FORGING AHEAD

A REPORT ON FEDERAL SCIENCE AND TECHNOLOGY — 1999

Government of Canada
Gouvernement du Canada

Canada

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THE final decade of the second millennium has been a time of significant change for Canada, and for the federal government. We entered this period in the throes of a major fiscal crisis, which required the Government of Canada to review all of its activities, and to make hard choices on its immediate spending priorities. However, the net result of these restraint measures was the elimination of the federal deficit, giving us the ability to re-invest in areas of long-term priority. The government's plan for sound financial management will allow us to build a more prosperous Canada with sustainable job and wealth creation, leading to an enhanced quality of life for Canadians.

The start of the 1990s also found us at the beginning of the fastest-growing technological revolution ever seen. This iteration of an industrial revolution — the "innovation revolution" — was based largely on advances made in computing and communications technologies. The impacts of these technologies have caused a fundamental change in the nature of the world's economy, and, indeed, in the way that citizens conduct their everyday lives. This innovation revolution led to the realization that, to compete effectively in the global economy, nations must be able to create and harness knowledge to generate jobs, growth and wealth.

The government understands that the innovation-fuelled knowledge-based economy rests on a base of science and technology (S&T), and that the government has a major role to play in fostering Canada's ability to be a major contributor on the world S&T scene. Recognizing that S&T is the engine that drives innovation, and hence economic growth, the government identified S&T as a priority area. In 1996, we released our S&T strategy, *Science and Technology for the New Century*, which gave direction and a framework for the government's future S&T investments.

Tangible proof of our commitment to this strategy, and to our support for the innovation revolution, came initially in the *Canadian Opportunities Strategy*, introduced in the 1998 federal budget, and expanded upon in the 1999 budget. The 2000 budget invests further in innovation, skills and knowledge. Recognizing that harnessing the innovation revolution is a shared responsibility, many of the government's investments seek to foster cooperative linkages and partnerships with other stakeholders in Canada's research enterprise.

With the additional funding provided to the Canada Foundation for Innovation, the government is assisting Canada's universities and teaching hospitals to renew and modernize their research infrastructure. Through partnerships with other players in the Canadian research enterprise, the federal investment in the Foundation, which now totals $1.9 billion, should leverage about $4.75 billion in new investments in research infrastructure.

Many analysts suggest that we are entering the "Age of Biology" and that many of the S&T advances in the near future will be based on the life sciences. The advances that have been made in our understanding of the human genome and of the genetic codes of plants and animals, and the real and potential applications of this knowledge, give credence to the view that biotechnology will significantly affect our lives. Consequently, the 2000 federal budget has made a number of investments to ensure that Canada remains at the forefront of this important field.

Innovation Investments of the 2000 Budget

- *University Research Chairs*
  $900 million over five years to create and support 2000 new research chairs in Canadian universities
- *Canada Foundation for Innovation*
  An additional $900 million for investment in research infrastructure at Canadian universities and research hospitals
- *Genome Canada*
  $160 million to advance the study of genes and biotechnology
- *TRIUMF*
  $200 million over five years for Canada's national subatomic physics research laboratory
- *Biotechnology*
  $90 million over three years for federal departments and agencies that regulate biotechnology products and processes
- *Social Sciences and Humanities Research Council of Canada*
  $10-million increase to the Council's annual budget, for research in the social sciences and humanities
- *Scholarships, Fellowships and Bursaries*
  An increase in the tax exemption to students receiving scholarships, fellowships and bursaries, from $500 to $3000
- *Environmental Technologies and Practices*
  $700 million in new initiatives, including:
  - a $100-million Sustainable Development Technology Fund
  - a $60-million Canadian Foundation for Climate and Atmospheric Sciences
  - a $100-million Green Municipal Investment Fund
  - $90 million over the next three years, and $45 million annually thereafter, for the protection of species at risk.

Environmental and sustainable development issues are important to many Canadians. We must ensure that we are able to live in harmony with our surroundings. For this reason, the government has made significant new investments to promote environmental technologies and practices, both to gain new knowledge, and to implement it.

The ability to create and apply new knowledge, to ensure that Canada is able to continue to be a major player in the innovation revolution, depends on having a skilled work force. We must be able to compete with the rest of the world. In 1998, the government created the Canada Millennium Scholarships Foundation; in January 2000, more than 90 000 bursaries were provided to post-secondary students. In the 2000 budget, the government acted to continue this investment in post-secondary training, by increasing the exemptions for income from scholarships, fellowships and bursaries to $3000 from $500. This increase will have a significant impact on many students pursuing advanced studies.

