ISTC, NRC, the Medical Research Council (MRC) and National Defence. Figure 2 shows the breakdown of federal R&D and RSA by intramural and extramural expenditures.

Areas of Application

There are three main categories of federal S&T activity: economic and regional development; government missions; and advancement of knowledge, which in turn can be described by areas of application of S&T. Expenditures for the advancement of knowledge account for 11.8% of total federal activity. The major departments/agencies funding advancement of knowledge were NSERC, NRC, and the Social Sciences and Humanities Research Council. Expenditures for government missions account for 51.5% of all federal activity, including overhead. Application areas that are included in this category are national security (National Defence); health and environmental protection (Health and Welfare Canada and Environment Canada); agriculture and fishing (Agriculture Canada and Fisheries and Oceans); weather services and geodesy (Environment Canada and EMR); culture and recreation (Communications Canada and Environment Canada); and statistics, economics and others (Statistics Canada and NRC).

Expenditures in support of economic and regional development account for 36.7% of total federal activity. The major funding departments and agencies are ISTC, NRC, Forestry Canada, Communications Canada, EMR, Atomic Energy of Canada Limited (AECL); Transport Canada; Fisheries and Oceans; and Environment Canada.

Performers and Funders

In 1989, the federal government funded 30% of all R&D performed in Canada, while industry funded 42%. The federal share of R&D performed was 17% while industry's share was 56%. The provinces and provincial research organizations (PROs) funded 7% and performed 3% of all R&D while universities funded 9% and performed 23%.

In contrast, in 1984, the federal government and industry both funded 37%. The federal share of R&D performed was 22% while industry's share was 50%. The provinces and PROs funded 6% and performed 3% of all R&D while universities funded 10% and performed 24%.

Regional Distribution of Federal R&D Expenditures

Figure 3 shows the 1987-88 regional distribution of federal R&D (the last year for which regional distribution data is available), with the National Capital Region shown as a separate region. The largest expenditure

TABLE 2
Expenditures on R&D
(Percent)

	1984	1989
Funders		
Federal Govt.	37	30
Provincial Govt.	6	7
Industry	37	42
Universities	10	9
Other	10	12
Performers		
Federal Govt.	22	17
Provincial Govt.	3	3
Industry	50	56
Universities	24	23
Other	1	1

Source: Statistics Canada, *Estimates of Canadian Research and Development Expenditures (GERD), National 1963-89, and by Region, 1979-87*, Cat. No ST-89-08.

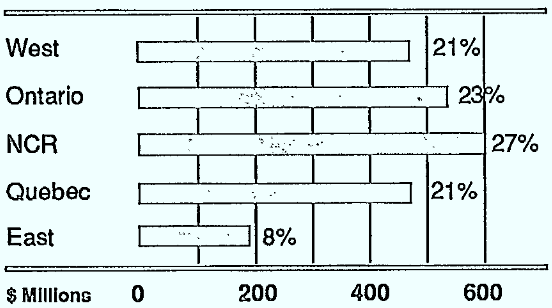
occurred in this region (27%) while Ontario and Quebec had 23% and 21% respectively. The regional distribution pattern reflects a variety of factors such as the nature of the R&D, the location of departmental clientele and the location of laboratory facilities.

These figures are for direct funding only. In addition, the federal government indirectly funds university R&D through Established Programs Financing transfers and funds industrial R&D through a system of tax incentives.

International Comparisons

In 1987, Canada's gross expenditure on R&D as a percentage of GDP was 1.4%, which ranked 10th among the countries in the Organization for Economic Co-operation and Development (OECD). The proportion of

FIGURE 3
Regional Distribution of R&D, 1987-88



Source: Science, Technology and Capital Stock Division, Statistics Canada, December 1989.

public sector funding is comparable to that of major international competitors. In Canada, government support for civilian non-defence R&D was 0.59% of GDP. In Japan, it was 0.60%, in the U.K. 0.46%, and in the U.S. 0.43%. Canadian private sector support for R&D lags behind that of the private sector in other OECD countries. In Canada, private sector support was 0.71% of GDP. In Japan, it was 1.97%; in Sweden, 1.83%; in West Germany, 1.82%; and in the U.S., 1.27%. However, as previously indicated, Canadian industry is becoming a relatively more important source of R&D funds.

(Figures 1 to 3 were selected from the annual *Science and Technology Resource Allocation Statistics* report.)

Highlights of Recent S&T Successes

Federal S&T activities make important contributions to economic and social well-being. Of the many highlights that could be mentioned, several of the major S&T achievements are listed below:

- Technology dominant in commercial markets for satellite station equipment has been developed by Canadian industry in collaboration with EMR's Canada Centre for Remote Sensing. Annual industry sales reached the $160–200 million range in 1984 and continue to rise, with more than 50% representing export sales. Similarly, airborne survey technology developed by EMR's Geological Survey of Canada has been used world-wide in reconnaissance for mineral exploration and geophysics surveys. The department's Canada Centre for Surveying has developed an aerial triangulation adjustment program (Space – M), which is currently being exploited by Canadian companies.

- R&D in oceanography by Fisheries and Oceans, particularly with respect to the Hydrographic Submersible (HYSUB) 5000 and other remotely operated vehicles (ROVs), is one example of government-industry co-operation. A commercial undersea exploration product was developed for the ocean industry sector. Contracts have been issued for improving manipulator control and development of stereo vision.

- Collaboration between Communications Canada, NRC and Telesat Canada in developing telecommunications technology and satellite systems has resulted in the creation of a successful indigenous industry with superior technology and significant export capabilities. The Mobile Satellite (MSAT) was developed by the Communications Research Centre to provide mobile links for telephone, radio and information systems in all areas of Canada, particularly rural and remote locations. MSAT will also enable the linkage of small radio terminals anywhere on the continent. It is scheduled for launch in 1993. Federal government support began in 1986 with the provision of $176 million, extending to a 1996 time-frame. It is anticipated that MSAT will lead to $4-5 billion of net economic benefits through new services, markets, products and employment in Canada.

- The federal granting councils (NSERC, MRC and SSHRC) all have programs that encourage the development of excellence in university research. NSERC's prestigious 1967 Science and Engineering Scholarships are awarded yearly to up to 55 outstanding graduate students. The Industrial Research Chair Program, which funds 65 chairs at Canadian universities, has great appeal to Canadian industry since, by joining with NSERC to support a chair, a company gains access to research expertise. MRC provides salary support over five years to more than 350 biomedical researchers.

- SSHRC has undertaken initiatives in the management of technology, competing in the global economy and ethics. In collaboration with NSERC and the private sector, SSHRC is supporting university chairs in the management of technological change and a Masters' scholarships program in science policy. NSERC has a University-Industry Program and a Strategic Grants Program.

- Under InnovAction, the federal strategy for S&T, the Minister for Science announced the selection of 14 networks in the $240-million Networks of Centres of Excellence program, which links industrial, university and government scientific researchers in engineering, natural and medical sciences, manufacturing, and business, resource and high technology sectors across the country. Each network involves five to twenty institutions and companies.

- Since its creation in June 1987, the Atlantic Canada Opportunities Agency (ACOA) has supported more than 300 innovative technology projects valued at some $83.2 million. Examples include the Technical People in Industry Program in Nova Scotia and a project for the development of helicopter-deployable fire-fighting systems by a company in St John's, Newfoundland.

- Western Economic Diversification Canada has supported more than 200 S&T projects valued at $160 million, out of the $625 million committed since June 1987. Including other federal and provincial contributions, as well as equity participation from the private sector worth $214 million, the department has levered $414 million for an S&T total of $574 million for the western provinces.

- Westaim is a new organization established as the first major advanced industrial materials initiative for Western Canada. This demonstrates the ability of the governments of Canada and Alberta, the private sector, and the academic community to work together in a productive venture.

- Jointly with ACOA, Western Economic Diversification Canada, industry, users and others, Communications Canada has set up seven regional research application centres for specific sectors of the economy to bridge the technology transfer gap between creators and users of advanced communications and information technology.

- The Canadian Space Agency has completed negotiations with the provinces, industry and the U.S. to move ahead with Radarsat, Canada's first earth observation satellite.

- NRC is involved in the Solid State Optoelectronics Consortium of Canada, an industry-led research consortium which has launched a major, long-term project involving the council's Laboratory for Microstructural Sciences in the Division of Physics.

- Agriculture Canada's Centre de recherche et de développement sur les aliments de St-Hyacinthe is designed to maximize collaboration with the agri-food industry through the sharing of specialized facilities and expertise. The centre has completed over 200 industrial projects, creating around 160 full-time private sector positions and investing approximately $10 million.

- Fisheries and Oceans, working closely with the Université du Québec à Rimouski, has established the Maurice Lamontagne Institute as a designated francophone centre for the marine sciences, thus permitting graduates whose mother tongue is French to work in the language and culture of their choice.

