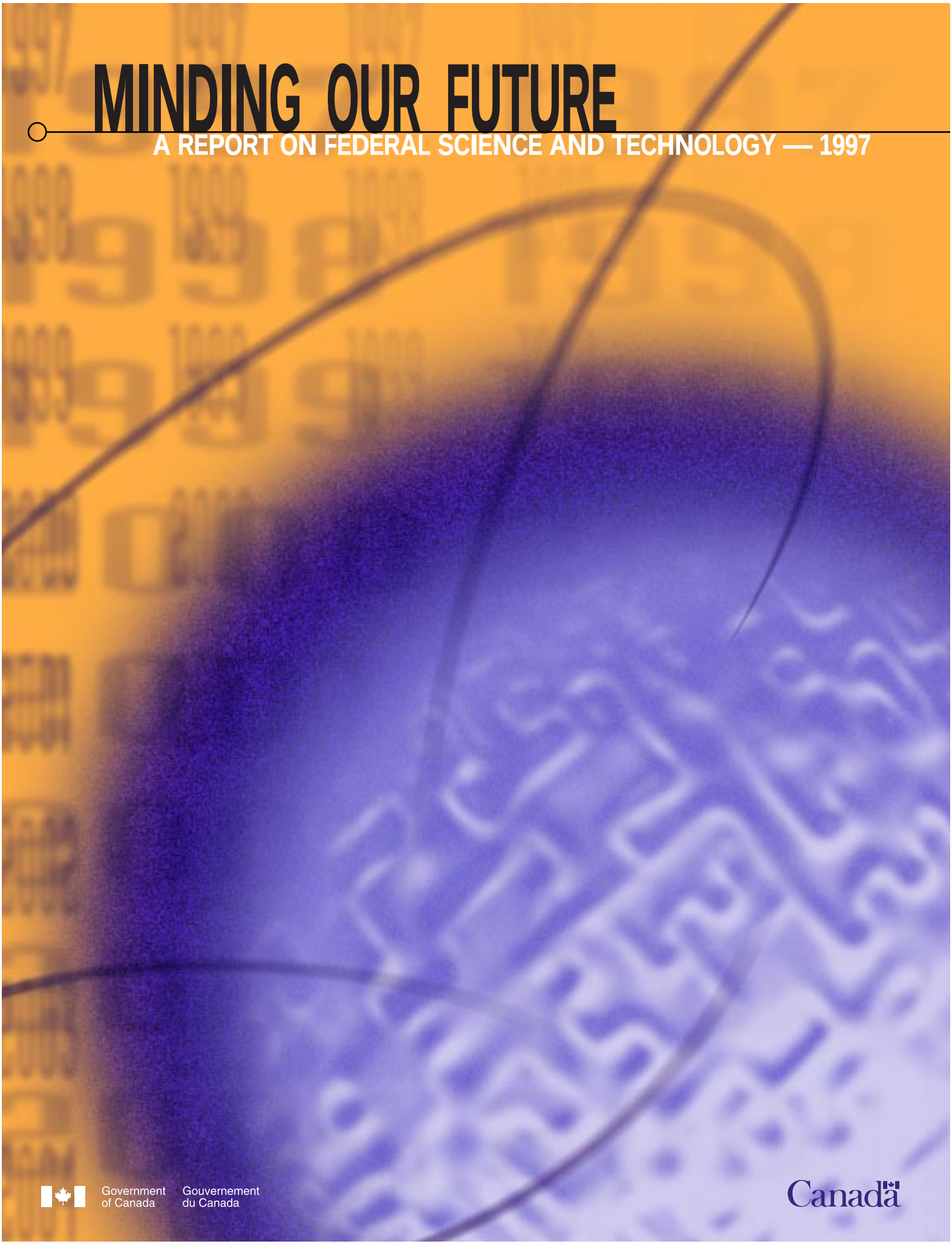
MINDING OUR FUTURE

A REPORT ON FEDERAL SCIENCE AND TECHNOLOGY — 1997



Government of Canada Gouvernement du Canada

Canada

The report is available electronically on Industry Canada's *Strategis* Web site:
http://strategis.ic.gc.ca/S-Tinfo

This publication will be made available in alternative formats on request.
Contact Distribution Services at the numbers listed below.

Additional copies of this report are available from:
Distribution Services
Communications Branch
Industry Canada
Room 205D, West Tower
235 Queen Street
Ottawa, Ontario
K1A 0H5
Tel.: (613) 947-7466
Fax: (613) 954-6436
Internet: http://info.ic.gc.ca/publications

Cat. No. C2-335/1997
ISBN 0-662-63290-7
51691 B

Message from the Minister of Industry

Canadians today live in a global society in which knowledge and innovation drive prosperity. The information revolution, led by dramatic improvements in computing and communications, is breaking down the barriers of time and distance and magnifying the role international developments play in our social and economic development. These changes are allowing individuals and businesses to operate across borders and around the world at the speed of light — sharing knowledge and trading in goods, services and capital 24 hours a day, seven days a week.

More than ever, people and innovation are the keys to growth and wealth creation. The knowledge economy is transforming all industrial sectors, from agriculture and natural resources to manufacturing, retail and services. As we move into the next century, the new economy will affect the life and work of every person, business, community and organization in Canada.

The Government of Canada recognizes that an effective federal science and technology (S&T) strategy is critical for positioning Canada to meet the challenges and seize the opportunities of the new economy.

The federal government plays a key role in all aspects of Canadian science and technology. It is the major supporter of university research in the country; it performs research and development (R&D) itself to support its policies, standards and regulations; and supports and invests in R&D by industry. It builds networks to promote partnerships among industry, academia and governments and to enable the best expertise possible to address national science and technology challenges.

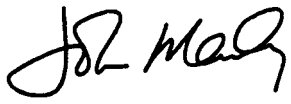
In March 1996, my Cabinet colleagues and I released *Science and Technology for the New Century: A Federal Strategy*. With concrete goals and guiding principles, the Strategy sets a course for transforming federal science and technology investments to better meet both the challenges of a changing world economy and of the evolving social and physical environment. The Strategy also ensures that Canadians receive a good return on their S&T investment.

The Strategy recognizes that ministers must be able to direct and manage their science and technology resources independently to best meet their organizational mandates. At the same time, the Strategy clearly states that ministers must be responsible as a group for ensuring that federal science and technology initiatives are coordinated and delivered effectively to meet the needs of Canadians.

Science and Technology for the New Century sets out an ambitious plan, focused on an enhanced reporting system, to improve the federal government's performance and accountability in the area of science and technology. This first annual report under the new system provides a clearer picture of the overall federal science and technology effort than has ever been presented before. Future reports will take advantage of better data becoming available, and of increased understanding of how science and technology are shaping the knowledge society and economy.

This report presents highlights of activities and policy directions to illustrate how the federal effort is being reformed to meet current and future challenges. The performance reports published by all federal science and technology departments and agencies contain additional information.

The federal S&T strategy is not static; it is designed to evolve to meet the new challenges Canadians will face as we move into the new millennium. It is a strategy designed to support the efforts of all Canadians to turn the promise of a new century into opportunity.



The Honourable John Manley P.C., M.P.

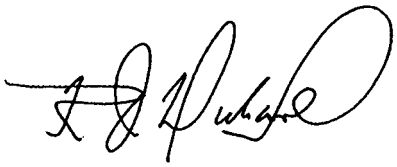
Message from the Secretary of State
(Science, Research and Development)

Canada's quality of life is the envy of the world. This quality of life has been earned by Canadians through hard work and dedication to building a better future for generations to come.

As we progress into the knowledge society, it is crucial that we maintain our focus on those future generations. We must ensure that the youth of today are able to acquire the skills they need for tomorrow. We must also ensure that the environment and the institutions we pass on remain healthy and productive. Now more than ever, Canada's success depends on our ability to innovate, as individuals, as communities and as a nation.

The Government of Canada's Science and Technology Strategy provides a sound roadmap to future success. This first report on the Strategy's implementation demonstrates our continuing commitment to federal science and technology as a cornerstone of future Canadian prosperity. It highlights how federal science and technology policies and activities help create stronger partnerships that lead to better jobs for Canadians and to an improved quality of life, and add to the world's stock of knowledge.

This report highlights the wide range of science and technology activities carried out by federal departments and agencies in support of their mandates and of the broader goal of ensuring Canada remains the best country in the world in which to live. I would like to draw attention to an equally important objective of these activities — enhancing Canadians' understanding of the importance of science and technology to their individual and collective lives and spreading the innovation culture that is key to Canada's continued excellence. Reinforcing this innovation culture will create the impetus for more young people to embrace science and technology to enable them to meet today's challenges and opportunities and to build a prosperous future for Canada.



The Honourable Ron J. Duhamel P.C., M.P.

Guide to Acronyms

The following acronyms are used in this report:

AAFC	Agriculture and Agri-Food Canada
ACOA	Atlantic Canada Opportunities Agency
AECB	Atomic Energy Control Board of Canada
AECL	Atomic Energy of Canada Limited
CIDA	Canadian International Development Agency
CMN	Canadian Museum of Nature
CSA	Canadian Space Agency
DFAIT	Department of Foreign Affairs and International Trade
DIAND	Department of Indian Affairs and Northern Development
DFO	Department of Fisheries and Oceans
DND	Department of National Defence
EC	Environment Canada
FORD-Q	Federal Office of Regional Development — Quebec
HC	Health Canada
HRDC	Human Resources Development Canada
IC	Industry Canada
MRC	Medical Research Council of Canada
NRC	National Research Council of Canada
NRCan	Natural Resources Canada
NSERC	Natural Sciences and Engineering Research Council of Canada
OECD	Organisation for Economic Cooperation and Development
SSHRC	Social Sciences and Humanities Research Council of Canada
TC	Transport Canada
WD	Western Economic Diversification Canada

Several abbreviations also appear regularly throughout the text:

R&D	Research and development
RSA	Related scientific activities
S&T	Science and technology
SME	Small and medium-sized enterprises

Table of Contents

1. Science, Technology and the Knowledge Society

Change, both technological and organizational, has always loomed large in humankind's social evolution. Indeed, some people argue that society's current state of existence would not be possible without its past history of advances in technological and organizational skills. Technological change has not only been the harbinger of economic progress but has also shaped culture and society, often with significant geo-political consequences. Unlike in the past, however, when change was slow and revolutionary developments few and far between, change is now permanent. The turbulent and uncertain environment of the late 20th century is but one more step on the road to the knowledge society.

Today, knowledge is the central determinant of economic growth, employment opportunities and quality of life, in large measure due to recent advances in science and technology. Advances in information and communications technology, for example, have created new industries and brought about major changes in workplaces and leisure time. These developments have influenced more than just how, where and when we work; they have also had dramatic effects on how we view and express ourselves. As a result, Canadians' health, wealth and prosperity increasingly depend on our ability to generate, acquire, transmit and use knowledge — specifically, knowledge that originates in science and technology (S&T).

Innovation is the key to continued success in this new, knowledge-based economy, to improvements in the health and education systems and to the general quality of life, and most innovations have their roots in technology. Surveys have shown time and again that organizations adept at developing, adopting and adapting technology are more successful than those that are not. To secure or enhance their competitive position in the global marketplace, companies in Canada and elsewhere have been expanding their research and development (R&D) programs, buying more best-practice technology, and entering into domestic and international partnerships with other firms (including competitors), with universities and with government.

Analysts have coined the phrase "national system of innovation" to describe the intricate set of institutions, links and interdependencies on which modern societies now depend. This innovation system functions within the constraints of a complex world ecosystem. A productive national system of innovation can generate the knowledge that society needs to make environmentally sustainable decisions, produce sustainable economic growth, and support a high quality of life for current and future generations. Because of the close connection between the success of the

innovation system and the need to achieve sustainable development, the various players, many of whom have been adversaries in the past, need to form partnerships. Having all parts of society working together toward common goals is key to determining the quality of life Canadians can expect in the future.

Biotechnology provides an excellent example of the opportunities and challenges presented by the knowledge explosion. Based on discoveries in university laboratories of how cells operate at the molecular level, biotechnology allows people to manipulate the basic building blocks of life, creating entirely new products, producing rare natural substances in industrial quantities, and treating previously incurable diseases. Advances in biotechnology's scientific underpinnings have led very quickly to new products and processes spanning a wide range of industrial sectors. Because of the rapid pace of change, skilled practitioners, with current knowledge of scientific principles and their applications, are in very short supply. As well, developments in biotechnology are happening faster than society can grasp some of their implications. The health and social effects of biotechnology are not well understood, at least by the general public, and some of the technologies raise moral and ethical questions that still need to be addressed.

It is becoming increasingly clear that developing a high level of scientific and technological competence and using it effectively are crucial to achieving a nation's social, cultural and economic aspirations. The Canadian government has a long and successful history of investing in science and technology and, as the next section of this report emphasizes, has played a central role in building and maintaining Canada's scientific and technological infrastructure. The federal government also directs investment at activities that help determine the available policy options and how policy is formulated, implemented and evaluated, and at programs that provide essential services to the public.

Increasingly, the search for knowledge transcends national borders, as countries seek out the best wherever it is to be found. While Canada's S&T effort takes place within this global context, Canadian researchers alone cannot generate all the knowledge and technology needed to maintain a high quality of life, nor can Canada isolate itself from the rapid pace of change around the world. Canada needs to continue making a strong contribution to the world's knowledge stock and to preserve access to it.