Within the Government of Canada, federal departments and agencies have built significant momentum in developing a more focussed and better coordinated S&T agenda. They are now able to forge ahead with the flexibility to harness capabilities across government to address issues that affect the health, safety and economic well-being of Canadians.

This third Report on Federal Science and Technology, *Forging Ahead*, provides a number of concrete examples of the collaborations promoted and established by federal departments and agencies to use S&T to address questions of importance to Canadians.

Canada has the capability of being a significant player in the global innovation revolution. In partnership with the other stakeholders in Canada's research enterprise, our collective investments in S&T will ensure that Canada maintains its United Nations ranking as the best country in which to live. Our investments will also ensure that we pass on to our children a better and brighter world.

Brian Tobin
Minister of Industry

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

THE Government of Canada's vision of the future is one of a society whose economy is competitive, whose population is healthy, whose children are prepared, and that invests in knowledge. Realization of this vision requires us to harness S&T in a collaborative and strategic manner to advance our economic competitiveness and industrial productivity.

Two of the tools the government is using to achieve this collaboration are the Prime Minister's Advisory Council on Science and Technology (ACST) and the Council of Science and Technology Advisors (CSTA). The ACST provides the Prime Minister with expert, non-partisan advice on national S&T goals and policies and their application to the Canadian economy. The Council reviews the nation's S&T performance, identifies emerging issues and advises on a forward-looking agenda.

The CSTA provides advice to the government on internal, cross-cutting issues related to S&T. As Chair of the CSTA, I am particularly pleased with the Council's role in developing *A Framework for Science and Technology Advice*. This Framework includes the following principles: Early Identification; Inclusiveness; Sound Science and Science Advice; Uncertainty and Risk; Transparency and Openness; and Review. By using these six principles, the Framework will help federal departments and agencies demonstrate, in an open and transparent fashion, that key decisions have been informed by science advice.

Details of the activities undertaken to date by both of these advisory bodies are provided in this report.

This third Report on Federal Science and Technology also provides detailed descriptions of the horizontal initiatives undertaken by federal departments and agencies to address two major issues of concern to Canadians: global climate change, and the continued ability of Canadian companies to undertake research and development. In addition, a number of S&T issues of current and future concern are identified, resolutions to which will require collaborative efforts on the part of government departments and agencies and their non-federal partners.

I firmly believe that the federal government's S&T infrastructure and its research capabilities have a critical role to play in the national innovation system. Canada is more than a land of vast and natural beauty, with an abundance of natural resources. It is also a land of virtually limitless resources of knowledge and skills. Capitalizing on all of these advantages will ensure the continued economic success of Canada, and the well-being of our citizens.

Gilbert Normand
Secretary of State (Science, Research and Development)

Guide to Acronyms and Abbreviations

THE following acronyms and abbreviations are used throughout this report:

AAFC	Agriculture and Agri-Food Canada
ACST	Advisory Council on Science and Technology
AECL	Atomic Energy of Canada Limited
CCRA	Canada Customs and Revenue Agency (formerly Revenue Canada)
CFI	Canada Foundation for Innovation
CFIA	Canadian Food Inspection Agency
CIDA	Canadian International Development Agency
CIHR	Canadian Institutes of Health Research
CRC	Communications Research Centre Canada
CSA	Canadian Space Agency
CSTA	Council of Science and Technology Advisors
DFAIT	Department of Foreign Affairs and International Trade
DFO	Fisheries and Oceans Canada
DND	Department of National Defence
HRDC	Human Resources Development Canada
IDRC	International Development Research Centre
IRAP	Industrial Research Assistance Program
MRC	Medical Research Council of Canada
NCE	Networks of Centres of Excellence
NRC	National Research Council Canada
NRCan	Natural Resources Canada
NSERC	Natural Sciences and Engineering Research Council of Canada
OECD	Organisation for Economic Co-operation and Development
SSHRC	Social Sciences and Humanities Research Council of Canada
TPC	Technology Partnerships Canada

Several abbreviations also appear regularly throughout the text:

5NR MOU	Memorandum of Understanding on S&T for Sustainable Development
GDP	gross domestic product
GERD	gross expenditures on research and development
R&D	research and development
RSAs	related scientific activities
S&T	science and technology
SMEs	small and medium-sized enterprises

1.0 Introduction

1.1 The Federal Context

It is well recognized that the federal government's investments in science and technology (S&T) have been and will continue to be a critical factor in securing the economic and social well-being of Canadians.