At a time when gloomy predictions about Canada's technological future are all too common, these examples show that initiatives are being taken. Our successes demonstrate excellence and provide an asset base on which to build a more prosperous economy which supports technological development and environmental conservation. But it will not happen automatically. It will require determined action by both the public and private sectors. New levels of co-operation and global partnerships will be needed to achieve scientific excellence and competitiveness.

Scientific Excellence and Competitiveness

Scientific excellence and international industrial competitiveness reflect the priorities of federal S&T policy. The government has set a new goal for Canada — to achieve national economic and social objectives through improved S&T performance.

S&T are vital to international competitiveness in that they can reduce labour, energy and material unit costs and enhance the quality, serviceability, and design of products and services. S&T are not just hardware; they are also "software" — the skills, the information, the collaboration and the human interaction that combine and advance knowledge. There is a strong relationship between technological change and organizational change.

Federal S&T excellence depends on quality personnel. Federal scientists and engineers conduct hands-on research in various departmental laboratories, but their skills and knowledge are also required as research managers, technology transfer officers, business consultants, advisers on science-related legal matters, program officers, policy analysts, information officers, standards setters and regulatory scientists. A federal commitment to excellence must be sustained to attract and train the qualified and innovative young people required to generate the discoveries and applications that create knowledge-intensive economic and social benefits for Canada.

Federal S&T activities are strongly affected by the dramatic increase in global trade competition based on new technologies. Canada's traditional reliance on abundant natural resources is no longer a guarantee of international competitive success. Competitiveness today depends on a country's ability to add value to its products through technological innovation, highly skilled labour, greater productivity, and knowledge of markets and customers. The process is never-ending; the struggle is always to stay ahead at the leading edge of product and process innovation.

S&T are not limited to any one industrial sector. Few industries are immune to the pressures of technology-based competition. Telecommunications equipment, computer, satellite and biotechnology industries have a vital S&T component. S&T are the bases of trade and competition in resource-based industries like pulp and paper, steel, agriculture, and petrochemicals.

The knowledge-intensive economy demands an unprecedented degree of co-operation among the S&T communities — industrial, governmental and academic. The enormous and rapid expansion of knowledge has escalated the cost of scientific research and technological development beyond what a single company or government can afford. Even the largest multinational corporations are now banding together to perform joint pre-competitive R&D.

The reliance of society in general, and industry in particular, on sophisticated technology is so entrenched that time itself has become a competitive advantage. The market demands speedy responses; there is no time to wait for advances in scientific knowledge to be transferred from government or university laboratories to industry for further development, specific product or process application, or commercialization in marketable form. Industry must be involved, along with universities and governments, from the outset in joint processes to establish strategic resource allocation and research priorities.

A major challenge for the government in pursuing its S&T mission is to exercise leadership, pulling together the nation's human resources in support of collaborative S&T activities. It is clear from recent reports by the National Advisory Board on Science and Technology, the Canadian Manufacturers' Association, the Advisory Council on Adjustment, and the Science Council of Canada, among others, that adjusting successfully to the turbulent times ahead will require a co-operative national effort.

The success of this national effort will depend heavily on the priority attached to two factors: scientific excellence and the competitiveness of the goods and services Canadians sell in international markets. The drive to become internationally competitive fosters excellence because only the best survive in today's competitive world environment.

A major federal initiative in this direction is the $240-million Networks of Centres of Excellence Program. The objectives of the program are: to stimulate the production of leading-edge fundamental and long-term applied research of importance to Canada; to develop and retain world-class Canadian scientists and engineers in technologies that are critical to future industrial competitiveness; to integrate Canadian research and technology development efforts into national networks with the participation and partnership of universities, the private sector, the federal government and the provinces, based on excellence as measured by international standards; and to develop strong university-industry partnerships to accelerate the diffusion of advanced technological knowledge to industry. In November 1989, the federal government announced the 14 winners of the Networks of Centres of Excellence competition. These networks will involve more than 500 Canadian scientists, predominantly in the university sector but also in government laboratories and industry.

Toward Excellence and Competitiveness

Excellence and competitiveness in S&T are supported by effective technology transfer and an adequate supply of appropriately educated and trained scientific personnel. Excellence in scientific work not only contributes to the public knowledge base but also yields results that may be used for specific commercial application and development. Scientific productivity is an important measure of the quality of research being done and the quality of the researchers who do it.

Excellence in science also contributes to our capacity to anticipate and prevent problems of national importance as well as our capacity to solve problems. Health, environmental and safety standards, for example, are essential for the safe and efficient operation of a modern technological society. The goal of sustainable development requires meshing excellence in science and competitiveness in a fundamental way to ensure not only the vitality of our environment but also continued growth.

The following three chapters illustrate how these three selected elements of the federal S&T strategy — technology transfer, scientific personnel requirements, and sustainable development — support the federal scientific effort and identify the issues and challenges which need to be met.

In discussing technology transfer and federal government laboratories, it is important to keep in mind that 42% of S&T funding is spent extramurally. This activity, especially that portion which is directed to industry, promotes a broad range of technology transfer activities such as contracting-out, directed procurement, industrial alliances, employee takeovers, licensing arrangements, provision of facilities and marketing of research capabilities. Of the remaining 58% that is spent intramurally, approximately 17% involves activities in support of industry. One would expect the highest level of technology transfer activities from this portion of intramural funding, however, technology transfer activity is not limited to just this component. As examples in this chapter will show, even where the intramural research is not directed to immediate commercial ends, technology transfer is taking place.

Technology transfer, in its broadest terms, is a collaborative process which may involve the development, purchase, sale or use of technology. The technology being transferred may entail hardware, but it goes far beyond that to include the "software" of technology — processes, abilities, knowledge, skills and know-how.

Technology transfer is neither a uni-directional process nor a discrete activity; it is a co-development process. To be effective from the perspective of federal S&T activities, it must involve transfer both into and out of government and must be seen as part of a continuum ranging from pure research aimed at pushing back the boundaries of scientific knowledge to competitive R&D involving commercial products and processes.

And, since most issues facing society are not purely technical but related to human behaviour, ethics and habits, this dimension cannot be forgotten. Social science and humanities researchers need to work with government, social agencies and the private sector on issues like AIDS, child care, productivity and violence, which have scientific and humanities components.

Transferring Technology

Contracting-out and government procurement are the two most common techniques of technology transfer in support of extramural S&T, but collaboration is key, given the importance of speed in turning discoveries into usable products. The techniques of technology transfer from intramural activity include the publication of research results in learned journals, formal agreements on information exchange as well as joint ventures and collaborative research. The federal government continues to have a number of collaborative arrangements with industry, universities, and provincial and foreign governments.

In an intensely competitive environment, however, technology transfer is a question of attitude as much as technique. People are often more important than paper as agents of technology transfer. Direct contact among government, industry and academic researchers — through formal channels such as collaborative research or joint projects and informal channels such as professional organizations and conferences — facilitates the business of technology transfer. Thinking about technology transfer in this way ensures that the products of research are directly relevant to establishing and maintaining competitiveness.

Technology transfer in support of national economic or social goals sometimes requires a leadership investment by government, especially in high risk research projects. Creativity and entrepreneurship are essential ingredients in exploring unsolved problems and taking risks to resolve them. Investment may be warranted where the research involved is large in scale and broad-based in scope, the commitment of time and financial resources is large, or the results are likely to produce multiple uses and widespread economic benefits. Often such projects require time horizons of 15 years or more, and a willingness to follow through with financial and policy support. Some examples reported include:

- The creation of a Canadian satellite/ telecommunications industry involved long-term government commitment to the goal, establishment of a Crown corporation, participation by several departments and agencies of government, selection of private sector contractors, considerable investment of funds, and continuing policy support.

- National Defence developed the CRV7 Rocket Motor to meet a Canadian Forces need for an upgrade of a 30-year-old motor. The project R&D lasted from 1971 to 1987 (16 years). This project, which was undertaken with Bristol Aerospace Ltd., has resulted in sales to date of $60 million within Canada and $125 million to foreign countries.

- AECL developed the Canadian Deuterium Uranium (CANDU) reactor, which led to the development of a nuclear industry in Canada, employing 30 000 people directly and stimulating $4 billion in economic activity yearly.

- NRC laboratories developed design rules for microcircuits on gallium arsenide chips (the next generation after silicon chips) which are now being used by 12 Canadian companies. Even if the rules had been developed in a private sector laboratory (which they might never have been), the economic benefits would have accrued only to one company, not to the industry as a whole.

Technology Transfer Activities

The approaches reported by departments and agencies vary considerably, often depending on the nature of the client, the industry and the issue. Current approaches include collaborative research, client participation, advisory boards, promotion and marketing, information exchange, supportive infrastructure, and skills development.

Collaborative Research

Collaborative research allows government laboratories to develop and transfer technology in partnership with industry and universities. Such projects range from informal arrangements between two researchers to large multi-disciplinary, multi-faceted projects involving contracts or memoranda of understanding. They run the gamut from basic research to prototype demonstration projects and enhancement of established technologies.