Governments around the world recognize that no country can operate on its own. Thus, they are taking action to strengthen their scientific bases and research communities, and to support innovation in domestic industry. These actions of other countries in the area of S&T clearly affect the ability of Canada's governments to respond effectively to S&T needs. As well, problems associated with health, water resources, sustainable development and the environment, among others, are not contained within the boundaries of any country. Formulating S&T policy, developing regulations, and grappling with even broader social and economic policy questions, must be done in the global context.

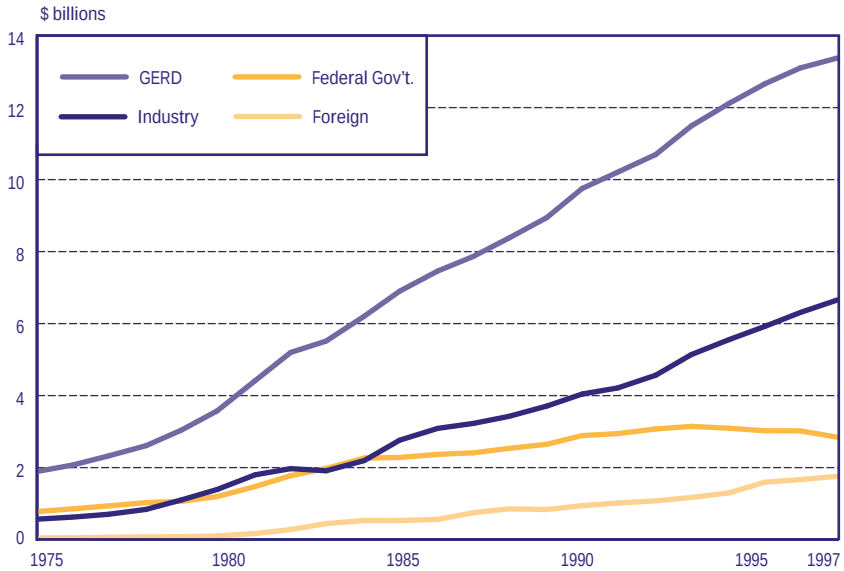
Science and technology play an important role in most federal policies and operations, and are deeply embedded in the fabric of many government programs. At last count, more than 40 departments and agencies supported science and technology programs. These organizations, like the public they serve, are not immune to the incessant changes and uncertainties that characterize the emergence of the knowledge society. Advances in science and technology present federal science and technology groups with new opportunities and challenges. The federal S&T strategy, *Science and Technology for the New Century*, provides a firm foundation for departments and agencies as they exploit new opportunities and overcome new challenges.

This report, the first in a series, provides an overview of the federal science and technology investment, reviews the federal government's performance against the goals outlined in the Strategy, and identifies some challenges that must be overcome in the transition to a knowledge society. It begins by providing an overview of the federal investment in science and technology.

2. Federal Investment in S&T

Canada's gross domestic expenditure on R&D (GERD) exceeded $10 billion for the first time in 1991, and is expected to increase to $13.1 billion in 1996 and to $13.4 billion in 1997 (Chart 1). Almost all of this increase is due to the continued expansion of private sector R&D investment. Encouraged by some of the most generous tax credits in the world, both domestic and foreign firms have been increasing their R&D spending in Canada at a faster pace than in any of the other major nations of the Organisation for Economic Cooperation and Development (OECD). Unlike in the 1960s, and well into the 1970s, when the federal government was the dominant player in the national R&D effort, industry now leads the way as the main supplier of funds and performer of research. Largely as a result of Canada's strengthening industrial R&D base, the International Institute for Management Development promoted Canada to ninth place (from 17th in 1991) on the science and technology league table in this year's *World Competitiveness Yearbook*. The growth of GERD has also outpaced that of the gross domestic product (GDP). In fact, in 1996 Canada's GERD-to-GDP ratio was at an all-time high of 1.64%; however, this is still low by international standards: Canada ranks 11th among OECD countries, nine of which have GERD-to-GDP ratios exceeding 2.0%. (For more information, see *Science and Technology Data*, 1997.)

Chart 1: GERD by Major Sources of Funds



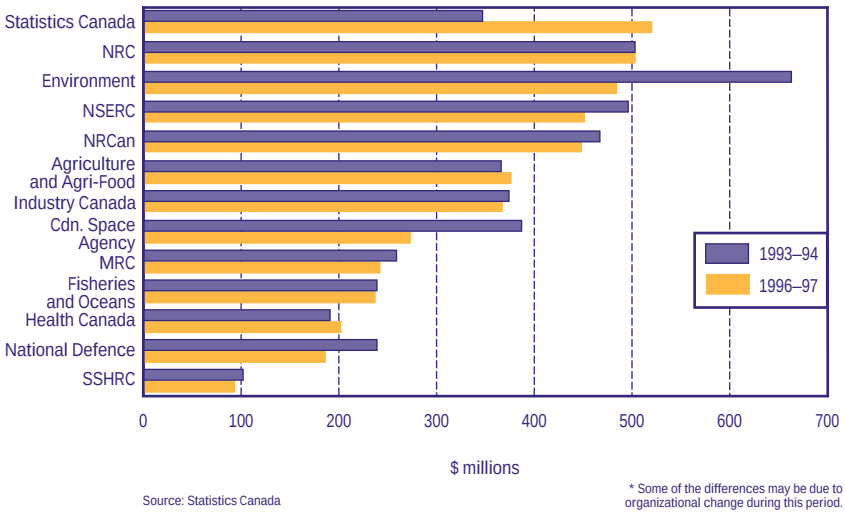
Source: Statistics Canada

The federal government directly funds about one fifth of the R&D performed in Canada. These expenditures include not only the financing of R&D undertaken in federal establishments, but also grants, contracts and contributions for R&D conducted by industry, universities and private non-profit organizations. The federal government also foregoes revenues of about $1.2 billion annually in industrial R&D tax incentives, and supports "unsponsored" university research through its payments to the provinces for post-secondary education. Even though its overall share of the national effort has decreased, the federal government is still the dominant R&D player in Atlantic Canada and on the Prairies, and remains an important contributor to Canada's work in biotechnology, information technology and advanced materials, and to the general advancement of knowledge.

The federal government also funds a number of "related scientific activities" (RSA), including data collection, both scientific and general, information services, museum services, economic and feasibility studies, and operational and policy studies. Together these activities account for between 38% and 40% of total federal S&T spending. Of the estimated $5680 million that departments and agencies spent on S&T in the 1996–97 fiscal year, $3404 million was for R&D. The remainder, $2276 million, went to RSA. Not included in these amounts is the funding for the newly created Canada Foundation for Innovation, which received an $800-million federal grant to provide new infrastructure support for university and medical R&D.

Reduced program spending has been a central element of the federal deficit fighting strategy, and has resulted in decreased expenditures on S&T. Between fiscal years 1993–94 and 1996–97, federal S&T expenditures decreased by 4%, from $5934 million to $5680 million. In this fiscal year, expenditures are expected to decline another 10% from their base level. In comparison, total federal program spending will have declined by 12% from 1993–94 to 1997–98. Although all departments have been affected by the restraint, not all have been affected to the same degree (Chart 2). Statistics Canada, for example, had a budget increase to cover the cost of the 1996 Census. Part of the decrease in other organizations, such

Chart 2: Federal S&T Expenditures for Selected Major Funders, 1993–94 and 1996–97*



Source: Statistics Canada

* Some of the differences may be due to organizational change during this period.

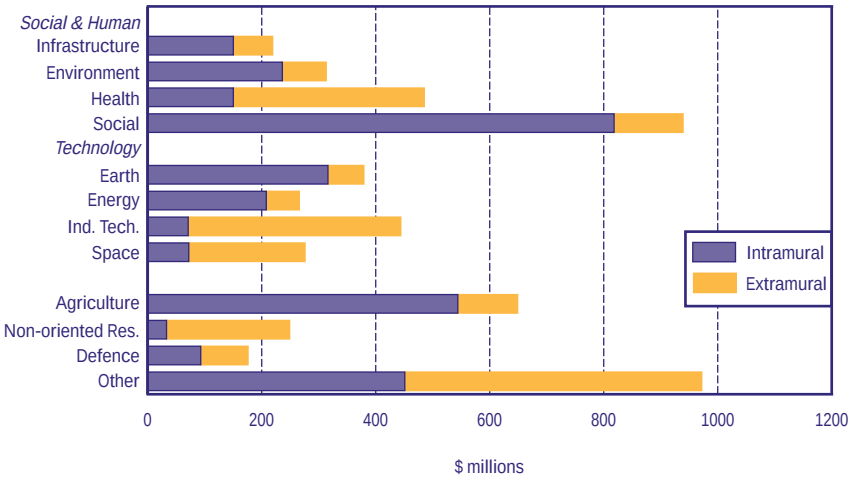
as the Canadian Space Agency, resulted from completing fixed-term projects. Restraint has also had an impact on the federal S&T community. Since 1993, the number of federal employees, expressed in person-years, working in science and technology has decreased by 10%, from 34 145 to 30 784, and is scheduled to decline to 28 745 by the end of the 1997–98 fiscal year.

Departments and agencies spent about 61% of 1996–97's $5680 million for their in-house activities, 16% for grants, contributions and contracts to business, 15% for Canadian universities, and 4% for overseas payments. The large share for in-house programs was due mainly to the historical dominance of federal establishments in RSA (about three quarters of federal RSA is performed internally, compared to about half of federal R&D). All of the museum services, more than 90% of the data collection, and about 80% of the information services are carried out in-house. Prominent among the major players are Statistics Canada and Environment Canada (EC), which provide industry, governments and the general public with the data and information they need for their daily activities.

Federal S&T initiatives principally support two major groups of socio-economic objectives: social and human, and technological (see Chart 3). Together these groups accounted for about 62% of the total federal S&T expenditures in the 1996–97 fiscal year, with the former receiving 36% of the funding. Activities in the social and human group are directed primarily towards providing services to the general public, protecting the environment, maintaining Canadians' health and safety, and preserving and displaying Canada's cultural heritage. Federal organizations with major expenditures in this group include Statistics Canada, EC, National Museums, Health Canada (HC), and the Medical Research Council of Canada (MRC). Within the technology group, the dominant players are Atomic Energy of Canada Ltd. (AECL), the Canadian Space Agency, EC, Industry Canada (IC), Natural Resources Canada (NRCan) and the Natural Sciences and Engineering Research Council (NSERC).

Expenditures for the social and human group are mainly directed toward RSA, while R&D is the primary focus for the technology group. In fiscal year 1996–97,

Chart 3: Socio-economic Objectives by Performance Sector, 1996–97



Source: Statistics Canada

R&D accounted for only 40% of the spending for the social and human group (although there are objectives in this group, such as public health, that have a large R&D component), but more than 85% of the technology group expenditures. The tendency to conduct RSA in-house is also evident in the distribution of expenditures by performance sector. About 70% of the spending for the social and human group supported intramural activities, but only about half did so for the technology group.

Most federally sponsored university research is funded through the public health and the non-oriented, or basic, research objectives. Support for industrial R&D, on the other hand, comes mainly from members of the technology group and the defence objective. When classifying the socio-economic objectives, another major player, the National Research Council (NRC), with its diverse role supporting enabling technologies — biotechnology, manufacturing, and information and telecommunication — included itself in the Other category.

The booklet *Science and Technology Data, 1997* provides more statistics on federal S&T investments, trends in federal and national expenditures, and some performance measures. This information is also available on *Strategis*, Industry Canada's business information Web site (http://strategis.ic.gc.ca/SSG/te01168e.html#indicators).

3. Performance and Outcomes

The Government of Canada released *Science and Technology for the New Century: A Federal Strategy* in March 1996. The Strategy defines national goals, describes the core federal science and technology activities, outlines a new governance system, and introduces principles to guide departments and agencies carrying out and investing in science and technology research. Individual departments and agencies or portfolios (e.g. the Industry Portfolio) developed action plans and committed to implementing the Strategy according to the principles.

The Strategy outlined changes to the established way of doing business. These changes were sweeping, and implementing change can be a difficult, painful and slow process, even under the most favourable conditions. It is important to recognize, therefore, that the performance and outcomes described below were achieved during a time of declining resources, both financial and human, and when departments and agencies were adjusting to significant modifications to the framework that governs federal resource management.

3.1 Pursuing Strategic Goals

Science and Technology for the New Century: A Federal Strategy set out

> *... a coherent set of national goals to which our S&T resources should be directed... for building a strong, forward-looking, dynamic Canadian innovation system: sustainable job creation and economic growth, improved quality of life, and advancement of knowledge.*

In 1997, the Government enunciated a set of priorities in the Speech from the Throne that extended and adapted the S&T goals developed between 1994 and 1996.

This section of the report describes achievements in addressing the goals defined in the Strategy and in adopting the new directions indicated in the Speech from the Throne.

3.1.1 Sustainable Job Creation and Economic Growth

> *Ensuring that we get the maximum economic and social return on our investment in S&T...*
>
> *Science and Technology for the New Century: A Federal Strategy,* **March 1996**

Addressing this goal brings the S&T Strategy to the centre of the Government's jobs and growth agenda. The complexity of issues and the magnitude and expense of S&T oblige the federal government to be more focused in its activities. It has targeted its investments in those areas likely to bring the most benefits to society. In the case of jobs and growth, four key leverage points shape the S&T agenda:

- a supportive and non-intrusive policy framework
- support for enabling technologies
- a level playing field for Canadian companies in strategic sectors
- commercialization of science and technology.