However, the fiscal crisis that faced the nation in the early 1990s required the government to undertake a wide-ranging review of its spending priorities, including those in S&T. One consequence of this review was the release in March 1996 of *Science and Technology for the New Century: A Federal Strategy*, which stated the government's commitment to S&T activities in support of the goals of improved quality of life, the advancement of knowledge, and sustainable economic growth and job creation. It also outlined the ways in which future federal S&T activities and investments would be oriented, to continue to ensure benefits for Canadians. The strategy's framework helps to enhance these benefits through increased cooperation and collaboration among federal departments and agencies on cross-cutting challenges.

The fiscal measures undertaken by the government since 1994 have resulted in the elimination of the federal deficit and have brought the nation's finances into order. This has allowed the government to make strategic new investments, for example, in innovation, thereby re-affirming its support of S&T as a vehicle for achieving economic and social goals and sustaining Canada's future.

The re-affirmation of the government's commitment to S&T and innovation, demonstrated in recent federal budgets as well as in the October 1999 Speech from the Throne, is a direct expression of the government's recognition that a nation's competitiveness in the new global economy is driven by its ability to create and utilize knowledge. The shift to a global, knowledge-based economy has created considerable pressure on the government to adapt to new roles and new ways of doing business. These adaptations will ensure that the government's investments, and the regulatory and other frameworks necessary for sustainable economic growth, are appropriate for meeting the challenges and opportunities of the new economic environment. They will also assure the continued social well-being and security of Canadians. Science and technology have a pivotal place in this changing environment.

The number of issues that fall within the domain of government and that require scientific input is expanding. Moreover, these issues could be said to be becoming increasingly horizontal in nature, as their resolution requires the active participation of a variety of departments and agencies. In addition, the pace of change in the knowledge-based economy continues to accelerate, and the implications of this change continue to broaden. Therefore, in order to provide the quality information needed to address many of the social, economic and political issues facing government, federal departments and agencies must be increasingly flexible and adaptable in their roles as both performers and facilitators of S&T.

Consequently, research must continue to become an increasingly collaborative activity among all players in the research enterprise, both domestic and international. Science and technology play a significant role in enhancing our understanding of the

world around us, and add value to the goods and services produced and used by Canadians. Through strategic investments in S&T and innovation, the government ensures Canada's ability to maintain our economic and social positions in the world in the new millennium.

1.2 The Role of Government in S&T

The Canadian innovation system — a term used to describe both our S&T institutions and the various linkages among them — creates, disseminates, and exploits the knowledge needed to fuel a progressive society and economy. To function effectively, this system depends on the presence of complementary strengths in three key sectors: the private sector, universities and governments. These sectors each fulfil a number of roles and, through cooperation and collaboration, ensure that our economic and social systems perform well, are able to keep pace with both domestic and international developments in S&T, and that the government is able to meet the expectations of Canadian citizens.

The government has a clearly identified dual role of performer and facilitator of research. It fulfils these roles both by performing research, using intramural capabilities and facilities, and by funding extramural research and fostering partnerships among the various research-performing sectors.

1.2.1 Facilitating Research

In its role as facilitator of research, i.e., funding research performed by others and fostering partnerships, government targets its programs primarily toward two sectors of the research enterprise: universities and the private sector.

1.2.1.1 Universities

Since World War II, the federal government has been the major supporter of university research. In assuming this role, the federal government has a symbiotic relationship with the provinces and territories: the federal government provides funding for the direct costs of research, and the provinces and territories provide the basic physical infrastructure and operating costs for universities and teaching hospitals across the country. This federal-provincial-territorial relationship ensures that Canadian universities have the facilities and funds necessary to conduct world-class research and are able to train the highly skilled people necessary for the knowledge-based economy.

Direct government support for university research and research training is provided predominantly through the three federal granting councils: the Natural Sciences and Engineering Research Council of Canada (NSERC), the Medical Research Council of Canada (MRC), and the Social Sciences and Humanities Research Council of Canada (SSHRC). These agencies collectively provide peer-reviewed funding for more than 17 000 researchers across the country, in fields as disparate as particle physics, behavioural psychology, oceanography, economics, molecular biology, medical ethics and cancer research. These investments support pure and applied research to enhance our understanding of the physical, biological and social worlds of which we are a part, by extending the boundaries of knowledge. Researchers are increasingly finding new applications for the results of their research, and are commercializing and disseminating their results for the benefit of Canadians. These investments also support the training

New Directions in Health Research: The Canadian Institutes of Health Research

A National Task Force on Health Research reported in 1998 that, despite the excellent health research work being carried out, there was significant room for improvement. For example, the Task Force pointed to underfunding, fragmentation of effort and lack of coordination. The Task Force recommended the establishment of the Canadian Institutes of Health Research (CIHR), a system of institutes without walls. In the February 1999 budget, the federal government committed to launch the CIHR, and to almost double the resources it spends on health research over a three-year period, to nearly $500 million by 2001–02.