Examples of successful collaborative research projects include the following:

- The Athena Project, launched by a consortium of Canadian audio manufacturers, is drawing on the expertise of NRC acoustics scientists in the development of the next generation of loudspeakers. In addition, the council's Biotechnology Research Institute has initiated 22 collaborative projects with industry.

- EMR has conducted a joint project with the University of Toronto on an innovative transient electromagnetic method to determine the electrical conductivity of the sea floor. Potential applications include determining the thickness of offshore hydrothermal mineral deposits, locating permafrost or gas hydrate layers, and providing estimates of porosity for geotechnical studies.

- Researchers at Agriculture Canada, working in collaboration with university scientists from the U.K., have discovered a unique nitrogen-fixing system. This landmark discovery may enable scientists to incorporate nitrogen-fixing capability into crops, thereby reducing the need for nitrogen fertilizer.

- Fisheries and Oceans, in co-operation with Quester Tangent of Victoria, B.C., developed the Integrated System for Automated Hydrography (ISAH) and, with Universal Systems Ltd. of Fredericton, N.B., developed the Computer Aided Resource Information System (CARIS) for mapping. Together these two developments make up a unique data logging and processing, chart production, and data base management system that has been successfully marketed internationally.

Client Participation and Advisory Boards

Essential to effective technology transfer is client participation at every stage of development, from planning to performance, delivery and funding. To this end, several departments and agencies have established external advisory boards composed of executives from industry, universities and the public sector. Examples include NRC's Canadian Construction Research Council; National Defence's Science Advisory Board; the Minister's National Advisory Council to CANMET at EMR; advisory boards for the Communications Research Centre laboratories; Forestry Research Advisory Councils; the National Marine Council at Fisheries and Oceans; and ISTC's National Advisory Board on Biotechnology and Advisory Panel on Advanced Industrial Materials. These boards advise management on:

- research priorities and directions;

- future needs and current gaps in research activities;

- methods of fostering R&D collaboration and co-ordinating R&D activities; and

- how government R&D can meet technology development, information diffusion and application needs more effectively.

These arrangements are of relatively recent origin. It may take some time before their full potential is realized.

Promotion and Marketing

To more directly promote technology transfer, several departments have established technology transfer or industry relations offices. Examples of marketing and technology promotion include the following:

- Agriculture Canada has established an Industry Relations Office to facilitate the commercialization of technology. This office will market its 68 Canadian and international patents, as well as receive approximately 50 new applications per year for patents. Recent successful activities include the transfer of technology for multiple ovulation embryo transfer and a new corn-drying technology.

- NRC has established industrial liaison officers in each of their laboratory divisions who are responsible for recognizing and implementing technology transfer opportunities.

- The Oceans Development Branch at Fisheries and Oceans promotes marine sector technological development such as the Deep Ocean Logging Platform with Hydrographic Instrumentation and Navigation (DOLPHIN) semi-submersible for hydrographic surveying.

- EMR's CANMET has negotiated 12 licences with industry during the past 15 months.

Information Exchange

The timely dissemination of data to Canadian industry plays an important role in supporting competitiveness. Examples of the mechanisms used to do this include:

- **Communications systems:** Communications Canada is collaborating with the Canadian cable industry (e.g. Rogers, Skyline, Maclean-Hunter) to assess the capability of broadband cable television channels to carry advanced television signals. The department developed test system and data collection software for both cable and off-air channel measurements. Methods for subjective comparison of high definition television (HDTV) systems were also developed. The HDTV test bed will enable Canadian electronics companies to apply their HDTV research, measure the results and compare their technology with other international standards.

- **Centres:** ISTC has funded numerous technology centres under the Technology Outreach Program. An additional technology awareness, acquisition and development tool is the department's Technology Inflow Program.

- **Information systems:** NRC, through the Canadian Institute for Scientific and Technological Information (CISTI), offers a renowned S&T information collection, dissemination and delivery service. CISTI responded to some 425 000 requests for material last year, of which about half were in support of industry. The National Library has become a world leader in research into the development, implementation and transfer of Open Systems Interconnection (OSI) standards for bibliographic data.

- **Publications:** EMR's Geological Survey of Canada published more than 500 reports in internal publications and another 500 in external scientific journals in 1988-89.

NRC edits and publishes 13 world-class scientific journals.

- **Seminars and workshops:** The Food Directorate of Health and Welfare Canada conducted a workshop on the use and application of immunochemical methods in pesticide residue analysis for regional chemists, representatives of Agriculture Canada, and several U.S. agencies. EMR held seminars on energy efficiency and alternative energies.

- **International conferences:** Conferences are an important venue for discussing and exchanging ideas and for establishing informal networks. Scientists from EMR's Geological Survey of Canada gave more than 700 presentations at scientific meetings and other events in 1988-89.

- **International exchanges and agreements:** Examples include National Defence's activities in NATO, work by Transport Canada with the U.S. Transportation Research Program and Agriculture Canada's extensive international activities.

- **Scientific associations:** These sources of information, such as the Chemical Institute of Canada, the Association canadienne française pour l'avancement des sciences and the American Society for Mass Spectrometry, keep scientists aware of developments in their fields of study.

Supportive Infrastructure

Non-financial S&T support by federal departments and agencies takes the form of providing access to laboratory facilities and personnel, giving assistance in the final stages of R&D, developing prototypes, and adapting new technologies. Examples include:

- **Laboratory facilities:** Access to the expertise and equipment of federal laboratories transfers technology and improves industrial competitiveness. National S&T facilities — including EMR's CANMET, NRC's service for construction materials testing, and Fisheries and Oceans' Bedford Institute of Oceanography — give Canadian industry collective access to infrastructures they could not individually afford. Collaborative projects using these facilities also give federal scientists and engineers knowledge, training and professional development opportunities they would not otherwise have.

- **Standards:** Standards are important in the successful commercialization of technology and Canadian competitiveness. Health and Welfare Canada, for example, is currently harmonizing its regulatory programs with those of our trading partners in currently important fields such as biotechnology. NRC's Calibration Laboratory Assessment Service identifies private sector and other non-federal laboratories capable of providing calibration services compatible with national and international scientific and technical standards.

- **Technical and financial assistance:** NRC's Industrial Research Assistance Program (IRAP) funds firms to adapt new technologies. In 1988, IRAP was a source of technical assistance for roughly

5 000 firms. IRAP seeks the technology needed by a firm and transfers it by any appropriate means. The needed technology may be obtained from government laboratories, universities, technological institutes, other firms or foreign sources. In some cases this can include licensing the technology, contracting-out development work, or supporting R&D performed by the firm in collaboration with other firms. Agriculture Canada's Productivity Enhancement Program helps firms adopt new agri-technology. The program provided Rainbow Farms of Nova Scotia with more than $100 000 towards the purchase of high technology sorting equipment that will reduce wastage from 20% to 4%.

- **Prototype development support:** Support to take technologies from the R&D stage to prototype formulation and marketing can enhance industrial capability. Although it is no longer available, the Unsolicited Proposals Program of Supply and Services Canada assisted various companies to develop new products. National Defence's Defence Industrial Research Program stimulates innovative research in defence-related technologies.

Skills Development

Through collaborative research, engineers, scientists and other technical personnel can improve their knowledge and skills. Most departments have training programs to give students hands-on experience prior to graduation. Interchange Canada facilitates personnel exchanges between the private sector and universities. Fisheries and Oceans spends about $600 000 annually for post-doctoral fellowships, bringing highly trained scientists into the organization to share their knowledge before they take up permanent positions in the private or public sector. NRC's Research Associates Program provides training for recent science and engineering graduates by placing them directly into the council's laboratories. The constant flow of young scientists through the laboratories at the rate of about 200 per year rejuvenates NRC's scientific population.

IRAP contributes directly to the development of industrial skills by helping firms engage and train the personnel necessary to meet their technology goals. One component of IRAP (IRAP-H) is targeted specifically to help university students obtain relevant on-the-job training. Small and medium-sized firms can hire university or technical college students, under the supervision of an IRAP industrial adviser or another professionally qualified project counsellor, to solve short-term problems.

Facilitating Technology Transfer

Given the importance of facilitating technology transfer, departments and agencies have identified a number of impediments to the process. Various governmental administrative policies and regulations restrict operational flexibility, e.g., purchasing and contracting regulations, which slow responsiveness to client needs; PY and financial restrictions, which hinder participation in collaborative research arrangements; and budgeting cycles, which limit a laboratory's ability to respond quickly to windows of opportunity.

While the Increased Ministerial Authority and Accountability initiative indicates positive changes, departments expressed concern over the lack of financial flexibility. Laboratories are offered few incentives to transfer technology since they are not allowed to re-spend the revenues from royalties or to use monies received from joint ventures to cover incremental costs or the salaries of personnel participating in such ventures. Departments noted a lack of in-house expertise to carry out technology commercialization activities. Human and financial resource restrictions, and a lack of both financial and non-financial incentives for laboratory staff, pose problems for managers in developing or acquiring the required expertise. However, demands are increasingly being made on laboratory personnel to contribute to technology transfer, and they are being rewarded for their performance in this area. Also, classification standards for research scientists are being developed to recognize technology transfer responsibilities.