A Supportive and Non-intrusive Policy Framework

The private sector is an important driver for investments in science and technology to support economic growth and jobs. This investment will take place only if the policy climate encourages and rewards innovation. The S&T Strategy, recent federal budgets, and the September 1997 Speech from the Throne all highlight the Government's strong belief that science, technology and innovation are central building blocks of a strong economy and a superior quality of life.

While these signals are important, they are not enough to spur the necessary level of investment. Companies also need to be confident that the regulatory regime they operate within is predictable, cost-competitive and effective.

Intellectual Property

Over the years, both departments and firms have been confused about who owns intellectual property developed by contractors working with the federal government. Does the Crown or the contractor retain ownership and, if so, under what conditions? This confusion has limited government-industry interaction and the effective transfer of technology and knowledge between the two. A draft revised policy, developed jointly by Industry Canada, Treasury Board Secretariat and Public Works and Government Services Canada, with input from Federal Partners in Technology Transfer, in consultation with a broad cross-section of other government departments and agencies, is currently being reviewed by the private sector, and will likely soon form the basis of a new directive. In general, the Government's position is that contractors should own any intellectual property they develop, except when the interests of Canadians would be better served by the Crown owning the property.

Reducing the Burden of Regulation

Reducing the burden regulations impose on companies has long been a government priority. Often, industry admits that regulation is necessary, but believes that there are better ways to implement it to minimize the negative effects on individual

Federal Partners in Technology Transfer

Federal Partners in Technology Transfer (FPTT) embodies the spirit of the S&T Strategy, especially when it comes to commercialization. The 14 participating departments and agencies, led by NRC, include most of the organizations involved in developing the Strategy and this report: AAFC, AECL, the Canadian Food Inspection Agency, CSA, the Communications Research Centre, DFO, DND, EC, HC, IC, MRC, NRC, NRCan and NSERC.

In its first year of operation, the FPTT team, with various members leading different projects, accomplished several objectives, including the following:

- developed a set of principles on intellectual property
- supported a study and workshop with federal and university participants on how to structure technology transfer offices
- launched the R&D Impact Network, led by NRCan and operated by the Conference Board of Canada, in affiliation with the Canadian Research Management Association.

Product Standards in Health

A major HC objective is to provide public standards for biotechnology products. These can then be governed in a timely fashion without the restrictions of specific, "hands-on" regulation, which becomes technologically outdated and difficult to change. In the areas of tissues and organs and blood and blood products, HC is improving the regulatory system by developing standards in collaboration with the Standards Council of Canada. The department also introduced the "well characterized biotechnology products" classification, based on laboratory R&D. This reduces the need for some products to undergo "lot release" testing and does not compromise quality and safety.

firms and on sector competitiveness. The Business Impact Test (BIT), developed by Industry Canada, the Treasury Board Secretariat and the Alliance of Manufacturers and Exporters Canada, provides for structured consultations between businesses and government to meet government's (and society's) regulatory objectives in ways that minimize the burden on industry. The federal government can then focus its regulatory S&T activities in areas that will have the maximum benefit for Canadians.

S&T activities can also support new approaches to regulation. With an adequate understanding of natural systems, governments can substitute standards and performance-based regulations for restrictive technology- or emissions-based regulations.

Federal S&T helps Canadian firms with foreign regulation

In 1996, Canada became the first country to establish certification standards for sustainable forest management. The Canadian Standards Association's Sustainable Forest Management Standards are consistent with ISO 14000 environmental management standards. The voluntary certification program enables forest companies to guarantee purchasers that the products they buy come from areas managed according to the principles of sustainability. Through its work with Japanese researchers and the Canadian construction industry, NRC's Institute for Research in Construction has enabled the Japanese to become more accepting of wood frame housing, relax their standards and regulations, and open up their market to Canadian companies and products.

Support for Enabling Technologies

In the knowledge-based economy, scientific understanding and the mastery of key enabling technologies are important determinants of economic growth. Developing new technologies in areas such as information and telecommunications, biotechnology and materials can be very expensive and require a broad range of expertise. As well, because many of these technologies cannot be commercialized

Regulating Resource Industries

Canada's resource industries continue to generate considerable wealth and employ significant numbers of Canadians. In recent years, however, Canadians have become increasingly concerned about the potential effect of resource use on the environment. Federal S&T activities allow the federal government to develop regulatory requirements that adequately protect the environment while encouraging sustainable commercial resource use. For example, over the last six years, EC has been updating and strengthening the Metal Mining Liquid Effluent Regulations (MMLER) that control the concentrations of contaminants in wastewater discharged from Canadian metal mining and milling operations. All stakeholders, including the mining industry, environmental groups, Aboriginal groups, provincial governments and five federal organizations (AECB, DFO, DIAND, EC and NRCan), participated in a review of the effects of metal mining activities on aquatic environments in Canada. The report recommended amending the MMLER, revising the design of a national Environmental Effects Monitoring program, and updating the Environmental Code of Practice for Mines. EC is now implementing the recommendations.

Federal S&T in Support of More Effective Regulation

- NRCan promotes the use of voluntary compliance instead of regulatory enforcement when S&T knowledge is available.
- TC researchers developed a table listing holdover times that specifies how long anti-icing fluids remain effective. The table was accepted by the international aviation community to support effective standards for winter aviation safety.
- TC completed a groundbreaking study of commercial vehicle driver fatigue and alertness. Analysis of the results led to recommendations for combatting driver fatigue and to further research to support regulatory change and voluntary fatigue management programs.
- HRDC is modernizing the Canadian Labour Code, including the sections dealing with health and safety and employment standards, to address new safety and labour issues arising from science and technological developments, and to consider means of improving reporting systems and reducing regulatory burdens.
- ACOA spearheaded an independent study of regulatory constraints affecting the development of the Canadian aquaculture industry.
- HC's Health Protection Branch advocates risk management strategies to support its activities. The Branch is moving toward outcome-based regulations, is developing codes of practice with other agencies and industry, and is pursuing international harmonization with trading partners. This will result in more flexible regulations that will encourage the use of innovative technology.

directly — rather, they form the basis for a wide range of new industries, processes and products — firms are reluctant or unable to make the necessary investments. There is a clear role for government in stimulating and participating in the development of these enabling technologies.

The Advanced Manufacturing Technologies Strategic Framework, for example, is a cooperative project of the 11 Industry Portfolio agencies and three private sector partners — the Alliance of Manufacturers and Exporters Canada, the Machinery and Equipment Manufacturers Association of Canada, and the Institute for Robotics and Intelligent Systems Network of Centres of Excellence. The Industry Portfolio brings togther a unique set of capabilities in advanced manufacturing, from the Granting Councils funding basic research and researchers creating new technologies to the regional development agencies helping small- and medium-sized enterprises (SMEs) identify appropriate technologies. The partnership is conducting a detailed assessment of the development and adoption of advanced manufacturing technologies and has just completed a market and technology outlook document. The Portfolio and industry are now cooperating on an action plan to introduce practical approaches for Canadian companies to finance technology acquisition and development, address the looming skills shortage in advanced manufacturing, overcome the lack of awareness within the Canadian manufacturing sector of domestic capabilities and of how to promote Canadian suppliers, and understand the manufacturing technology and innovation system.

The development of biotechnology as an enabling technology is a long-term economic priority of the Government of Canada, but its experience in this technology area illustrates the challenges of promoting enabling technologies in the changing global economy. The National Biotechnology Strategy, put in place in 1983, focused on building research and industrial capabilities in Canada, and is currently being reviewed to meet future challenges. While economic factors are still driving the agenda, the Government recognizes that sustainable development, emerging ethical standards and public acceptance of the technologies and their products must be dealt with explicitly in order for biotechnology to deliver its full economic and quality of life benefits. The strategy renewal effort, led by IC, has active participation from Agriculture and Agri-Food Canada (AAFC), the Department of Fisheries and Oceans (DFO), EC, HC, NRC and NRCan, along with MRC, NSERC and the Social Sciences and Humanities Research Council (SSHRC).

Environment Canada's Environmental Technology Centre also focuses on enabling technologies. EC scientists at the Centre developed the patented Microwave Assisted Process (MAP™) to help chemical laboratories prevent pollution and achieve energy savings. MAP can work in a wide range of industrial sectors, such as agri-food, that make use of extraction techniques. MAP improves industrial-scale extraction efficiency. The technology has been licensed by private sector partners in a number of countries.

Portfolio Coordination of S&T

The 11 science and economic organizations[1] of the Industry Portfolio oversee a combined annual investment in S&T capabilities of more than $2 billion — about 41% of total federal S&T spending.

The Portfolio is currently concentrating on two priority areas: information technology and telecommunications and advanced manufacturing technologies.

[1] Atlantic Canada Opportunities Agency, Business Development Bank of Canada, Canadian Space Agency, Federal Office of Regional Development — Quebec, Industry Canada (including the Communications Research Centre), National Research Council of Canada, Natural Sciences and Engineering Research Council of Canada, Social Sciences and Humanities Research Council of Canada, Standards Council of Canada, Statistics Canada, and Western Economic Diversification Canada.

A Level Playing Field for Canadian Companies in Strategic Sectors

The federal government has been helping the private sector strengthen the economy though its efforts to "level the playing field" for Canadian S&T companies. Aware of the critical importance of technology and knowledge-based industries to economic growth, national governments around the world are supporting domestic industries, such as aerospace and defence. In the face of this global competition, Canada must ensure companies can compete. The federal government's efforts are directed towards two key leverage points — technology development in targeted industries and trade.

Technology Development

Technology Partnerships Canada (TPC) is an investment fund that will reach $250 million in 1998–99 to help commercialize new technologies and to help Canadian firms compete with heavily subsidized international firms. TPC's contingently repayable contributions mean the federal government and the private sector share both risk and reward.

As of March 31, 1997, TPC had approved $414 million in R&D investments with private sector partners. These investments will lever an estimated $2 billion in industrial R&D spending, and are expected to create or maintain nearly 10 000 direct and indirect jobs and generate close to $22.4 billion in sales. TPC has a broad effect on growth and jobs, with specific emphasis on enabling technologies and on levelling the playing field in key international technology areas.

The Department of National Defence (DND) contributes to the technological growth of the Canadian aerospace and defence industries (which receive significant direct government support in many countries) by investing $75 million annually in industrial R&D. This investment positions industry to respond to defence requirements and to develop commercial markets in dual-use technologies. The Defence Industrial Research Program promotes industrial innovation in these fields by sharing up to 50% of the costs of innovative research projects that are potentially relevant to defence. The program has been very successful in providing seed funding for innovative research by small companies.

IRAP

NRC's Industrial Research Assistance Program (IRAP) stimulates innovation in Canadian SMEs. IRAP is a $96-million annual program to provide SMEs with technology solutions for product and market development that enable them to grasp a bigger share of the global market. Each dollar invested by IRAP in an industrial R&D project levers two dollars of industrial R&D spending, and each IRAP dollar results in $20 in sales or related commercial activity in the three years following the completion of the R&D project. These investments generate 9000 new highly productive jobs annually.

Enabling Technologies in the Canadian Resource Industries

- Research by NRCan has made Canada a leader in applying biotechnology to improve the productivity and quality of commercial forests, while reducing pressures on Canada's forest land base.
- The continued strength of Canada's oil industry depends on technical innovations that will help make the most of existing resources. The National Centre for Upgrading Technology, a joint venture between NRCan and the Alberta government, is helping ensure that the country's oil sands and heavy oil resources are used efficiently.
- DFO has created the Strategic Science Fund to support the work of multidisciplinary teams of DFO scientists in partnership with universities and the private sector in areas such as improved forecasting of fish stock productivity and ocean climate changes, and the dynamics of toxic chemicals and their effect on fish and fish habitat.

Trade

The Government's trade focus has been on opening markets to Canadian firms and gaining further access to internationally funded projects on an equal footing with companies from other nations.

The Government recognizes the increasingly strong connection between S&T and trade and is strengthening its international ties in this area. NRCan and EC are among the federal organizations that have addressed this challenge.

NRCan has developed strategies to afford Canadian firms better access to projects financed by development agencies such as the World Bank or the Canadian International Development Agency (CIDA). For instance, NRCan is working with CIDA to help other countries address environmental issues associated with mineral resources development, and to increase their capacity to manage their forests in a sustainable way.

Environment Canada has set up a fund to support the involvement of Canadian scientists in identifying, preparing and appraising projects funded by the Global Environment Facility (GEF) and other International Financial Institutions. This fund will help strengthen the Canadian consulting and environmental industries and enhance opportunities for participation in downstream project implementation financed by the GEF. The knowledge gained in the early work associated with GEF projects will also generate later opportunities for Canadian manufacturing and equipment suppliers.

The federal government is working with the Standards Council of Canada to open up new markets for Canadian forest products. A team comprising the wood products industry, NRCan and DFAIT was successful in its efforts to harmonize lumber standards with Japan. Canadian firms can now export their lumber products to meet the growing demands of the Japanese market.

Western Medical Technologies Strategy

The Province of Manitoba, the National Research Council and Western Economic Diversification Canada have joined together to create a medical technologies strategy for Western Canada.

NRC will support research and innovation in magnetic resonance imaging technologies and molecular spectroscopy. The Winnipeg Health Sciences Centre and the St. Boniface Hospital Research Centre, both associated with the University of Manitoba, will serve as commercial demonstration sites. A commercialization and innovation office will be located at NRC in Winnipeg.