The technology transfer process is further constrained by the inability of potential receptors to exploit technology properly once it is transferred. Many small firms lack the financial resources and/or the scientific and technological, engineering and marketing expertise required to commercialize technologies properly. Furthermore, the geographic dispersion of some industries (i.e. the construction industry) makes the proper dissemination of new information difficult.

Issues

Traditionally, technology transfer involved internal development followed by transfer to an outside client. Technology transfer is now co-development, involving partners at all stages of technology transfer as a natural part of the process. Collaborative projects also lever funding from clients, thus extending departmental financial capacities and ensuring the relevance of outputs. The key issues which are emerging include:

- Not all departments identify economic or industrial development as an objective of their S&T mandate. For those that do, especially those in the natural resource and non-renewable resource fields and NRC, technology transfer is a key activity. For others, with departmental missions related to health and safety, national security and protection or basic research, technology transfer can still be an important component of program activity.

- Technology transfer faces many constraints, including administrative regulations that do not allow flexibility in staffing positions, financial restrictions such as the inability to retain revenues from successful joint projects, and the wide dispersal of companies across the country, which makes dissemination of information difficult.

- Many potential recipients of technology transfer do not have the financial or technical resources to adequately receive and utilize R&D from government laboratories. This is especially a problem with small and medium-sized businesses and when competitive lead-time for product development and commercialization is short.

Scientific Personnel Requirements

People supply the intelligence, creative insights and unswerving dedication that generate scientific and technological advances. Their workplace skills, organizational abilities and entrepreneurial ingenuity enable us to achieve national goals of scientific excellence and competitiveness. People are the essential agents of technology transfer, industrial renewal and economic change. And people do the thinking that initiates public debate about how society should respond to, and manage, the social repercussions of technological development. The human context of S&T is an integral part of technological development and change.

As in all organizations, maintaining vitality and creativity in federal S&T organizations requires steady infusions of new ideas and talent, as well as careful management of existing resources to ensure their continuing contribution. This is achieved largely by recruiting new staff and developing existing staff. The quality of government research is also sustained through personnel and project evaluation processes.

Over the last decade, however, staff turnover in the federal S&T community has declined. While low turnover is desirable in many respects, e.g., because it promotes continuity and helps to protect the government's investment in human resource development, it also results in fewer opportunities to hire new staff.

Many current members of the federal research community, recruited in the late 1940s and early 1950s, are now reaching the end of their careers. University research and teaching personnel were also recruited from the same age group. The result is that, by the year 2000, many key researchers, in both government and the academic community in all parts of the country, will be retiring. Especially over the long term, and as the number of retirements increase, there will be increased demand for new science professionals with state-of-the-art skills not only within the government and university communities but also in the private sector. We will need more highly qualified personnel to meet the competition in the marketplace of the future.

But there are indications that the number of university graduates in many science disciplines will not be sufficient to meet anticipated demand. Recent information compiled by NSERC shows possible shortages of graduates in mathematics, computer science, geology, and civil, chemical and electrical engineering. Fisheries and Oceans has identified a probable shortage of marine scientists as well as an ongoing problem recruiting women with qualifications in science. In summary, a variety of actions appear necessary to meet the emerging challenges of the 1990s, and these are examined in more detail in the following section.

TABLE 3
Scientific Personnel by Occupational Category
Actual PYs Allocated, 1985-1990

	Research & Development		Related Scientific Activities		Total S&T Activities	
	1985-86	1989-90	1985-86	1989-90	1985-86	1989-90
Executive	300	271	496	585	796	856
Scien. & Prof.	6 206	5 870	4 376	5 317	10 582	11 187
Admin. & For. Serv.	1 112	1 082	2 393	2 604	3 505	3 686
Technical	4 693	4 501	4 156	4 159	8 849	8 660
Admin. Support	2 345	1 942	4 618	4 157	6 963	6 099
Operations	2 861	2 392	697	901	3 558	3 293
Military	166	190	16	17	182	207
Total	**17 683**	**16 248**	**16 752**	**17 740**	**34 435**	**33 988**

Source: Statistics Canada, *Federal Science Expenditures and Personnel, 1989-90,* Cat. Nos. ST-89-01 and ST-90-01.

Federal S&T Personnel

Table 3 shows the breakdown of PYs by category for R&D, RSA and total S&T activities. In 1985-86, 34 435 PYs were dedicated to scientific and technological activities (17 683 in R&D and 16 752 in RSA). In 1989-90, 33 988 PYs were allocated for this purpose (16 248 in R&D and 17 740 in RSA), a decline of 1.3%.

Although there were changes at the individual establishment levels (e.g. a closure or an opening), the overall and relative size of the federal S&T population changed little during this four-year period. The major changes occurred in the proportion of R&D and RSA personnel. There were declines in almost all categories of R&D PYs while almost all categories of RSA PYs saw increases.

Demographic Status

During the 1970s, the turnover rate in the federal S&T community was typically 5%, though it sometimes reached 7% to 8%. The current rate is 3%, or less. One reason for this low turnover is the median age of 45. There are fewer promotional opportunities for younger staff as long-service employees occupy senior positions. As a result, research establishments are unable to hire significant numbers of recently graduated researchers.

About 11 000 of the 33 988 people engaged in federal S&T activities are classified in the scientific and professional category. Of these, 2 000 are research scientists with doctoral degrees or post-doctoral qualifications who are classified in one occupational sub-group (SE-RES), thus facilitating a demographic examination. One aspect, group distribution by age band, is illustrated in Figure 4.

① IDENTIFY
ECONOMIC
DEVELOPMENT
AS S&T

② FLEXIBLE ADMINISTRATION

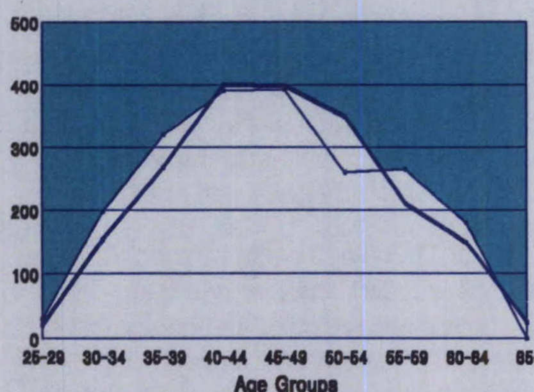
③

SCIENCE
TECHNICAL
DREAM

The demographic examination of the SE-RES group reveals several interesting points:

- The average age of group members has increased from 45.9 in 1987 to 46.7 in 1989. Although this average can be attributed to the absence of younger recruits as much as to the age of existing staff, it is still relatively high when compared with many non-government research organizations.
- This suggests a significant demand for replacements in the SE-RES group within the next 10 to 15 years, even compared to the public service as a whole, which itself is downsizing and amalgamating functions. We do not necessarily need to increase the technical personnel base, but we will be faced with replenishing this base as people begin to retire. An additional problem will be competing with the private sector for a limited number of highly qualified persons.
- Since the removal of compulsory retirement at age 65, the number of scientists working beyond that age is increasing. Their continuing contribution may be invaluable, but does add to the problem of promotion blockage and entry-level hiring.
- Reductions in the number of senior scientists in the next decade will help to overcome the promotion blockage problem, but there may also be a substantial impact on program continuity as new replacements are hired and trained.

FIGURE 4
SE-RES Demographic Profile Federal Public Service Age Distribution, 1987 and 1989



Year:	1987	1989
Population:	2 055	1 975
Average:	45.9	46.7

Source: Treasury Board Secretariat Incumbent.

Ensuring Adequate Supplies of Scientific Personnel

Many departments — including Agriculture Canada, Communications Canada, Transport Canada, Health and Welfare Canada, Fisheries and Oceans, and EMR — expressed concern about the availability of certain highly qualified specialists who will be required to work on long-term interactive projects.

NSERC studies have shown that university enrolments are decreasing in many natural science and engineering disciplines, even though Canadians between the ages of 18 and 24 are entering university in greater numbers. At the same time, the university-age population as a whole is shrinking. Demographic trends indicate its size will drop by roughly half a million people during the next decade. Hence the number of individuals entering science will decrease.

At the bachelor's level, while more science students are entering the biological sciences, there are declines in the number enrolling in engineering fields (civil, chemical and electrical), agriculture, and the mathematical and physical sciences, including computer science and geology. In the last few years, science and engineering enrolment for master's degrees has levelled off, reflecting the diminishing number of bachelor's level graduates. Although doctoral enrolment is growing at present, the factors just discussed will probably reverse this trend. Thus the supply of highly qualified scientific and engineering researchers, especially in fields such as biomedical research, ergonomics, health administration, marine science and science policy, may be severely restricted in the coming decade, and shortages in specific fields could develop.