The people side of the Strategy will build on the existing NRC–Red River Community College program and on WD's First Jobs in Science and Technology Program.

Federal S&T Growing Canada Globally

- Canada is a world leader in countermine technology, developed over many years by defence researchers. This technology is now being used for the removal of mines. DND supports this activity by transferring technology to Canadian industry, and by providing technical advice and support to national, UN and NATO initiatives.
- TC started full-scale field trials of a prototype automated border clearance system in 1997 at the two busiest crossings in Eastern Canada. The system is based on electronic data exchange, vehicle-to-roadside communications, and automatic identification and weighing technologies. The department's goal is to allow non-stop crossing for pre-cleared freight and passenger vehicles.
- EC's new International Environmental Management Initiative (IEMI) promotes Canada's environmental industry by facilitating the transfer of environmental management expertise to support the export of Canadian environmental technologies and services. In China, IEMI sponsored a workshop on environmental data so Canadian experts could showcase their technology products and services under internationally funded clean-up projects.
- EC's new Environmental Technology Verification Program fosters the growth and marketability of Canada's environmental industry by providing validation and independent verification of performance claims.
- NRCan, through its research program and contracts, enters into partnerships with the Canadian geomatics industry to develop and commercialize technology and apply remote sensing data. Transfer of the technology to produce RADARSAT satellite imagery has helped to create a new enterprise with a global market.

International standards are increasingly important in a world of international competition and globalization. This is no more true than in the advanced technology fields of telecommunications and information technologies. In these areas, product life cycles are short and technological change rapid. The Standards Council of Canada, working in partnership with Canadian industry, ensures that the interests of Canadian companies are protected as global standards are put in place.

Commercialization of Science and Technology

In recent years, the federal government has worked to enhance Canada's efforts to bring research findings to market quickly and successfully. This is a multidimensional challenge that includes enhancing the university-industry interface, helping academics build commercial enterprises based on the results of their research, enhancing firms' capacity to commercialize new technologies, ensuring that there are no impediments to rapid commercialization in the private sector, whether the research development occurs in a multinational enterprise, an SME or a start-up business, and improving the flow of knowledge and technology out of government laboratories.

The federal government has focused attention on reducing or overcoming the barriers that have traditionally separated the business and academic communities. Industry-sponsored research chairs, funded in part by the three Granting Councils (MRC, NSERC and SSHRC), increase the crossfertilization of ideas between industry and university researchers. The Technology Partnerships Program, administered by NRC, NSERC and SSHRC, supports partnerships between universities and Canadian SMEs to develop university research to the point at which it can be exploited and commercialized by industry. The ultimate objective of the program is to create new and/or improved products and services, as well as jobs for Canadians.

Advancing the Commercialization of S&T

- FORD-Q has signed agreements with five financial institutions to set up a pool of funds readily available to SMEs wishing to develop research results into new or improved products and technologies.
- NRC has established an entrepreneurship program to "enhance the commercialization of NRC technologies with the aim of creating new business opportunities." In 1996–97, NRC formed six spin-off firms in the information, telecommunications and life science sectors.
- The Canadian Environmental Technology Advancement Centres are private not-for-profit corporations that help SMEs commercialize environmental technologies. The Centres result from partnerships among EC and provincial governments, environmental industry associations and the private sector.
- At its new Winnipeg facility, HC will operate the International Depositary Authority of Canada, which will allow Canadian inventors and the Canadian biotechnology industry to archive biological and genetic material for legal, patent and historical purposes.
- ACOA supported the establishment of NU-TECH, Nova Scotia's non-profit technology transfer and commercialization office.

Successful Commercialization of Federal S&T

- Through years of research, NRCan pioneered the development of a biological pesticide, *Bacillus thurigiensis*, which is now the most widely used alternative to chemical pesticides in both the forest and agriculture sectors.
- Through a collaborative agreement with DFO, SOCOMAR, a firm whose focus is port and waterway development, has developed a real-time water level measurement system enabling mariners, engineers, regulators and other interested parties to access water level information for the St. Lawrence River system. SOCOMAR has recently installed a large system of gauges and telemetering equipment in China.
- Scientists at the Defence Research Establishment in Valcartier have developed analog and digital high-angular-resolution laser irradiance detectors (HARLID) that can be used at low cost for localized surveillance, laser source localization, aircraft landing assistance, spacecraft alignment and vehicle guidance. EG&G Optoelectronics Canada, a Canadian detector manufacturer in Vaudreuil has been awarded a contract to manufacture HARLID.
- The Brewer Spectrophotometer, developed by EC scientists to observe the stratospheric ozone layer and UVB, is now being manufactured by Scitech Instruments of Saskatoon. The technology is used by more than 30 countries around the world, including the United States, whose Environmental Protection Agency recently purchased 17 units.
- One of NRC's licensees won an award for outstanding innovation from the American Society of Agricultural Engineers for being a leader in air-assisted agricultural spray systems using patented spray nozzle technology from NRC's Institute for Chemical Process and Environmental Technology.
- Nortel developed the ENTRUST public-key cryptography system, a technology critical to the implementation of electronic commerce. DND and the Communications Security Establishment were the lead customers providing early investment, guidance and testing in the evolution of the product line.

Trends in the external environment are increasing the importance of close connections between researchers and industry clients. To encourage additional industry investment in agricultural R&D priorities, Agriculture and Agri-Food Canada introduced the Matching Investment Initiative. Projects carried out under this initiative are co-funded by industry, and aligned to ensure market signals are considered when research priorities are set, and to transfer jointly developed technology quickly to private sector collaborators. Market preferences will directly influence research spending through these collaborative arrangements. Pre-selling to industry the knowledge and technologies that result from these arrangements guarantees technology transfer.

The Canadian Medical Discoveries Fund, the development of which was led by MRC, has been providing venture capital for the commercialization of health research discoveries originating in university and hospital laboratories. As of January 1997, the Fund had invested $57 million in 22 companies and helped draw an additional $192 million of capital investment from other sources. The fund expects to invest a further $110 million in 1997.

3.1.2 Improved Quality of Life

> *... to ensure that Canada applies S&T to improve the quality of life for our citizens through... the most effective social, environmental and health care programs in the world.*
>
> *Science and Technology for the New Century: A Federal Strategy*, **March 1996**

Many federal science and technology activities aim to improve quality of life for Canadians. This is, perhaps, the most important example of the "public good" federal S&T delivers. Canada already stands at or near the top of United Nations rankings for quality of life in most years. Federal S&T focuses on sustaining this advantage and building on it in four key areas:

- protection and enhancement of the health of Canadians
- protection and enhancement of the environment
- safety and security of individuals, communities and the nation
- using S&T to improve the social well-being of Canadians.

Impact of the Canadian Medical Discoveries Fund

In 1994, Dr. Jack Hirsh, a researcher in Hamilton long supported by MRC, made a discovery that will change the odds of survival for heart attack victims. However, to prove the practical relevance of his findings, he needed millions of dollars to test his work and eventually even greater funding for clinical trials to prove the safety and efficacy of the developing drug, now called *Vasoflux*. A group from the United States invested $4 million in his work, and transferred the intellectual property and the associated work to California. It appeared that the benefits of another Canadian research discovery had been lost for lack of development funding.

But, in 1996, MRC led the creation of the Canadian Medical Discoveries Fund (CMDF), a labour-sponsored venture capital fund dedicated to investing in the Canadian health sciences. CMDF led the way for other venture capitalists to invest in this complex area by demonstrating that risk can be evaluated and that, in the medium to long term, investment in Canada's biotechnology sector will provide truly outstanding returns. Led by CMDF, early-stage high-risk financing of biotechnology changed from a Canadian competitive weakness to a national strength.

With the advent of CMDF, Dr. Hirsh found Canadian investors willing to provide $18 million for Vascular Therapeutics, a new Hamilton company. With this investment, the benefits of Dr. Hirsh's discovery have been returned to Canada. Vascular Therapeutics has filed for seven new patents in the last two years, and is creating new jobs to develop its discoveries at an accelerating pace.

Protection and Enhancement of the Health of Canadians

Research is fundamental to improving the health of Canadians, either in general or in the workplace. Discoveries redefine diagnosis, treatment and care; new knowledge and insight renew the organization and delivery of health services. The federal government's multifaceted approach is designed to provide the best health system possible at affordable costs.

Quarantine Health Surveillance, a global medical surveillance project, uses the information highway to anticipate and monitor outbreaks of infectious diseases. Canadian participation protects citizens travelling to other countries and visitors coming into Canada. A proposed collaborative project between CIDA and HC will enhance tuberculosis control in Latin America, an area of the world that is an increasing source of immigration, trade and tourism for Canada.

Clean air is essential to Canadians' health. As part of the Air Quality Program, Health Canada is leading the federal government's work to assess air quality for adverse health effects and, in conjunction with EC, IC, NRCan and the provinces, to formulate air quality strategies to lessen the effect of air pollution such as acid emissions, particulates, hazardous substances and tropospheric ozone (smog). HC, in partnership with the province of Prince Edward Island, is conducting research on the effects of indoor pathogens on the health of infants and children.

Environmental factors can adversely affect human health, and improved scientific studies provide clearer evidence of the role that environmental factors play. Federal S&T has contributed to international understanding of environmental health risks and to identifying particular threats to Canadians.

Population health research is improving our understanding of the broad determinants of health and well-being. Health Canada is supporting research designed to enhance the health of Canadians. For example, Health Canada's Senior's Independence Research Program has been geared to developing knowledge to promote health and maintain independence among older Canadians. Funded research

Healthier Workplaces

Besides the normal hazards associated with working in an underground mine, there are long-term human health issues to consider. One such issue is the possibility of adverse health effects being caused by microscopic soot particles that form when diesel fuel burns. Ways to reduce these emissions into the workplace are being looked at by a government-industry-labour research consortium called the Diesel Emissions Evaluation Program (DEEP), established in 1996–97 with the help of NRCan.

Protecting and Enhancing the Health of Canadians

- The HC risk determination framework for assessing and managing health risks is fundamental to the way business is conducted in many programs. For example, the New Chemicals program is designed specifically for assessing the toxicity of newly manufactured or imported chemicals before they are introduced to the Canadian market. Other programs focus on priority substances, hazardous chemicals and drinking water.
- The Health Services Research Fund supports research to ensure effective and efficient health services. This research is critical as Canada moves from a hospital-based health-care model to one focused on community care and prevention.
- The Fraser Basin Health Program, a new initiative to identify and assess environmental health issues in the Fraser Basin, is based on human health outcomes and a population health approach. HC, as program leader, has signed a partnership agreement with the B.C. Ministry of Health, and has joined the Fraser Basin Council, a unique multigovernment/First Nations body that oversees and provides strategic guidance on all aspects of sustainable development in the Basin.

programs have addressed such areas as social, economic, environmental and behavioural determinants of health in later life, evaluated innovative models of care and service to maintain health or minimize dependency, and contributed to increasing the knowledge of significant age-related disease conditions. Another example of Health Canada's effort to enhance Canadians' health is the department's work with Human Resources Development Canada on the National Children's Agenda. Research in support of this initiative has focused on factors affecting different developmental stages for children, youth and their families.

The Medical Research Council's investment in Canadian health research sets the foundation for considerable R&D work. Universities and hospitals depend on MRC to help them find and retain the best research staff in the world. Volunteer agencies start with MRC-supported fundamental discoveries and then build research to counter specific diseases. Industry depends on the academic research base to help build and evaluate new therapeutics and technologies.

Acid Rain and Ozone Depletion

EC's Acid Deposition and Oxidant Model has been used to predict the outcome of the implementation of the current Canadian and U.S. acid deposition legislation up to the year 2010 and to determine whether further controls may be necessary. A sun photo spectrometer, designed by EC staff and flown on space shuttle missions, has been used to measure ozone and other trace gases in the upper and middle atmosphere. Results from these experiments provided the first verification that ozone depletion leads to increased ground-level UV flux.

Protection and Enhancement of the Environment

Canadians now worry that much of the progress they have made through hard work in this century will be lost in the next through environmental deterioration or disaster. Federal S&T is directed at these concerns. For example, a high priority for Canadians and for the federal government is understanding and dealing with climate change — a global problem requiring a global effort to solve. Canada is active internationally in the Ocean Drilling Program, the Inter-American Institute for Global Change Research, the Intergovernmental Oceanographic Commission and many other efforts designed to better understand the causes and effects of, and solutions to, global climate change.

Federal S&T Protects and Enhances the Environment

- The Northern Contaminants Program involved four federal departments (DIAND, EC, HC and NRCan) over six years doing research on atmospheric transport, wildlife ambient environment, and human health and risk assessment for traditional foods, fish and marine mammals. DIAND coordinated the program and emphasized communications and education, international control actions and Aboriginal partnerships. The two territorial governments and five northern Aboriginal organizations were also partners. As a result, Canada has accelerated its domestic response to persistent toxic substances and has taken an active leadership role in getting the issue of long-range transport of persistent toxic substances onto the international agenda.
- Scientists from the Defence Research Establishment in Valcartier, in partnership with NRC's Biotechnology Research Institute, developed a bacterial substance that can be used to clean up soils contaminated by energetic materials such as explosives and propellants.
- R&D at DFO and EC is directed at understanding oil and chemical spill behaviour and effects better, as well as developing sampling and analytical techniques, airborne remote sensing technologies, and on-site countermeasures for spills.
- The Metals in the Environment program, a cooperative effort of AAFC, DFO, EC, HC and NRCan, has provided input to several national and international initiatives to define natural levels of metals in the environment, to control industrial sources of metals, and to provide appropriate policy responses on metals, including potentially dangerous metals such as mercury.
- NRC has created the Institute for Chemical Process and Environmental Technology, which is fully dedicated to helping manufacturing clients develop cleaner products and processes so they can meet their environmental stewardship responsibilities.

Public concern with climate and climate change is a major driver of the federal government's scientific effort, conducted in partnership with universities, other governments and companies around the world. R&D in support of this issue is directed primarily at understanding the climate system by investigating key processes, developing models of the climate system to integrate knowledge and predict future climates, and assessing the current state of the climate, its variability and extreme events. In addition, knowledge is required to determine the potential and measurable impacts of climate change on ecosystems and human health. Federal S&T activities are important in this field because of their global scope and impact. Canadian government R&D has produced widely accepted equilibrium climate-change scenarios, which have been used nationally and internationally in climate diagnostics and impact studies and have influenced change assessments by the Intergovernmental Panel on Climate Change.

In 1997, Environment Canada published the final results from the six-year Mackenzie Basin Impact Study (MBIS), which produced an integrated regional assessment of climate change scenarios for the entire Mackenzie River Basin watershed. The Study was the first of its kind in the world, directed by a working committee comprising representatives from Aboriginal organizations, industry and various government departments. The MBIS produced findings demonstrating the negative regional effects of climate warming and presented adaptation scenarios. NRCan's Climate Change Program contributes to improving climate models and to understanding the climate system and greenhouse gas cycles. Results from the federal science effort on climate change will contribute to the Canada Country Study — a national look at the potential effects of climate change.

Developing more energy efficient technologies, including reducing greenhouse gas emissions, has been an ongoing focus of federal S&T investments. Working towards this goal, NRCan has developed the first combustion facility in North America to incorporate processes to separate and capture carbon dioxide (CO_2) and other pollutants. If successful, the technology could have a monumental impact on power production from fossil fuels by eliminating emissions. NRCan is spearheading the first consortium for this facility that will look at coal combustion. The research will focus on developing novel processes for the enhanced separation and capture of CO_2 and other pollutants from coal combustion, and examine the most economical ways to dispose of CO_2, including selling or storing it. Consortium members include the Canadian Electricity Association, TransAlta Utilities Corporation, Sask Power, Canadian Liquid Air, the Alberta Chamber of Resources, Alberta Energy and Environment Canada.

Protecting Wilderness

The four-year Northern Rivers Basin Study, completed in 1996, examined the relationships between human development and aquatic ecosystems in the Peace, Athabasca and Slave River basins. EC experts led much of the scientific effort, in partnership with other governments, industry and Aboriginal organizations. The Study targeted the Peace Athabasca Delta in northern Alberta, one of the world's largest inland freshwater deltas and home to Wood Buffalo National Park. The Ramsar Convention recognized the region as a wetland of international importance because of its biological productivity and diversity. Over the last 20 years, however, it has been drying out, with serious consequences for the vegetation and wildlife in the area. Scientists from EC's National Hydrology Research Institute have worked with Parks Canada, Alberta Environment, BC Hydro and local Indian and Metis communities to understand and restore the ecosystem.

Under the Fraser River Action Plan, EC has established partnerships with universities, DFO and private sector consultants to research the effects of pollutants on the aquatic-based ecosystem and to define the health of the basin's ecosystem. The program continues to result in knowledge and tools necessary for managing the Fraser Basin to sustain its aquatic ecosystem and the fish and wildlife resources supported by it.

NRCan is developing sustainable forest management techniques, in partnership with local forest companies, that are tailored to forest species and ecosystems across Canada. For example, NRCan recently transferred the results of research into alternatives to clear cutting in high-elevation forests in British Columbia to provincial and industry clients.

To protect and enhance the marine environment, DFO has consolidated its climate research activities under the Oceans Climate Program (OCP). Through the OCP, the department is contributing to several international research programs such as the World Ocean Circulation Experiment, the Joint Global Ocean Flux Study, the Climate Variability Study and the Arctic Circulation System Study. The studies will yield more reliable information on the role of the oceans in global climate change than is currently available and will allow for more accurate predictions for policy development.

NRCan is developing models to determine the net contribution of Canada's forests to the global carbon cycle and to predict potential effects of forest-management options. NRCan presented the results of Canada's Carbon Budget Model to the international community for peer review. This work was cited in the Intergovernmental Panel on Climate Change's *Second Assessment Report*. Researchers completed models for measuring forest ecosystem dynamics and land-use changes to support the assessment of potential mitigative and response measures.

Safety and Security of Individuals, Communities and the Nation

Beyond concerns about health and the environment, Canadians' quality of life, depends to a significant degree on the federal government's efforts to understand and manage risks.

Weather forecasts and warnings are a vital service for all Canadians. The safe operation of transportation systems, for example, is highly dependent on these forecasts. The high quality of Canada's weather forecasts is the direct result of Environment Canada's R&D. The department has begun installing a new Canada-wide Doppler Radar network to enhance the accuracy and scope of its forecasts. In addition, EC has initiated work on the Canadian Lightning Detection Network in an effort to provide warning information that can reduce the loss (valued at $14 billion annually) of forests to fire.

Canada has gained international recognition as a leader in the development of models and information systems for managing forest fires, which pose serious risks to remote communities and consume almost as much wood each year in Canada as is harvested.

Risk Management Through Increasing Knowledge

Real-time monitoring of earthquakes, through NRCan's 80-station seismograph network, enables the federal government to provide rapid information on earthquake size and location for emergency response purposes. The year-2000 edition of the National Building Code — drafted by NRC for provincial regulatory bodies — will incorporate NRCan's most recent seismic hazard information. The Insurance Bureau of Canada incorporates this information into realistic loss estimates and reinsurance levels.

A team at the Defence Research Establishment at Suffield developed a real-time chemical and biological agent detection system based on the Fluorescence Aerodynamic Particle Sizer (FLAPS). This is the first system that can detect, in real time, the presence of living biological agents in an aerosol cloud. FLAPS has proven itself to be the most effective biological agent detection system in the world. It received an R&D 100 award, given by *R&D Magazine*, recognizing it as one of the year's 100 most technologically significant products and processes.

Images from the CSA's RADARSAT satellite play an important role in disaster management and mitigation, as shown in the Red River flood of 1997. During the flood, CSA was able to quickly and effectively plan, acquire and deliver (through RADARSAT International) RADARSAT images. The Government of Manitoba and DND used the images to support tactical decisions made during the flood. As well, the images will prove valuable in post-flood analysis and in the development of new mitigating measures.

NRCan has developed the Canadian Active Control System to provide an enhanced Global Positioning System for the Canadian landmass. The precision location system, accurate to one metre in real time and less than three centimetres after data processing, supports geodetic surveying, mapping, precise geospatial referencing, navigation and recreational or wilderness use.

To improve navigational accuracy in Canadian waters and to minimize risks of maritime accidents, the Canadian Hydrographic Service (CHS) has played a lead role in developing internationally approved standards for producing electronic charts, and provides these charts for Canada's navigable waters. The CHS developed an electronic chart updating service in partnership with Nautical Data International, an industrial partner.

Protecting Canada's sovereignty is the goal of the Department of National Defence, and the Canadian Forces requires technical systems to fight alongside the best, against the best. To ensure that the capability to support and develop this technical competence is in place, DND invests approximately 2% of its budget in R&D each year.

Using S&T to Improve the Social Well-being of Canadians

The federal government provides vital support to research into the social sciences, which strengthens Canada's social fabric. Through its Joint Initiatives Program, the Social Sciences and Humanities Research Council has concluded more than 12 agreements with partners from the public and private sectors to fund collaborative research to enhance decision making in key socio-economic areas. These initiatives, representing an investment of $30 million, have generated critical knowledge on issues such as the management of technological change, Canada's science culture, the impact of immigration on Canadian cities, family violence, and health promotion. Social science research is also key to understanding the needs and structure of Canada's innovation system. To this end, NRC, NSERC and SSHRC are currently working on a joint initiative to create a network of researchers focused on regional innovation and knowledge-based growth.

Managing Forest Fires

The Canadian Wildland Fire Information System, developed by NRCan, is an integrated database network that produces daily maps and forecasts of the risks, location and spread of forest fires across Canada. The system, which is used by all Canadian fire management agencies, is now available nationally and globally on the World Wide Web and has been included as a component of the G-7 Global Emergency Management Information Network.

Weather Technology

A state-of-the-art Automated Weather Observation System (AWOS), developed by EC's Atmospheric Environment Service with private sector partners, is the latest evolution of weather observing equipment. Designed as a rugged field unit, AWOS is effective, durable and compact and is easily maintained.

A newly implemented meteorological information tool, the Global Environmental Multiscale (GEM), has become a cornerstone of EC's environmental prediction capability. GEM is capable of providing weather forecasts for any geographical area on the globe.

Search and Rescue

Passport is a sophisticated decision-support software package the applications of which may help search and rescue coordination centers and the Canadian Forces plan their operations. Passport provides aircraft searching the ground for persons or objects with the best possible trajectories, thereby increasing the likelihood of success. Passport's designers from the Defense Research Establishment in Valcartier, ATS Aérospatiale and the Centre de recherche informatique de Montréal won the 1996 OCTAS innovation trophy from the Fédération de l'informatique du Québec.

3.1.3 Advancement of Knowledge

> *... to create in Canada world centres of excellence in scientific discovery; to build a broad base of scientific enquiry; to foster Canadian participation in all major fields of science and technology; and to ensure that new knowledge can be acquired and disseminated widely, from Canadian sources and from around the world.*
>
> *Science and Technology for the New Century: A Federal Strategy*, **March 1996**

Canada makes a significant contribution to the world's knowledge stock. Canadian universities have developed world-class research and teaching activities, and the private sector has dramatically expanded R&D activities to provide the basis for new products, processes and services. The federal government's research laboratories are maintaining their long-standing reputation for producing scientific and technological breakthroughs that have had significant economic and social returns. There is general agreement that the federal government has a number of roles to play in advancing knowledge in Canada:

- funding university research
- enhancing the flow of knowledge throughout society
- promoting excellence and relevance
- generating new scientific and technological knowledge in support of regulation, policy making, and economic and social objectives
- developing a science and innovation culture in Canada.

Research Chairs

Through the NSERC Industrial Research Chair Program, EC has co-sponsored chairs in Climate Research at McGill University, in Atmospheric Chemistry at York University, in Climate Research and Marine Meteorology at Dalhousie University, and in Atmospheric Remote Sounding from Space at the University of Toronto. The Canadian Wildlife Service at EC co-sponsors two Cooperative Wildlife Ecology Research chairs at the University of New Brunswick and the University of British Columbia.

DND co-sponsors chairs in Ocean Acoustics at the University of Victoria and Dalhousie University.

In collaboration with Memorial University of Newfoundland, the Newfoundland Department of Fisheries, Food and Agriculture, Fisheries Products International and NSERC, DFO is contributing support to three chairs in Fisheries Conservation at Memorial. DFO also contributes to a chair in Oceans Mapping at the University of New Brunswick in partnership with ocean industry interests.

The Flow of Knowledge in the Environmental Sector

- NRCan, in co-operation with EC and IC, has launched Canada's Clean Combustion Network on the Internet. The site allows developers, manufacturers, regulators and users of stationary combustion services and equipment to exchange information quickly and cost-effectively.
- The EC Atmospheric Environment Program (AEP) provides weather, ozone and UVB information, forecasts and warnings to Canadians every day. Services include the 1-900 telephone services and sponsored recordings on free, taped Weather Lines across Canada. Industrial services include custom-designed media services to newspapers and specialized weather services to Radio Canada and the CBC.
- EC's Atmospheric Environment Service operates the World Ozone and UV Data Centre to collect data from networks around the world. The data are then published by the World Meteorological Organization. EC also operates the National Atmospheric Chemistry Database (NATChem). NATChem is now being expanded to include data on particle and related trace gases for North America and Europe and has established a Web site (http://airquality.tor.ec.gc.ca/natchem/particles).
- EC's National Hydrology Research Institute has published a set of state-of-science texts to be distributed internationally that summarize the state of scientific knowledge and identify research needs on themes such as northern hydrology, remote-sensing applications in environmental science, and water-quality modelling.

The federal Granting Councils, MRC, NSERC and SSHRC, are a key part of Canada's S&T Strategy. For example, MRC's programs to support basic research are the foundation upon which Canada's capacity for future innovations in health sciences, and their practical applications, rest. MRC provides about $230 million in direct research funding each year across all health disciplines and the continuum of health research. In the 16 universities in Canada with faculties of medicine, health sciences research, much of which is sponsored by MRC, accounts for more than 50% of all R&D expenditures.

Funding University Research

The federal government remains the major supporter of scientific research in Canadian universities. Canada has earned a reputation for its excellent university research and researchers. However, in recent years, this research effort has been hampered by aging equipment and infrastructure. This not only affects the ability to carry out state-of-the-art research, but also the ability to attract and retain highly qualified people. In response to this need, the Government established the Canada Foundation for Innovation, which will provide significant financial support for the modernization of research infrastructure at Canadian post-secondary educational institutions, research hospitals and associated not-for-profit institutions in the areas of science, health, engineering and the environment. The federal government has provided an up-front investment of $800 million. This principal and the accrued interest will allow the Foundation to provide, on average, about $180 million annually for research infrastructure over the next five years. Partnerships with other organizations will give the Foundation the potential to inject up to $2 billion into renewing laboratories.