In response to this situation, the government established the Canada Scholarships Program in 1988. Its objective is to increase the number and quality of highly qualified Canadians in fields critical to our future industrial and economic competitiveness. The program awards 2 500 scholarships annually to recognize and encourage more of our top students to pursue undergraduate studies in natural sciences and engineering. Academic excellence is the basis for the selection, with a minimum of one-half of the scholarships being presented to outstanding women. Each scholarship is worth $2 000 per year, tenable for up to four years, for a maximum value of $8 000. When the program reaches maturity, there will be up to 10 000 active scholarships each year. The budget is $80 million over five years (1988-93).

In summary, S&T managers noted these concerns:

- the impact of public service downsizing, combined with the demographic profile of the federal research community;
- morale problems associated with reduced opportunities for promotion and new hiring;
- restaffing research organizations following the anticipated exodus of retirees in the 1990s;
- the need for researchers capable of working in multi-disciplinary teams, who are not only experts in their own fields, but also able to understand and deal with issues in other fields of the natural and social sciences;
- a potential shortage of technicians and technologists as well as scientists and engineers; and
- the need for researchers with skills in collaborative research as well as in technology transfer, management and marketing.

Departments are responding to these issues through post-doctoral fellowships, research fellowships, visiting experts, and part-time or contract work by retired employees. While these strategies help to infuse new talent, or cope with temporary shortages, they do not satisfactorily, or fully, address issues like turnover, the aging of the population, hiring

DOWN SIZING PROBLEMS
S&T

MORALE LOW

RESTAFFING

MULTI DISCPILINARY

SHORTAGE OF SCIENTISTS
TECHNICIANS

COLLOBARATION

and promotion blockages, or the dwindling pool of potential entrants. Some initiatives are:

- Agriculture Canada reports that a PhD graduate student data base of some 800 students enrolled in agricultural PhD programs at 23 universities across Canada has been established to supply labour market and qualified resource information.

- Communications Canada, along with other departments, is developing an emeritus researcher program to permit the retention of retired researchers on contract while recruiting junior researchers using the same PY allocation.

- Transport Canada has established a Visiting Experts Program with the private sector and universities for specific R&D activities, and this has had a beneficial effect on staff development.

- Indian and Northern Affairs Canada promotes the development of scientific expertise in the Canadian North through: the Northern Scientific Training Program, which supports graduate research studies in the North; the Northern Science Award, which is given in recognition of scientific excellence in northern and Arctic studies; and the core support the department provides for the Association of Canadian Universities for Northern Studies.

- Health and Welfare Canada has instituted the National Health Research and Development Program Training Awards to support master's and PhD candidates in fields such as public health and medical sociology. Each year, 22 annual awards are offered in addition to the 60 now in the system. With the University of Manitoba, the department sponsors candidates for Master of Food Science degrees and, with Dalhousie University, seeks qualified nurses for the Outpost Nursing Program.

- Fisheries and Oceans, in addition to participating in the Research Scientist Emeritus Program, recruits female scientists through the Science Revitalization Program and, four years ago, created the western hemisphere's first francophone centre for marine sciences, the Maurice Lamontagne Institute.

- NSERC has now established 65 industrial research chairs at Canadian universities in areas from environmental engineering systems to fisheries oceanography. Among other initiatives, NSERC has also established the Register of Canadians Studying Abroad to provide a source of potential Canadian employees to industrial, government and academic employers.

- MRC's Group Program has existed for over two decades and currently supports twelve groups at levels of $1–2 million each, per annum. These interdisciplinary teams in areas such as medical genetics, protein structure and function, neurological sciences, periodontal physiology, allergy research and neonatal health provide an important means of training future biomedical researchers and provide interactive centres with the health care products industry.

Issues

The question that remains is how to deal with current challenges and the ability of federal S&T personnel to support scientific excellence and industrial competitiveness while planning to address the challenges of the 1990s that require science professionals with state-of-the-art skills. Among the issues involved are the following:

- There are indications that the number of university graduates in many science disciplines, such as mathematics, computer science, geology, agriculture, marine science and engineering, may not be sufficient to meet anticipated long-term demand in either the public or private sector.

- New or modified ways of developing scientific talent are needed to ensure an adequate supply of highly qualified personnel for our future needs as well as to ensure the continuity of ongoing research.

- Training and development courses for S&T managers to manage more effectively in the public service environment have not been widely available. Initiatives such as Public Service 2000 and the work of the Canadian Centre for Management Development should advance such training needs.

- Science managers will also need to develop management, marketing and staffing approaches that will take into account ongoing work force adjustments, fiscal restraint and the need for collaborative projects.

- Continuing efforts will be needed to integrate the social sciences and humanities more closely with the natural sciences and engineering in inter-disciplinary, cross-sectoral teams.

Sustainable development has been defined as "a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development and institutional change are made consistent with future as well as present needs" by the World Commission on the Environment and Development (Brundtland commission). As a means of orienting S&T activities, sustainable development is both right and smart. Ensuring that the world's water, soil, forestry, agricultural, fishery and other resources can continue to benefit future generations is unquestionably the right thing to do. But there is also an element of enlightened self-interest, because the shift in world attitudes creates substantial opportunities for countries like Canada in the technological development and adept commercialization of sustainable products and processes for international markets.

Sustainable development skills are just beginning to develop. S&T are integral components of the skills that will be developed, and the quality of those skills will be a key measure of our success in dealing with these problems. The impetus for sustainable development lies in environmental disasters like Bhopal and Chernobyl and in the gradual degradation of the natural environment through atmospheric carbon dioxide concentration, deforestation, desertification, soil erosion, oil spills and water pollution. The challenge lies not only in reversing the damage but also in devising new ways to pursue development without environmental damage.

Canada's Commitment to Sustainable Development

The May 1987 Brundtland commission report focused international attention on:

- the inextricable links between the state of the environment, the strength of the global economy, and the health of the world's inhabitants; and
- the urgent need for new, environmentally benign S&T, which are essential to sustainable economic and industrial development.

Canada has demonstrated its commitment to sustainable development by:

- endorsing the Brundtland report and establishing the National Task Force on Environment and Economy, plus provincial and national round tables;
- hosting the 1988 international conference in Toronto, The Changing Atmosphere: Implications for Global Security, and the Globe 90 conference in Vancouver;
- funding major environmental cleanups (e.g. the Great Lakes, the St. Lawrence River, Hamilton harbour);
- negotiating and signing the Montreal Protocol to reduce emissions of chlorofluorocarbons;
- supporting the G-7 countries' call at the Paris Summit for new S&T strategies and the development of internationally recognized standards for sustainable development;

- implementing more stringent *Canadian Environmental Protection Act* standards and strengthening EARP; and
- identifying sustainable development as a priority item in the April 1989 Speech From the Throne.

Sustainable Development and Federal S&T

This commitment to sustainable development will influence the conduct of S&T, criteria for funding projects, methods of technology transfer, and planning for human resource needs. Three elements of that commitment are examined here:

- inclusion of S&T environmental concerns in all decision-making processes;
- S&T programs and policies linking economic and environmental concerns; and
- new environmental issues.

S&T Environmental Concerns and Decision Making

Federal departments and agencies are being called upon to review their S&T activities and how they address environmental concerns. Environmental considerations will ultimately affect decisions on priorities and resource allocation. No drastic shifts in the nature and objectives of departmental S&T activities are anticipated, but compatibility with sustainable development principles must be demonstrated. Some departments and agencies have traditionally linked economic and environmental concerns, dealing with them concurrently in decision making. Examples include:

- the commitment of Transport Canada, by statute and in practice, to the conduct of environmentally oriented transportation R&D;
- Fisheries and Oceans' Interdepartmental Committee on Oceans, with its focus on sustainable development;
- EMR's Panel on Energy Research and Development and its commitment to an environmental action plan, philosophy and strategy; and
- Forestry Canada's S&T program dealing with the impact of forestry practices on the environment and the effects of pollution on the health and productivity of forests. The environmental costs and consequences of forestry practices are increasingly being incorporated into forest management planning.

Departments are also developing new ways to include sustainable development in decision making. Of central importance is the current work of Environment Canada. Other departments' activities include:

- Agriculture Canada's operational planning framework on sustainable development, affecting all programs, and its establishment of a program review and environmental issues task force;
- *EMR's Commitment to the Environment,* a report which promotes the use of EMR science to improve the environment and encourages industry to attain environmental objectives;

- support by NSERC and SSHRC for the Canadian Global Change Program, under the auspices of the Royal Society of Canada; and

- the provision of a solid legal and scientific base for the sustainability of Canada's oceans in the proposed *Canada Oceans Act.*

Linking Economic and Environmental Concerns

Sustainable development also requires better links between economic and environmental concerns. Departments with a traditional interest in the environment, and concurrent emphasis on partnerships with industry, have made the greatest strides in adapting existing S&T programs. Progress to date includes:

- ISTC's Environmental Industries Sector Initiative involves investigating new markets and enhanced industrial capabilities and focusing on the development, transfer and application of critical S&T.

- Health and Welfare Canada's Environmental Framework, developed with Environment Canada, links health and environmental concerns in joint policy development and action plans.