A second, broad-based effort is the Networks of Centres of Excellence, aimed at building a "virtual critical mass" of research expertise in key fields. The Networks link researchers across the country working in fields as diverse as robotics, genetic diseases, and pulp and paper. Having clearly demonstrated the advantages of collaboration, the program was made permanent in 1997 and was renewed with a commitment of $47 million annually funded through existing sources and reallocations.

Enhancing the Flow of Knowledge Throughout Canadian Society

In addition to creating new knowledge, much federal science and technology work is aimed at sharing knowledge. It is through these knowledge flows that the innovation system can adapt and respond to the challenges of the global, knowledge-based economy.

Networks of Centres of Excellence (NCEs)

Fourteen NCEs currently involve more than 1000 researchers, 48 universities, 405 companies and 175 other organizations across Canada. Some 1400 students, 500 postdoctoral fellows and 1200 research and technical staff are involved in NCE activity. The active involvement of Canadian industry provides stimulating training environments and employment opportunities for students, with a remarkable 97% of network graduates finding jobs, many with participating companies. Canadian industry benefits by hiring students with hands-on experience. A six-month decrease in the learning curve of network graduates in globally competitive areas such as microelectronics and telecommunications is estimated to produce annual savings of more than $3 million for their employers. As well, 36 spin-off companies have been created to date.

Enhancing Canadian Access to Scientific Data

CMN is developing a strategy to link databases of natural history collections at the national level, and potentially internationally, through the National Collections Consortium, which is being developed with a strategic partner, Digital Equipment Company of Canada.

The National Geoscience Mapping Program, developed by NRCan, addresses the need for more geoscience data from both traditional and new clients, and the need to develop new digital technologies to ensure compatibility of data among government geoscience agencies.

NRC, through its Institute for Marine Biosciences, has led a multi-institute initiative to form the Canadian Bioinformatics Resource to serve the needs of NRC's genomics activities, and eventually the public, through CISTI.

NRCan is establishing a federal-provincial technology initiative, the Canadian Geospatial Data Infrastructure (CGDI), to develop a common national framework for computerized geographic information and policies promoting access and use. NRCan and the Inter-Agency Committee on Geomatics are working with the Canadian General Standards Board to develop international geomatics standards within CGDI.

Phase II of the Canadian Network for the Advancement of Research, Industry and Education (CANARIE II) will establish a national high-speed telecommunications network (CA*NET II), help develop innovative networking technology and applications, and expand the understanding and use of the information highway. CANARIE II marks the first significant upgrade of Internet services in the world, and could mean that Canadian scientists and industries, who are already at the forefront of telecommunications technology advances, could open up a lead on the competition.

In recent years, there has been a significant increase in the federal government's role as a provider of, and facilitator of access to, strategic business and scientific information. Industry Canada's *Strategis* is Canada's largest business Web site and provides direct access to technology information and opportunities, such as *dISTCovery*, a database of more than 35 000 licensable technologies from Canada and around the world; *Canadian Technology Gateway*, which lists Canadian S&T activities and capabilities; and *Trans-Forum*, a technology transfer tool for universities and colleges. *Strategis* also provides links to the home pages of other federal, provincial and private agencies involved in technological innovation support.

Canada's expertise in statistical data collection and analysis is well-respected around the world. However, Canadian researchers have difficulty accessing the raw data at reasonable cost. The Government established the Data Liberation Initiative (DLI) to provide academic institutions with affordable access to Statistics Canada data files and databases for teaching and research. DLI is a cooperative effort among the Humanities and Social Science Federation of Canada, the Canadian Association of Research Libraries, the Canadian Association of Public Data Users, the Canadian Association of Small University Libraries, Statistics Canada, SSHRC and other government organizations.

Promoting Excellence and Relevance

The S&T Strategy noted the need to continue the federal government's tradition of scientific excellence, and to couple this excellence with relevance to national needs. Federal scientists maintain this excellence through discussion and publication of their results, subjecting their findings to the judgement of their peers. Relevance is being enhanced in many science-based departments and agencies through the creation (or restructuring) of scientific advisory bodies, made up of key clients and stakeholders for that research area.

Excellence in S&T requires excellent people. The federal government is undertaking initiatives to attract outside researchers to federal laboratories and to give federal researchers access to industrial laboratories.

Canada Institute for Scientific and Technical Information

NRC's Canada Institute for Scientific and Technical Information (CISTI), North America's top source of scientific, technical and medical information, is an international leader in the development of services that take advantage of the information highway and that support innovation in communities across Canada.

CISTI added 500 electronic titles to its collection in 1996–97. Web-based services have been enhanced to provide improved access, including the CISTI on-line catalogue, which has seen 250% growth in registered clients. The document delivery service has been redesigned and extended to include the Canadian Agricultural Library, the British Library Document Supply Service and other worldwide sources. Improvements to systems resulted in 51% of documents being delivered electronically.

The NRC *Virtual Library*, launched in March 1997, provides NRC researchers with desktop access to CISTI's collection and services. Products are being developed to extend similar services to researchers outside NRC.

CISTI also develops and manages information networks on the Web, such as *InfoBiotech Canada*, which provides enhanced access to information on biotechnology in Canada and around the world, and the *Canadian Technology Network* (CTN), which links Canadian companies to sources of technological expertise. In 1996–97, CTN reached 600 nodes and affiliate members.

Computer Animation

The federal government's work in enhancing the use of computers to produce and manage animated images created a new knowledge base that has now found its way into the main industries associated with computer animation. NRC was recognized in 1997 for this achievement with a special Academy Award for the two principal researchers involved, Nestor Burtnyk and Marceli Wein.

Many science-based departments and agencies are active in NSERC's Visiting Fellowships in Canadian Government Laboratories program. This program gives young scientists and engineers the chance to work with research groups or leaders in Canadian government laboratories and research institutions. In support of the federal Youth Employment Strategy, a number of science departments (AAFC, DFO, EC, HC, NRC and NRCan) have launched internship programs to help young scientists gain necessary technical expertise and practical experience, and to benefit from an expert mentor.

The Canadian Climate Research Network (CRN) began in 1994 as a mechanism for the federal government to engage the energy, ideas and talents of university and private sector researchers to provide the critical scientific knowledge required for policymaking related to climate change and climate variability. CRN comprises a network of Collaborative Research Groups that are linked through an electronic network, interchange of personnel, workshops and similar activities. The Network signed agreements in 1996–97 involving nine major projects carried out by more than 32 investigators plus their staff and students at 18 Canadian universities, three government laboratories, the EC supercomputing facilities and one non-governmental organization, for a total value of $2.6 million. The University of Victoria's Centre for Earth and Ocean Research administers CRN for Environment Canada.

The social sciences also contribute to the advancement of knowledge about science and technology. SSHRC invests approximately $14 million per year in research on the determinants of economic development, science and technology and related issues.

Generating New Scientific and Technological Knowledge in Support of Regulation, Policy Making, and Economic and Social Objectives

Performing research to benefit the public remains a key activity for many departments and agencies. Government laboratories often have large-scale or otherwise difficult to obtain equipment or facilities that support research across both industry and the academic community. As well, needed research in areas such as environmental protection and health and safety requires government involvement.

Considerable research done for the public good is conducted to support the mandate and regulatory-related activities of the Department of Fisheries and Oceans, Environment Canada, Health Canada, Natural Resources Canada, Transport Canada,

Sharing Scarce Resources

EC's National Water Research Institute (NWRI) and Noranda Forest Products have signed a Cooperative Research Agreement that allows NWRI researchers access to Noranda mills. NWRI also participates in a Research Consortium at the Pulp and Paper Centre of the University of Toronto that is focused on using chemistry and biology to improve bleaching effluent quality. The consortium team consists of eight scientists, including some from EC who are adjunct professors at the university. The consortium is supported by 12 private sector companies and one provincial environment agency, which have committed to provide $30 000 each per year for three years.

In May 1996, the space shuttle *Endeavor* served as a laboratory for a number of experiments coordinated by CSA. Scientists from NRCan were involved in an experiment to grow the perfect crystal. During the experiment, which was monitored by Canadian astronaut Dr. Marc Garneau, an oxide material, bismuth germanate, was successfully float-zoned in microgravity for the first time. The space-grown crystals were much larger than those developed on Earth, and appeared to be of exceptional quality. The knowledge gained through this work may ultimately lead to computers that process information faster, cellular phones that have clearer sound and CD-ROMs that hold more information.

Photovoltaics for the North

NRCan's Photovoltaics for the North program, through its integrated program of technology demonstrations, training and technology transfer activities, is helping Canada's northern communities achieve greater economic self-reliance, lower energy costs, and acquire new technology skills for exploiting solar electricity.

and others, as well as provincial and municipal governments in Canada. Industry-related research at Agriculture and Agri-Food Canada and NRC exemplifies the role of federal laboratories in supporting sectoral development. Less obvious, but equally important, is research in areas such as space, which has fostered the development of a domestic space industry, and research at the Communications Research Centre, which underpins the telecommunications industry.

Developing a Science and Innovation Culture in Canada

Canada's ability to prosper as a nation in the knowledge society depends on its people being able and disposed to innovate. At the broadest level, this means fostering an understanding of scientific and technological concepts in all Canadians and ensuring that they have the skills necessary to work in the 21st century (see section 4.2). Many federal departments and agencies, such as Industry Canada, have specific mandates for science promotion. Others, with line science and technology activities, are responsible for explaining them, and their significance to the everyday life of Canadians, to the public.

World Wide Web sites are used by many science-based departments and agencies to communicate activities and educate Canadians (a listing is provided in the Annex). NRCan's *National Atlas* Web site on *SchoolNet* is an interactive educational resource on Canadian geography. NRCan also runs the related *Canadian Communities Atlas* project. EC's award-winning *Green Lane* site features searchable meta-data text. The department is currently developing new interactive pages for the site that will improve S&T information management, information entry, and public access. *Action 21* focuses specifically on encouraging Canadians to innovate to create and sustain healthy environments in their communities. *Stock Status Reports*, available on DFO's *Sealane* site, provides the data that form the scientific basis for conserving living marine resources and managing Canada's fisheries.

Television is another useful medium for building Canadian science culture. In collaboration with the Discovery Channel, EC produced a series of vignettes titled *Earth Tones*, which aired on *@discovery.ca* from January to April 1997. The series profiled EC scientists, and gave viewers the chance to see how science is performed, and to understand the effects of scientific findings and the contribution of EC science to a cleaner and healthier environment. EC has added *Earth Tones* pages to *Green Lane*, and AAFC is co-funding a further four vignettes. Discussions are underway about producing for 1999 16 more vignettes on themes common to the four natural resource departments. The Great Lakes Health Effects Program recently worked with

EC Research Leading to Environmental Regulation

EC research has shown that waterfowl hunting has resulted in an unintended environmental problem: lead shot has become one of the most significant sources of lead deposited into the environment. EC has concluded that an estimated 200 000 to 360 000 game ducks die annually from lead shot poisoning in Canada and that several million suffer sub-lethal lead poisoning. In 1996, EC used this knowledge to ban the use of lead shot in all National Wildlife Areas and to develop a draft regulation banning the use of lead shot for waterfowl hunting across Canada.

A key consideration in restoring the St. Lawrence River is the reduction of industrial toxic effluents. A total of 106 industrial plants along the St. Lawrence and 16 of its tributaries have been targeted by EC for priority emissions reduction. The department has developed the Chimiotox index to measure the reductions in toxic releases. Fifty plants have already achieved an overall reduction of 95% in toxic liquid effluent and, by March 1997, an overall reduction of 83% in toxic effluent was recorded for the remaining 56.

Promoting Science

National Science and Technology Week — a 10-day celebration of Canada's achievements in science, technology, engineering and mathematics — is a major collaborative venture, coordinated by IC, that includes partners from federal and provincial governments, educational institutions, museum and science centres and the private sector.

In 1997, the CMN signed an MOU with the Nunavut Research Institute to enter into research and educational ventures. The Arctic Natural History Summer School in Cambridge Bay is the first such project.

NRC published a brochure titled *Time After Time*, documenting 80 years of scientific contributions benefiting Canadian society, including research on a vaccine against tuberculosis, the cobalt "bomb," canola hybrids, 3-D vision and the Space Vision System.

TV Ontario on a series of one-hour specials for a program called *Great Lakes Alive*, and has developed interactive kits to teach children about water, air and other sources of contaminants and how they relate to human health in the Great Lakes basin.

3.2 Creating New Institutions and Mechanisms for Governance

> *Other G-7 nations have well-established S&T governance infrastructures linking government, business, finance and academic institutions. Developing such an infrastructure is particularly important for a mid-sized country like Canada.*
>
> *Science and Technology for the New Century: A Federal Strategy,* **March 1996**

The Strategy identified the need to renew the federal S&T governance infrastructure and find more effective ways of ensuring that government S&T efforts complement one another. Further, the Strategy recognized the need for outside advice to help set priorities. The federal government's efforts to address these issues are discussed below under six major themes from the Strategy.

3.2.1 Making Better Use of Scientific Advice

The rapid pace of change in S&T, and the heightened importance of S&T as a driver of economic and social change, make it imperative for the federal government to be able to consult regularly and directly with the best-qualified advisors in the country. Improving access to this advice, and strengthening the federal government's ability to act on it, has been a priority.

Advisory Council on Science and Technology

At the highest level, the Government wanted advice from Canada's leading innovators and strategic thinkers on future directions for Canada's S&T investments. The Advisory Council on Science and Technology (ACST), which was announced in the S&T Strategy, provides advice to the Prime Minister. Chaired by the Minister of Industry, the Council comprises 11 eminent Canadians — six from industry and five from academia. The Council's mandate is "to review the nation's performance in S&T, identify emerging issues and advise on a forward-looking agenda." Members meet annually with the Cabinet Committee on the Economic Union to make recommendations.

Space Sells Science

The CSA's Space Awareness Program uses the unique appeal of space to improve scientific literacy and create a science and technology culture in Canada. A specific objective is to increase the number of students pursuing studies and careers in the sciences, engineering and mathematics, thereby strengthening the Canadian scientific and technological base and facilitating the transition to a knowledge society. The program consists of four elements that are undertaken in cooperation with provinces, science institutions, universities and educational sectors across Canada. One of these elements is the network of five Canadian Space Resource Centres, through which teachers, students and the general public have access to a range of information and resources about space, including curriculum resource materials created by the CSA.

Since its creation in July 1996, ACST has focused its work on three important issues: facing the human resource challenges as Canada moves to become a more knowledge-intensive society; improving the commercialization of Canadian research and development by the private sector, the academic community and government; and developing a more coherent and publicly accepted vision for the future of science and technology in Canada.

Departmental Scientific Advisory Bodies

To ensure the excellence and relevance of its S&T activities, the federal government sees a critical role for external advice from the scientific community and other stakeholders. This advice will help focus S&T activities to best contribute to the delivery of departmental missions and, through these missions, to overall national needs. Most federal organizations with a role in S&T have now established independent, external scientific advisory bodies, including AAFC's Research Branch Advisory Committee, the Defence Research and Development Advisory Council, DFO's Science Advisory Council, EC's Research and Development Advisory Board, HC's Science Advisory Board and NRCan's Minister's Advisory Council on Science and Technology.

The responsibilities of these bodies include making recommendations on departmental strategic directions in the areas of science and technology; assisting the organization in ensuring its science goals are consistent with overall priorities; reviewing and advising on S&T programs and activities; and focusing on emerging issues to ensure that each organization's S&T activities anticipate future developments and protect society.

3.2.2 Decision Making and Management

> *The government has concluded that it should strike a balance. Achieving greater coherence while preserving flexibility, responsiveness and ministerial accountability requires a more rigorous collective review of priorities and greater coordination of activities.*
>
> *Science and Technology for the New Century: A Federal Strategy*, **March 1996**

A Coherent Approach to Setting Future Directions in S&T

Canada's parliamentary system assigns ministers the responsibility and authority to manage their resources, including their S&T activities, to deliver on their mandated commitments to Canada and Canadians. The S&T Strategy reaffirms that accountability, but calls for improved mechanisms to better ensure that the federal government's overall priorities are reflected in its S&T activities. In this regard, Cabinet's role in S&T priority setting has been formalized. The Cabinet Committee on the Economic Union will review the Government's progress and priorities in

Northern S&T Strategy

Canada's North is an area of both considerable economic potential and environmental challenge and sensitivity. Science and technology are critical to sustainable development in this region. At the moment, the federal government's S&T effort in this region is the combined result of the research programs of a number of departments. While research in the North has benefited historically from collaboration and cooperation between some of these programs, there is room for improvement. To ensure that the North, and the North's contribution to national and global issues, continues to have the S&T that it needs for the future, departments are examining how best to enhance their cooperation and collaboration by developing a Northern S&T Strategy. The Strategy's development is being led by DFO, DIAND, EC, HC, NRCan, TC and the Canadian Polar Commission, with the cooperation of other federal agencies, northern governments and northern residents. Through implementation of the Strategy, the scientific resources and expertise of the federal government will be used effectively to help achieve sustainable development for the North and contribute to national and international goals.

science and technology annually. The interdepartmental process leading up to the issuing of the annual report on science and technology, and the review of the report by the Cabinet Committee, creates a much greater cross-government awareness of, and ability to identify, shared S&T goals, needs and priorities than ever before. This further enhances the coordination of efforts at the highest level.

Horizontal Coordination and Integration

The ADM Committee on Science and Technology, composed of assistant deputy ministers from science-based departments and agencies, works to coordinate government-wide approaches to managing S&T and to ensure that departmental initiatives and priorities are shared across the federal science and technology community.

Government-wide, the ADM Committee, contributing to the Cabinet Committee's review of federal S&T, provides the high level integration of federal S&T called for by both the federal S&T Strategy and the Auditor General.

At the departmental level, EC and NRCan have developed Science and Technology Management Frameworks to give managers of science-based activities principles, guidelines, policies and tools to manage science and technology. The Frameworks are intended to foster new initiatives that improve the planning, coordination, monitoring and reporting of science and technology within the respective departments, improve the sharing of information across each department, maximize the return on science and technology investment to the taxpayer, and ensure that the investment addresses government priorities.

3.2.3 Performance Measures and Indicators

Parliament and the Canadian public are demanding that the federal government be more open, accountable and transparent in carrying out its activities, including science and technology. There are clear calls to measure the effects and results of federal spending. This is a challenging task in the S&T area, as often results are long term and effects indirect. However, the federal government has made significant progress.

Individual departments and agencies are subject to accountability mechanisms that include a spring *Report on Plans and Priorities* and a fall *Departmental Performance Report*. This system lays out how departments and agencies intend to carry out their mandates as well as how previous commitments have been met. In practice, for departments and agencies whose core business is science (e.g. DFO, EC, HC, NRC, NRCan and the Granting Councils), these reports form the primary accountability mechanism to Parliament on science and technology.

The Memorandum of Understanding Among the Four Natural Resources Departments on S&T for Sustainable Development

Natural resources are key components of Canada's economy. Over the last decade, there has been a growing recognition that these resources must be used wisely and managed in a sustainable manner to help Canada maintain economic growth. Success in this area requires coordinated efforts and teamwork among departments, across sectors and with key stakeholders.

This recognition was one of the major factors that spurred the development of a Memorandum of Understanding (MOU) among the four federal departments that deal with natural resources (AAFC, DFO, EC and NRCan). The MOU was signed in January 1995. Current working groups include R&D Priority Setting, Metals in the Environment, Climate Change and Variability, Coastal Zone Management, Ecosystem Effects of UVB Radiation, Regionalization (Atlantic Pilot), Value of Natural Capital, Endocrine Modifying Substances, Internet, Nutrients, and State of the Environment Reporting.

The main strength of the MOU has proved to be its ability to bring departments together to address ongoing and emerging horizontal issues. Bridges have been built to other departments, including Health Canada and Statistics Canada.

Many departments and agencies are in the process of developing their own performance measurement regimes. The Industry Portfolio has adopted an S&T performance framework to help managers describe, manage and report on the performance of S&T programs and organizations. NRCan conducted two impact studies in 1996–97: one reviewed selected projects in the Mineral Technology Branch; the other focused on the effect on industry of selected activities of the Canada Centre for Remote Sensing.

3.2.4 Science and Technology Information System

S&T decision making and performance measurement require a good information base. The shift to a knowledge society has dramatically increased the complexity of this information base. The federal government is developing a new S&T information system that will be better able to measure Canada's progress toward becoming more innovative and internationally competitive. The objective of the system is to produce a useful set of indicators within a conceptual framework that gives a comprehensive view of the state of S&T in Canada.

Working with Industry Canada and a network of consultants, Statistics Canada is developing statistical measurements for five key areas: innovation systems, innovation, government S&T activities, industry, and human resources, including employment and higher education. The agency has also improved existing measurements of S&T activity and begun to develop new measurements.

When the project is completed in 1998–99, it will have gathered enough information to provide a more complete description of the Canadian innovation system and input into assessing the federal government's role in that system. New indicators will also be available to provide a fuller, more accurate picture of S&T activity in Canada than previously possible.

3.2.5 Scientific Human Resources in the Federal Government

The federal government recognizes that the competencies and motivation of its scientific and technical workforce are essential to its ability to deliver a high quality S&T program. Treasury Board Secretariat is working with science-based departments and agencies to resolve these issues by developing a strategy that emphasizes consultation and uses innovative and tailored approaches.

As a first step, the Government published *Science and Technology for the New Century: A Framework for the Human Resources Management of the Federal Science and Technology Community* in March 1996. This document identified the human resource ingredients necessary to accomplish the goals of the S&T Strategy and established a leadership and management structure to accomplish these goals. The report led to consultations that identified and validated more than 140 recommendations to address human resource concerns.

These recommendations have been integrated into a blueprint for human resource management that identifies priorities, deliverables, timing, resource limitations and accountabilities for a number of activities, projects and pilots. Three key concerns identified through the consultations are undergoing further scrutiny:

- potential skills shortages and future recruitment needs for science-based departments
- a management development program for science managers
- issues and concerns affecting technologists who support federal science efforts.

In addition, 10 pilot projects led by various science-based departments and agencies will address issues identified during the consultations. These projects will lead the way to providing increased flexibility and authority in some areas of human resource management, as well as improving access to career opportunities and information flows to scientists.

To support these activities, the S&T HR Web site (www.tbs-sct.gc.ca/tb/hr/scitech) has been designed as a virtual forum to communicate with the federal S&T community at large, to discuss and exchange information and to post proposals for solving human resource problems.

3.2.6 Cooperation and Coordination

The S&T Strategy and recent reports by the Auditor General emphasize the need to ensure that departmental activities are coordinated to achieve government priorities. While the Cabinet Committee on the Economic Union and the ADM Committee on Science and Technology carry out this objective across government, a variety of approaches have been developed to carry it out at program levels. In many cases this cooperation and coordination goes beyond the federal government and involves provincial governments and those of other nations.

The Western S&T Memorandum of Understanding (MOU) is an innovative approach to joint planning and policy formulation and the delivery of programs and services by government. The MOU represents an effort to move beyond shared funding of projects to a strategic effort to coordinate complementary strengths and better serve the needs of Canadians across the region. This agreement, among the four Western provinces, Western Economic Diversification, Industry Canada and NRC, calls for joint planning and collaboration on S&T to address the economic and social development needs of the region.

Partnerships with provincial and local bodies are a key tool in Health Canada's surveillance of diseases including cancer and acute coronary syndrome. The Sentinel Health Unit Surveillance System is a network of nine public health units funded to carry out surveillance of particular diseases. In the past, they have collected data on hepatitis, asthma, invasive bacterial disease and pertussis.

The Program of Energy Research and Development (PERD)

PERD is an NRCan program delivered inter-departmentally through 11 federal departments and agencies. Energy R&D priorities and the strategic plan for the Program are developed in consultation with various committees and through annual workshops. These meetings usually include representatives from the private sector (companies, consortia and alliances), universities, provincial governments and research organizations. This process ensures that the energy R&D community addresses jointly a number of common horizontal issues in the fields of energy efficiency, renewable resources, fossil fuels, energy and climate change, and transportation.

International cooperation and collaboration in S&T is also critical to the long-term strength of Canada's S&T effort. To remain at the leading edge in key research areas, to formulate policy and regulations based on the most up-to-date information available, and to contribute its fair share to the global stock of knowledge, Canada has to maintain strong links to the international S&T community. Canada has a proud history of involvement in international S&T activities. Canada's reliance on scientific discoveries and technological developments from around the globe pushes us to work with the best and involve ourselves in large international endeavours ranging from the International Geophysical Year to the International Space Station.

While most international cooperation takes place between individual researchers and their peers around the world, there are increasing needs for larger investments in more structured collaborative efforts.

In particular, participation in international S&T provides access to a much larger S&T base than is available in Canada. This is particularly true of large multilateral programs in which no one country can, or should, bear the brunt of the research effort or costs. Exploring space and the oceans, researching the arctic environment, and unravelling and mapping the human genome are all areas demanding international cooperation of which Canadians should be a part.

Bilateral collaboration is also important; Canada's largest single partner is the United States. Canada also has formal agreements with a very few countries such as Germany and Japan to facilitate cooperation with these important sources of research and technology. Canada also signed an important access agreement with the European Union in 1996.

The federal government is currently developing an International Science and Technology Framework to facilitate the coordination of federal investment in, and activities related to, international S&T. The framework is expected to address a variety of issues affecting more than one department or sector. These include framework policies such as are discussed by the OECD and the involvement of the federal government in supporting or promoting industrial R&D cooperation as it did in the Japanese-led Intelligent Manufacturing Systems project.

The federal government relies extensively on interdisciplinary and international S&T partnerships and cooperation such as was developed under the Boreal Ecosystem-Atmosphere Study (BOREAS). This is a large-scale interdisciplinary field experiment, sponsored jointly by the U.S. and Canada with involvement of Britain, France and others. The goal of the study is to obtain an improved understanding of the exchanges of radiative energy, heat, water, carbon dioxide and trace gases between the boreal forest and the lower atmosphere. The work helps clarify the role played in global change by the boreal forest. A Canadian coordinating committee, which includes representatives from AAFC, EC, NRC, NRCan (lead department) and NSERC, oversees Canadian involvement.