- The granting councils (NSERC, SSHRC and MRC) emphasize environmental priorities in their strategic grants operations. NRC conducts research that supports industry in addressing environment-related problems.

- Environment Canada, Health and Welfare Canada, Fisheries and Oceans, and ISTC are working together to clean up the St. Lawrence-Great Lakes waterway.

- The Canada-U.S.S.R. Agreement on Cooperation in the Arctic and the North provides a comprehensive framework to enhance exchanges and broaden bilateral co-operation in many areas of Arctic development. The new agreement will include scientific and technical co-operation, economic co-operation, and co-operation on social and cultural questions. A Canada-U.S.S.R. mixed commission will be created to oversee the implementation of this agreement.

- Indian and Northern Affairs Canada's *Northern Political and Economic Framework* for achieving a *Northern Conservation Strategy,* a *Northern Environment Strategy,* and an evaluation of the *Northern Oil and Gas Action Plan* ensure an appropriate technology for the safe development of northern oil and gas.

- The newly announced Canadian Polar Commission will monitor the development in Canada, and in its circumpolar neighbours, of Arctic knowledge and provide information about northern research and management matters.

New Environmental Issues

Departments and agencies highlighted environmental issues as requiring extensive co-operation among all science-based departments. Some of the issues arise from specific problems such as climate change, deforestation and water quality while others involve broader concerns. The issues fall into three groups: legislation, regulations and negotiations; issues related to financial and personnel resources; and scientific/development problems.

Legislation, Regulations and Negotiations

Many environmental issues have cross-sectoral impacts and national or international dimensions. Action (setting priorities, allocating resources and revising compliance guidelines) to deal with these "macro" issues is taking the form of new standards, legislation and processes (e.g. EARP reform) and of negotiating federal-provincial or international accords (e.g. the Montreal Protocol). This creates a broad legal framework within which industries and citizens can contribute to sustainable development. Examples include:

- Trans-boundary environmental problems (air pollution, ozone depletion, acid rain, and ground water and ocean pollution) affect all nations and require international negotiations/accords.
- Government-university-private sector partnerships are needed to tackle environmental problems and share facilities and resources.
- Full implementation of EARP and the accompanying legislation will change the way S&T activities are conducted.
- There is a need for a sound natural and social science base for industry and government policy development and legislation. There are uncertainties in current scientific thinking about environmental causes and effects, as well as basic knowledge gaps with respect to the physical, chemical and biological processes affecting ecosystem disturbance and recovery.

Financial and Personnel Resources

There are financial and human resource constraints on our capacity to act on the sustainable development/environmental agenda. Departments' ability to satisfy new demands is linked to the availability of monetary resources and to the supply of skilled scientific personnel. New demands on existing programs could result in resources being spread thinly. Examples include the following:

- EARP reforms will necessitate increased, or reallocated, resources for screening, assessment, evaluation, and monitoring.
- The key natural resource departments will face increasing scientific personnel pressures. The continuing need to carry out basic, mission-oriented research will compete with related scientific activities. This issue, together with questions surrounding the supply of highly skilled scientific personnel, will curtail the development of leading-edge technologies required to meet sustainable development goals and ensure competitiveness.

Scientific/Development Problems

Most of the issues raised by departments focused on mission-oriented S&T. Many of these issues are global and are linked to issues in the first two groups. Our ability to solve basic scientific problems can be either enhanced or hindered by the availability of resources and the existence of appropriate policy and legislative frameworks. Examples include the following:

- Human activity affects global processes controlling climate and the atmosphere. The decomposition of atmospheric ozone caused by the burning of fossil fuels and the destruction of tropical rain forests may shift temperature and affect the world's oceans, biological systems, agriculture, forestry and rainfall. In Canada's North, an extremely sensitive region, climate, landscape and communities could be altered drastically. Remote and undeveloped Arctic areas are already beginning to be subjected to toxic waste pollution.

- Chemical pollution of waters has spread, in less than 20 years, from freshwater resources to large systems like the St. Lawrence River. Waste disposal will continue to be a problem, given the focus on reducing environmental degradation (land and ground water).

- The search for alternative, non-carbon and cleaner energy sources intensifies with the growing evidence of global warming from the burning of fossil fuels.

- The operations of many industrial clients of departments like EMR and ISTC have environmental effects. Technologies that reduce environmental stress, while protecting the competitiveness of departments' clients, will be in demand. This is a major theme in ISTC's Environmental Industries Sector Initiative, with its focus on critical technologies. New environmentally friendly and cost-competitive technologies for Canadian industry will be essential to competing in the global marketplace.

- Forestry Canada is working to increase the availability and effectiveness of: biological insecticides; silviculture controls on forest weeds; and species of fast-growing, pest-resistant trees. The department is also trying to ensure that environmental costs are incorporated into all stages of forest management planning.

- The preservation of Canada's written heritage (through the National Library and National Archives) is benefiting from a cost-effective chemical process for the de-acidification of books and would further benefit from the establishment of standards for paper use. Acid-free, permanent paper is cheaper to produce than acidic paper, and the use of alkaline processes to produce it has a ready market.

- Concern about the links between health and environment will continue and will focus on: improving health information systems using national data bases; developing pollution-abatement technologies and accident clean-up technologies; and developing more environmentally benign approaches to problems.

- Some economic models overestimate the efficiency of conventional agriculture because they do not account for factors such as agri-chemical use, deterioration of water quality and soil degradation. Natural resources and the environment are not free goods; their real value needs to be reflected in the social cost of end products.

Issues

While the importance of sustainable development globally, and in Canada, is already significantly reflected in the federal government's S&T activities, departments and agencies are seeking to balance the development of environmentally benign technologies with the need to maintain and enhance industrial competitiveness. Some of the current issues include:

- The implementation of EARP by all departments, agencies and R&D partners to promote sustainable development will have a resource impact on the development of new policies and programs and the delivery of existing and future programs.
- Strengthening the link between economic and environmental concerns in decision-making processes, policies and programs will require even greater consultation and co-ordination with interested groups.
- The resolution of financial resource issues, human resource management needs and scientific constraints in the development of environmentally benign technologies and products requires long-term approaches.

Conclusions

The federal government has a national commitment to excellence in science and to competitiveness with 290 federal scientific establishments and 33 988 scientific PYs, located in all regions of Canada. Total expenditures on S&T activities in 1989-90 were $5.05 billion. Collaborative R&D involving the federal government and industry will be a key to enhancing the effectiveness of these resources, especially in priority areas such as the environment and medical science. Successful collaboration has taken place in a number of areas, including: remotely operated undersea vehicles for commercial exploration, mobile satellite systems, and geophysical surveys. Forms of government-industry co-operation have included contracting-out, joint ventures, term hiring and staff exchanges. The Networks of Centres of Excellence also link industrial, university and government researchers. Many of these collaborative efforts are under way and effects are already being felt. But there are still a lot of opportunities to be seized before the full potential of all federal government S&T programs can be realized.

Although there are many techniques used, collaborative R&D with industry is the preferred vehicle for technology transfer. Industry has little time to adapt research to commercial applications. It must be involved from the outset with government and the academic community in order to meet the tight time-frames that cost structures and market pressures demand. At the same time, it is clear that a number of mitigating circumstances affect industrial potential to exploit R&D. Even multinational enterprises do not have unlimited resources to underwrite R&D, and most small and medium-sized companies simply do not have the resources to obtain and utilize the technology. For many federal departments, commercialization is not the primary mandate. They must assume various mission responsibilities. However, technology transfer tools such as technology marketing offices and technology information centres continue to be supplementary transfer mechanisms.

Skilled personnel are the key part of a successful S&T effort. Increasingly, issues such as health care and sustainable development require multi-disciplinary S&T skills that integrate social sciences and humanities with natural sciences and engineering. In light of the demographic profile of the public service generally, and the scientific community in particular, strategies to manage our existing human resources effectively must continue to be instituted to ensure continuity in the federal effort. Training and development courses for S&T managers have not been widely available. Initiatives such as Public Service 2000 and the work of the Canadian Centre for Management Development should advance such training needs. In addition, co-operative work-study programs are under way in federal laboratories, the Canada Scholarships Program is in place, 65 industrial research chairs have been funded at Canadian universities, post-doctoral fellowships and the Visiting Experts Program are enhancing the education of highly qualified personnel, and targeted recruitment programs are bringing more new scientists into fields critical to our future industrial and economic competitiveness.

Federal S&T for sustainable development will change the formulation of public policy and government support to industry. Federal departments and agencies are linking economic and environmental concerns in their operational frameworks and balancing environmental action with technological development. For some departments, the environmental focus has always existed, as with the multi-departmental environmental activities of the Panel on Energy Research and Development. For other departments, there will be new developments to augment the environmental component of existing operational programs. Sustainable development is an important element of domestic and international competitiveness as Canada progresses in its S&T efforts through collaborative leading-edge environmental innovation. Success will also be a function of our ability to harness the creative talents of skilled public and private sector scientists.