SNO

The Sudbury Neutrino Observatory (SNO) is a major scientific facility under construction in an active nickel mine near Sudbury, Ontario. This unique and technically challenging Canadian-led project involves scientists from the U.S. and Britain, in addition to Canadian researchers. The project, which is designed to provide answers to the problem of solar neutrinos, one of the most significant areas of astrophysics, has the financial support of the governments of Canada, the U.S., Britain and Ontario. In addition, Inco Ltd. is providing funding as well as access to its mine, while AECL is loaning $300 million worth of heavy water to SNO. The collaboration among governments, universities and the private sector makes this a world-class project, at fraction of the cost that would be required anywhere else in the world.

The Department of National Defence obtains significant information from Canada's allies through various agreements. The most notable of these are the new NATO Research and Technology Organization, and the Technical Cooperation Panel, an international cooperative R&D agreement between Australia, New Zealand, Canada, the U.S. and Britain. Participation in these international endeavours provides Canadian researchers with access to a much larger science and technology base than is available at home, and keeps DND and its S&T partners at the leading edge of worldwide technological developments.

4. Canada in the Knowledge Era

Canada is poised for success in the knowledge society — it has control over its finances, a solid resource base, strong technological capabilities, good access to capital, a highly trained workforce, and excellent access to world markets. Canada's social and economic transition will be built on existing strengths, while, at the same time, maximizing the capacity to create and use new knowledge for social and economic gain.

This report outlines the federal government's progress in implementing the S&T Strategy. It highlights how federal S&T investments are contributing to a strengthened innovation system and a better quality of life for Canadians. Canada's S&T Strategy was designed to move the country forward and advance departmental transitions to a knowledge-based way of business and raison d'être. The result has been a more focused federal S&T effort that better positions the federal government to provide leadership in adapting to the knowledge society.

The Government outlined its priorities in the Speech from the Throne. Investing in knowledge and creativity and developing the workforce for the 21st century are key aspects of the efforts to build a stronger Canada. These objectives will also shape the federal S&T effort in coming years.

This first annual report on federal S&T looks at the initial stages of redirecting federal investments in response to the S&T Strategy and Program Review. This review of the federal S&T system has revealed two areas to which the Government will pay particular attention: **innovation** and **people**. Both challenges and opportunities exist for the future in these areas. As the Minister of Industry, John Manley, stated recently:

> *In this emerging new economy more than ever people and innovation are the keys to growth and wealth creation. The knowledge economy is transforming all industrial sectors from agriculture and natural resources, through manufacturing to retail and services. As we move into the new century, the new economy will affect the life and work of every person, every business, every community, every organization in Canada.*
>
> *John Manley, Minister of Industry*
> *Reply to the Speech from the Throne —*
> **A Vision for Canada in the 21st Century:**
> **A World-Leading Knowledge Economy**
> *September 29, 1997*

4.1 Innovation — Reaping the Benefits of Good Ideas

Good ideas have always been the foundation for improvements in economic and social well-being. In a knowledge society, ensuring that there is a continuing supply of ideas and the means and will to put those ideas into practice, is even more important than ever, as change is far more rapid. Innovation is critical not only to economic success, but also to preserving the environment and renewing the social fabric. Innovation is about finding better ways of doing things and about addressing problems in entirely new ways. Canadians must work to make innovation a part of everything we do.

Canada's economy, and the world's, is undergoing a fundamental change. With globalization of not only trade, but also much of the economy through investment and migration, and the increased role of information and knowledge as principal engines of long-term growth, Canada must work smarter — using innovative approaches to create new markets, keep costs down and add value to existing products.

In developing its innovation agenda, the Government faces two challenges. The first is leading through innovation to carry out its activities and delivering its services to the optimum benefit of Canadians. The second is to create an environment that encourages and rewards innovation by firms, academic institutions and individuals. Addressing the first challenge will help to reduce costs and overlap, improve efficiency and effectiveness, facilitate joint planning, provide "one-window" service delivery, and exploit complementary capabilities, among other things. Addressing the second will ensure that we have a strong economy and society on which to build a prosperous future.

In looking to this future, four key, innovation-based challenges face Canadians and their governments:

- **making Canada the most connected nation in the world**
  By ensuring that Canadians are connected to each other, to their institutions, to their governments, and to the world through a variety of means, including the information highway, we will build a stronger understanding of who we are, our place in the world, and the potential we have in the global marketplace. It is imperative that Canada be an outward-looking nation, a society eager for, and accepting of, knowledge from around the world.

- **encouraging innovation in addressing Canada's challenges for the future**
  The federal government is leading by example in this area by adopting innovative approaches to delivering on its mandates. Through its efforts to improve the information available to all Canadians, it is encouraging them to seek out the best, not necessarily the easiest, solution to the challenges they face.

- **turning knowledge into jobs, commercial products and services**
  The federal government is focusing its S&T efforts in support of its jobs and growth objectives. It encourages, supports and performs research and technology

development to help create new products, processes and industries. At the same time, it is strengthening the S&T infrastructure and providing incentives for the creation of the partnerships and links that will build a strong national system of innovation. Federal research in support of policy, regulation and public protection also plays an important role in developing a supportive climate for commercialization and job creation in emerging technology areas.

- **innovating to achieve national and international social, health and environmental goals**
  Innovation is critical to all forms of human endeavour. Technological innovation offers useful responses to many of the challenges facing Canada in the future. Technological innovation can contribute to improved environmental quality and can enhance the quality of life for all Canadians. At the same time, social innovation — in the way we work, the way we manage people, and the way we live — will be necessary to meeting Canada's goals for the future. To improve Canadians' quality of life, we will require innovation in the types of research being pursued, and in the management of S&T-related issues.

4.2 People — Investing in the Leading-edge Workforce of the 21st Century

The role of people in the knowledge-based economy cannot be overstated: they are the creators, keepers and manipulators of knowledge. People are not just human capital. They are, most importantly, individuals who live and work together. This leads to two thrusts for policies directed towards people: investing in a leading-edge workforce for the 21st century, and ensuring that no Canadians are left behind as the country moves forward. To be effective, we must ensure that these thrusts are always closely linked. Focusing solely on the supply issue can overlook the social impacts of the transition to a knowledge society.

However, in looking at human resource issues for the future, policymakers face a number of apparent contradictions, which are resulting in a gap between Canada's economic outlook, which is optimistic, and the perceptions of many Canadians of their future, which is pessimistic. Here are some examples of this:

- Unemployment (especially youth unemployment) remains stubbornly high in Canada, but numerous companies are facing a shortage of skilled workers.
- Jobs require ever higher educational requirements, but a significant number of people with high levels of education are underemployed
- Canada's per-capita investment in education is among the world's highest, but the performance of its students in standardized math and science tests is only average.
- While Canada is a leader in public education spending, the private sector's contribution to building the workforce for the future trails competitors significantly.

Addressing these contradictions is a key component of the Government's overall social and economic agenda. Devising the right solutions requires improved measurement of the impact of advanced training, skills development, social innovation, and other "people initiatives" in the knowledge society, leadership and investment from both governments and the private sector, and innovative approaches to policy formulation and human resource management.

Ensuring that there is an adequate supply of knowledge workers is a multifaceted challenge, and each facet has its own policy challenges and needs. It is too simplistic just to say that there must be more students enrolled in S&T-related programs. Overall, the goal must be to ensure that Canada develops and maintains a rich pool of people who understand scientific and technological concepts and can apply them in innovative ways to meet the challenges of the 21st century. In this regard, some areas to be focused on include the following:

- **ensuring that our society values science, technology and innovation**
  innovation must become a way of life, and a way of thinking for Canadians. To move forward on this issue, the federal government faces challenges such as developing improved measures of the impact of innovative activities (e.g. S&T indicators) in order to demonstrate their importance to Canadians; encouraging enhancements in the education system (through partnership with the provinces) to promote improved understanding of natural science and engineering concepts in general education, and social and business concepts in natural science and engineering programs; and communicating the role and outputs of government S&T to society.

- **encouraging people to be innovative in addressing their challenges and opportunities**
  part of preparing people for a knowledge society is preparing them to try new approaches and ideas. While such an exploratory approach to problem solving must be introduced in the education system, it should also be carried over to life in general. The federal government should take a leadership role in this regard, showing a willingness to seek out innovative solutions to policy challenges such as sustainable development.

- **ensuring that our young people and today's workers have the knowledge, inclination to innovate, and scientific and technological skills base to meet the demands of the knowledge society**
  despite all the discussion in both policy circles and the popular press about the need for scientific literacy and skills for the information age, the number of people choosing natural science or engineering career paths is not increasing. Companies are unable to find suitably skilled workers to fill vacant positions. Priorities in this area include enhancing the "market value" of scientific careers to make them

a more attractive choice; working with the provinces, universities and colleges, the high tech industry and other rapidly growing sectors to better forecast the number and types of jobs that will be available and to develop a plan for ensuring that people are appropriately educated to fill these positions; creating an environment that encourages and rewards people for upgrading their skills and employment-related technical understanding; and ensuring that systems will allow and encourage highly skilled immigration, and that the economic and social structure also provides this encouragement.

- **ensuring that our economy and society maintain rewards for innovation to encourage the best and brightest to live and work in Canada**
  Canada needs to have "critical mass" in specific science and technology areas and needs to have facilities and equipment that support state-of-the-art research. In this regard, the federal government must look at the need to enhance support for basic science and S&T infrastructure and establish a regulatory/business/taxation climate that supports innovation in products, processes and management practices.

- **understanding the impacts that the transition to a knowledge society will have on individuals, communities and social structures**
  the knowledge-based economy is creating new patterns of work and learning and new sets and structures of rewards. Across the world, there is growing polarization of income. As well, more needs to be known about the causes of the persistent unemployment in many countries and in several Canadian regions — how much of it is due to structural changes in the economy? Policies must ensure that all Canadians have an equal opportunity to benefit from the transition.

The federal government has been very active recently in addressing the human resources management challenges of its own science and technology community (see section 3.2.5). This community is, in many ways, confronted by challenges similar to those faced by Canada's broader scientific community. Issues such as the ability to attract and retain skilled personnel, an aging workforce, and changing reward structures are common to both. The Advisory Committee on Science and Technology (ACST) has taken on human resource issues as one of its priorities. The Council's interest stems from the difficulties that firms applying advanced technologies are having in finding and retaining qualified and skilled staff. ACST is looking at such things as how to improve the domestic supply of skilled people and ways to encourage skilled workers to come to, or stay in, Canada.

5. Conclusion

Science and Technology for the New Century: A Federal Strategy reflects a wide spectrum of views on how federal science and technology should contribute to building a solid future for Canada. This report clearly demonstrates that the Strategy has been a positive force for change. The Strategy's **goals** have shaped the Government's directions on S&T, and its **principles** now define how departments are using S&T to deliver on their mandates. The federal S&T Strategy is, however, more than a document. It is a changing and evolving framework for ensuring that the federal government is able to use S&T effectively to meet the needs of Canada and Canadians.

The two themes of innovation and people are further shaping the Strategy at this time, and this influence will continue for the foreseeable future. As Canada moves into the new century, the implementation of the original strategy will continue, and new issues will likely emerge. The federal government's S&T effort will evolve to meet these new challenges and continue to occupy a central place in building a stronger Canada.

Annex

For more information on the S&T Strategy, departmental activities and performance reports, and government policy directions affecting science and technology, consult the following sources:

Science and Technology for the New Century, A Federal Strategy
Government of Canada
Minister of Supply and Services Canada, 1996
Cat. No. C2-290/1996
ISBN 0-662-62066-6

Science and Technology Data, 1997
Industry and Science Policy Sector
Industry Canada

Federal Scientific Activities
Statistics Canada
Catalogue 88-204-XPB, 1997
ISSN 0824-0310

Departmental performance reports —
available at http://www.tbs-sct.gc.ca/tb/irpp/irppe.html#DPR9697

Industry Portfolio S&T Progress Report (consultation draft)
Government of Canada
National Research Council

Speech from the Throne to Open the First Session
of the Thirty-Sixth Parliament of Canada
September 23, 1997, Ottawa —
available at http://pm.gc.ca/cgi-win/pmo_view.exe/ENGLISH?643+0+NORMAL

More information on departmental S&T activities is available at the following Web sites:

Agriculture and Agri-Food Canada
http://aceis.agr.ca/

Atlantic Canada Opportunities Agency
http://www.acoa.ca

Canadian Space Agency
http://www.space.gc.ca/

Department of Fisheries and Oceans
http://www.ncr.dfo.ca/

Department of Foreign Affairs and International Trade
http://www.dfait-maeci.gc.ca/english/trade/science.htm

Department of National Defence (Defence Research and Development Branch)
http://www.crad.dnd.ca

Environment Canada — *Green Lane*
http://www.doe.ca/

Federal Office of Regional Development — Quebec
http://www.bfdrq-fordq.gc.ca

Health Canada
http://www.hwc.ca

Human Resources Development Canada
http://www.hrdc-drhc.gc.ca/common/home.shtml

Industry Canada
http://www.ic.gc.ca

Strategis
http://strategis.ic.gc.ca

Medical Research Council
http://www.mrc.hwc.ca

National Research Council
http://www.corpserv.nrc.ca

Natural Resources Canada
http://www.nrcan.gc.ca/

Natural Sciences and Engineering Research Council of Canada
http://www.nserc.ca

Social Sciences and Humanities Research Council of Canada
http://www.sshrc.ca

Statistics Canada
http://www.statcan.ca

Transport Canada
http://www.tc.gc.ca

Research and Development
http://www.tc.gc.ca/tdc/index.htm

Treasury Board (Federal Science and Technology Human Resources Management)
http://www.tbs-sct.gc.ca/tb/hr/scitech