S&T are critical to our economic and social well-being. Federal S&T activities are an important part of the national effort. In the current climate of fiscal restraint, it is important that the contributions made by federal S&T are recognized and that the level of federal support is adequate to generate the results needed. Success will be achieved by moving to a multi-disciplinary approach, collaborative teams and more effective networks. Young scientists will have to be integrated now into the federal S&T effort to ensure continuity of research. The S&T needed for sustainable development offer outstanding industrial opportunities and interesting public policy challenges. The federal government has established a number of frameworks and consultative structures to provide guidance and respond with action, including: the National Science and Technology Policy; InnovAction; and the National Advisory Board on Science and Technology, chaired by the Prime Minister. Success will be measured by our future standard of living and quality of life. More than ever before, this will depend on how industry, university and government co-operate to manage and develop the existing S&T infrastructure.

ANNEX A

Science and Technology Statistics

Federal S&T Resources, 1989-90

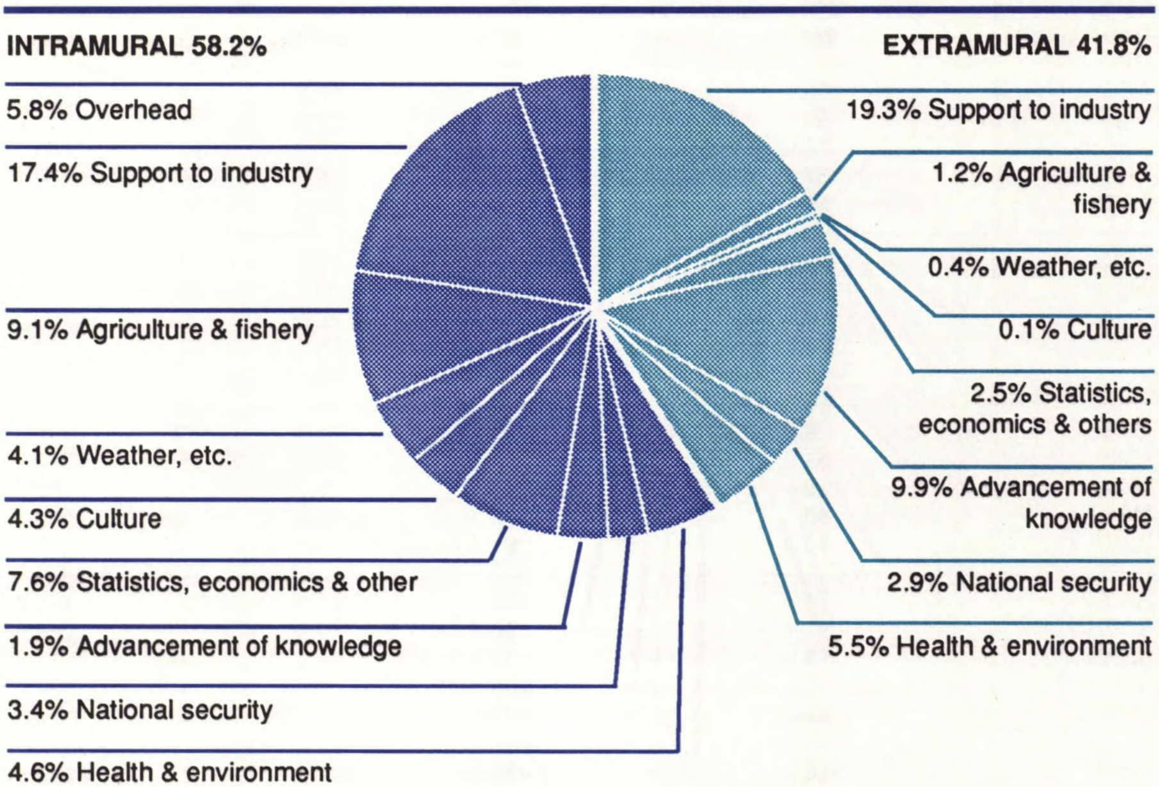
Department	Research & Development		Related Scientific Activities		Total S&T Activities	
	$ Millions	PYs	$ Millions	PYs	$ Millions	PYs
NRC	496.9	2 983	53.1	474	550.0	3 457
EC	80.8	775	409.3	3 814	490.1	4 589
NSERC	346.8	153	44.4	20	391.2	173
EMR	149.1	803	212.9	1 799	362.0	2 602
Agr	299.6	3 610	38.3	399	337.9	4 009
CIDA	65.6	30	259.9	117	325.5	147
ISTC	284.8	181	34.9	205	319.7	386
ND	290.8	1 869	4.6	72	295.4	1 941
SC	10.8	122	279.9	3 982	290.7	4 104
F&O	128.7	1 258	116.3	1 095	245.0	2 353
MRC	194.5	51	7.9	2	202.4	53
HWC	42.6	313	123.6	1 403	166.2	1 716
AECL	134.2	2 334	8.4	155	142.6	2 489
SSHRC	54.8	60	27.3	36	82.1	96
ForCan	68.3	742	7.8	186	76.1	928
Com	59.5	361	5.9	54	65.4	415
NLC	0.0	0	47.3	506	47.3	506
TC	33.8	71	7.1	44	40.9	115
INAC	2.4	7	4.6	19	7.0	26
OTHERS	205.6	637	410.9	3 246	616.5	3 883
Total	**2 949.6**	**16 360**	**2 104.4**	**17 628**	**5 054.0**	**33 988**
% Change Over 1988-89	**6.0**	**0.7**	**2.0**	**(0.8)**	**4.0**	**(0.1)**

Source: Statistics Canada, *Federal Science Expenditures and Personnel, 1989-90,* Cat. Nos. ST-89-01 and ST-90-01.

Note: Total S&T expenditures have increased by 4% over 1988-89 levels in absolute terms (no increase in real terms). R&D has increased by 6% in absolute terms (slight increase in real terms) while RSA has increased by only 2% in absolute terms (a slight decrease in real terms). S&T personnel has remained static, with a minor increase in R&D personnel and a small decrease in RSA personnel.

Significant increases in departmental resources are in AECL (20%), SSHRC (8%), MRC (7%) and NSERC (7%). Significant decreases in departmental resources are in ForCan (14%), CIDA (9%), and EMR (6%).

Applications of S&T, 1989-90



Source: Statistics Canada, *Main Estimates Science Addendum, PYs and Applications, 1989-90*, Cat. No. 88-2040.

Note: This chart is based on categories used by Statistics Canada for the collection of S&T data in the Main Estimates Science Addendum. In 1989-90, expenditures for the advancement of knowledge account for 11.8% of total federal S&T. Expenditures for agriculture and fishery (10.3%), statistics, economics and other (10.1%), health and environment (10.1%), national security (6.3%), overhead (5.8%), weather services and geodesy (4.5%), and culture (4.4%). The remaining 36.7% is for S&T in support of industry.

Regional Distribution of S&T Expenditures, 1987-88 ($ Millions)

Department	West	Ontario	NCR	Quebec	East	Total
AECL	35.1	79.5	9.3	12.5	0.0	136.4
Agr	97.1	31.6	82.4	28.8	26.4	266.3
ForCan	15.0	25.6	7.6	9.0	11.9	69.1
CIDA	37.9	53.2	7.7	89.1	8.8	196.7
F&O	53.1	13.3	11.3	20.4	101.8	199.9
INAC	5.3	0.5	1.0	0.2	0.3	7.3
ND	44.8	54.6	72.8	50.6	18.1	240.9
Com	0.3	1.0	31.7	22.5	0.2	55.7
EC	128.1	122.3	38.4	59.5	40.4	388.7
TC	3.8	3.4	11.1	7.1	1.0	26.4
ISTC	9.7	65.3	46.3	111.6	7.8	240.7
EMR	54.2	18.7	200.1	39.5	27.2	339.7
NLC	0.0	0.0	36.1	0.0	0.0	36.1
MRC	40.7	58.7	9.6	51.6	7.6	168.2
HWC	10.3	12.4	81.5	10.1	3.2	117.5
NRC	74.9	43.2	239.7	57.0	25.4	440.2
NSERC	91.6	117.4	26.8	72.2	22.4	330.4
SSHRC	10.3	18.7	11.3	18.4	2.9	61.6
SC	7.9	5.6	230.1	3.6	4.3	251.5
OTHERS	30.2	37.4	273.9	19.1	14.9	375.5
Total	**750.3**	**762.4**	**1 428.7**	**682.8**	**324.6**	**3 948.8**
Percent	**19**	**19**	**36**	**18**	**8**	**100**

Source: Science, Technology and Capital Stock Division, Statistics Canada, December 1989.

Note: The largest expenditures occurred in the NCR (36%) while Ontario and Quebec had 19% and 18% respectively. However, the high percentage of S&T activity in the NCR is buoyed by the amount of RSA conducted in this region.

The regional distribution pattern reflects the results of a variety of factors such as the nature of the S&T, the location of the department's clientele, and the historic development of the department's programs. For example, the high level of F&O involvement in the West and East reflects the regional nature of the department's mandated S&T activity.

The next two tables show the regional distribution of RSA and R&D for 1987-88. The RSA distribution illustrates the amount of RSA in the NCR, 50% of the total.

Regional Distribution of RSA Expenditures, 1987-88 ($ Millions)

Department	West	Ontario	NCR	Quebec	East	Total
AECL	2.4	4.6	0.7	0.0	0.0	7.7
Agr	5.9	0.3	15.7	0.3	0.0	22.2
ForCan	3.5	2.1	0.7	0.2	0.1	6.6
CIDA	32.1	46.4	6.6	75.9	7.5	168.5
F&O	14.7	7.7	8.3	9.2	50.8	90.7
INAC	3.3	0.0	0.9	0.0	0.0	4.2
ND	0.0	0.6	3.4	0.0	0.0	4.0
Com	0.0	0.5	3.0	0.3	0.0	3.8
EC	114.8	88.9	36.8	55.1	36.6	332.2
TC	0.3	0.6	3.2	0.5	0.0	4.6
ISTC	2.3	2.2	19.2	2.7	1.9	28.3
EMR	38.4	5.9	139.8	9.2	19.1	212.4
NLC	0.0	0.0	36.1	0.0	0.0	36.1
MRC	1.4	2.0	0.7	1.7	0.2	6.0
HWC	6.2	6.1	62.1	6.1	2.6	83.1
NRC	4.2	1.0	34.7	5.3	2.9	48.1
NSERC	7.3	13.3	3.2	8.7	1.6	34.1
SSHRC	2.3	5.8	6.1	4.2	0.5	18.9
SC	7.9	5.6	220.5	3.6	4.3	241.9
OTHERS	19.1	30.3	217.2	13.9	7.6	288.1
Total	**266.1**	**223.9**	**818.9**	**196.9**	**135.7**	**1 641.5**
Percent	**16**	**14**	**50**	**12**	**8**	**100**

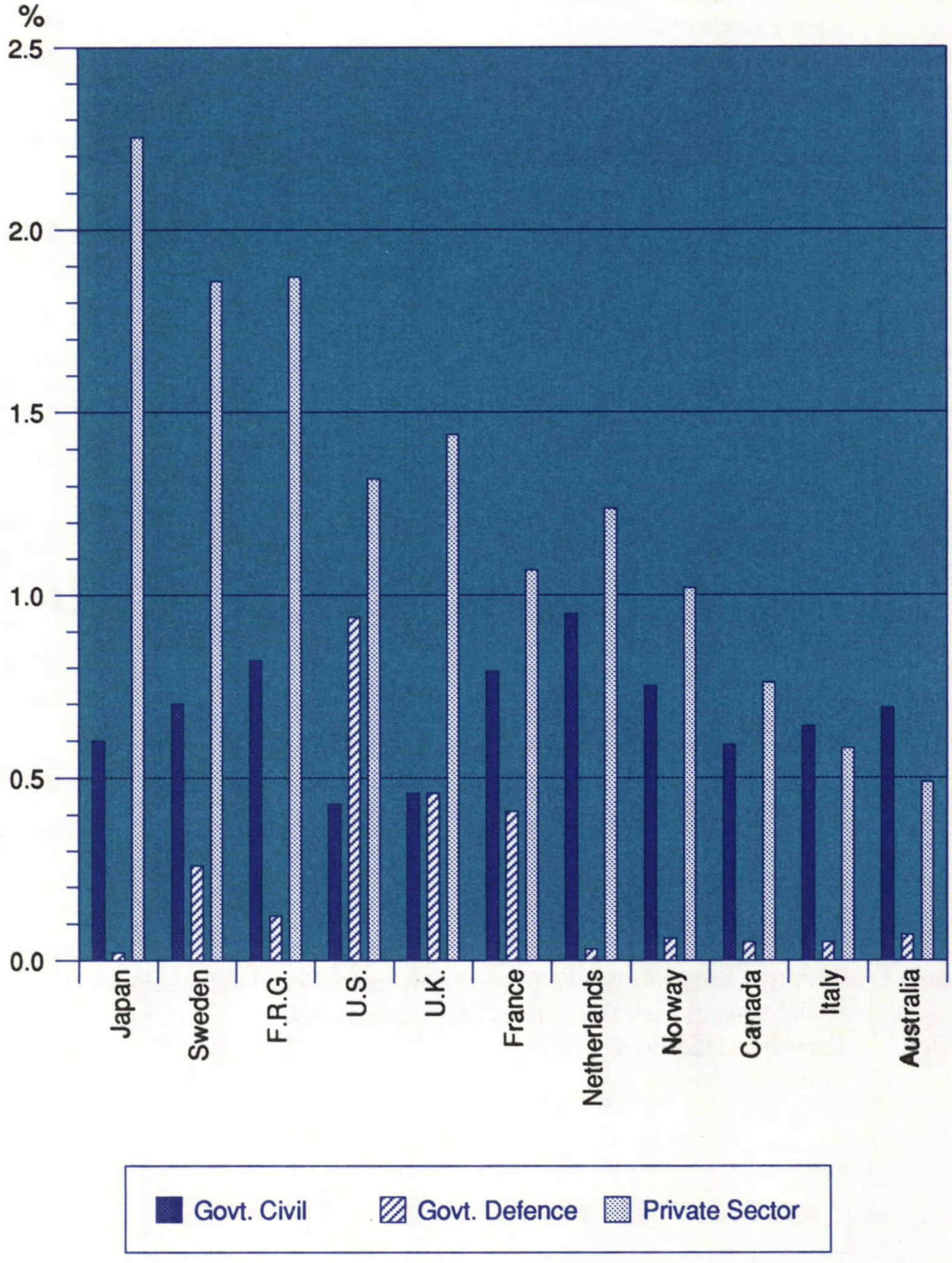
Source: Science, Technology and Capital Stock Division, Statistics Canada, December 1989.

Regional Distribution of R&D Expenditures, 1987-88 ($ Millions)

Department	West	Ontario	NCR	Quebec	East	Total
AECL	32.7	74.9	8.6	12.5	0.0	128.7
Agr	91.2	31.3	66.7	28.5	26.4	244.1
ForCan	11.5	23.5	6.9	8.8	11.8	62.5
CIDA	5.8	6.8	1.1	13.2	1.3	28.2
F&O	38.4	5.6	3.0	11.2	51.0	109.2
INAC	2.0	0.5	0.1	0.2	0.3	3.1
ND	44.8	54.0	69.4	50.6	18.1	236.9
Com	0.3	0.5	28.7	22.2	0.2	51.9
EC	13.3	33.4	1.6	4.4	3.8	56.5
TC	3.5	2.8	7.9	6.6	1.0	21.8
ISTC	7.4	63.1	27.1	108.9	5.9	212.4
EMR	15.8	12.8	60.3	30.3	8.1	127.3
NLC	0.0	0.0	0.0	0.0	0.0	0.0
MRC	39.3	56.7	8.9	49.9	7.4	162.2
HWC	4.1	6.3	19.4	4.0	0.6	34.4
NRC	70.7	42.2	205.0	51.7	22.5	392.1
NSERC	84.3	104.1	23.6	63.5	20.8	296.3
SSHRC	8.0	12.9	5.2	14.2	2.4	42.7
SC	0.0	0.0	9.6	0.0	0.0	9.6
OTHERS	11.1	7.1	56.7	5.2	7.3	87.4
Total	**484.2**	**538.5**	**609.8**	**485.9**	**188.9**	**2 307.3**
Percent	**21**	**23**	**27**	**21**	**8**	**100**

Source: Science, Technology and Capital Stock Division, Statistics Canada, December 1989.

GERD/GDP by Source of Funds, 1987 (For Selected OECD Countries)



Source: *OECD Main S&T Indicators*, December 1989.

Guide to Acronyms and Other Short Forms

ACOA	Atlantic Canada Opportunities Agency
Agr	Agriculture Canada
AECL	Atomic Energy of Canada Limited
CANMET	Canada Centre for Mineral and Energy Technology
CIDA	Canadian International Development Agency
CISTI	Canadian Institute for Scientific and Technical Information
Com	Communications Canada
EARP	Environmental Assessment and Review Process
EC	Environment Canada
EMR	Energy, Mines and Resources Canada
F&O	Fisheries and Oceans
ForCan	Forestry Canada
GDP	gross domestic product
GERD	gross expenditure on research and development
HWC	Health and Welfare Canada
INAC	Indian and Northern Affairs Canada
ISTC	Industry, Science and Technology Canada
MRC	Medical Research Council
MSAT	mobile satellite
NABST	National Advisory Board on Science and Technology
NCR	National Capital Region
ND	National Defence
NLC	National Library of Canada
NSERC	Natural Sciences and Engineering Research Council
OECD	Organization for Economic Co-operation and Development
PRO	provincial research organization
PY	person-year
R&D	research and development
RSA	related scientific activities
SC	Statistics Canada
SE-RES	Scientific and Professional Category, Research Scientist Sub-Group
SSHRC	Social Sciences and Humanities Research Council
S&T	science and technology
TC	Transport Canada

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