The legislation to create the CIHR was introduced in Parliament on November 4, 1999. The CIHR will be a modern and uniquely Canadian approach to health research and will replace the Medical Research Council of Canada. The CIHR's objective will be "to excel, according to international standards of scientific excellence, in the creation of new knowledge and its translation into improved health for Canadians, more effective health services and products, and a strengthened Canadian health care system."

The CIHR is about excellence and integration across disciplines, sectors and regions. It is concerned with:

- setting priorities;
- fostering the discussion of ethical issues and the application of ethical principles to health research;
- addressing emerging and re-emerging health threats and challenges;
- promoting the dissemination of knowledge;
- encouraging innovation; and
- building capacity.

The CIHR will bring together researchers in all areas of health research: biomedical research, applied clinical research, research into health services and systems, research into the societal and cultural determinants of health, environmental influences, and other research, as required. It will link health researchers in academia, the private and voluntary sectors, and government. It will also foster connections with international networks of research excellence.

The CIHR will be charting a new course for health research in Canada. As stated by Health Minister Allan Rock, "The CIHR is going to set a world standard."

of the brightest young minds in our country — our leaders of the future — by imparting important skills and expertise that can be applied in all sectors of our economy.

While the primary focus of most university researchers is to advance knowledge through basic research, many are working in collaboration with government, private sector and international partners on research questions of strategic interest. The government assists in fostering these efforts through specific programs instituted by the granting councils to support university-industry and university-community partnerships, and through inter-council programs such as the Networks of Centres of Excellence. In addition, through funding made available through the Canada Foundation for Innovation (CFI), the government has enabled universities and research hospitals to seek new types of partnerships with the provinces and the private and voluntary sectors to renew and upgrade their critical research equipment and other research infrastructure.

The federal government has demonstrated its belief in the value of, and commitment to, world-class university research in each of the federal budgets since 1997, by increasing funding for the granting councils, establishing the CFI, and by creating the Canadian Institutes of Health Research (CIHR).

With the creation of the CFI and the CIHR, the federal government has also demonstrated that it is prepared to examine new ways in which to bring about multi-stakeholder partnerships in leading-edge research. Most recently, the government recognized the need to re-examine the mechanisms that support research of importance to the health of Canadians, and so approved the establishment of the CIHR. This innovative new funding vehicle will, for the first time, provide a means for researchers in all areas of health-related research to collaborate in a series of virtual research institutes. The CIHR will also represent a means of translating new knowledge into improved health for Canadians, more effective health services and products, and a strengthened Canadian health care system.

1.2.1.2 Private Sector

The participation of the private sector is essential to sustain and enhance Canada's innovation system, and the government participates in a variety of collaborative and partnering arrangements with the private sector. While some of these activities are directed toward the objectives of the particular firm, many are undertaken to further government objectives. For instance, working with the private sector not only helps the government to deliver programs, but also helps to maintain an industrial base that is internationally competitive through technology transfer. This in turn provides the government with access to a broad range of new technologies.

In terms of maintaining and enhancing the international competitiveness of our industrial base, the government has recognized the high level of risk involved in leading-edge industrial research and development (R&D). Consequently, it has established a number of partnership programs through which the risks of developing new products and services are shared. Through these risk-sharing initiatives, the government ensures that Canadian industry, particularly in the small and medium-sized enterprise (SME) sector, is able to undertake the R&D necessary to become and remain competitive in the global, knowledge-based economy. The following are examples of such programs:

- Technology Partnerships Canada (TPC)
- Industrial Research Assistance Program (IRAP)

- Canadian Network for the Advancement of Research, Industry and Education (CANARIE)
- Agri-Food R&D Matching Investment Initiative
- Defence Industrial Research Program
- Industry Energy Research and Development program
- Technology Early Action Measures (TEAM).

In addition, the federal government provides assistance to SMEs via programs that assist companies in hiring recent college and university graduates whose skills can help to develop a company's technology. Through programs such as these, the government provides opportunities for new graduates to gain work experience while providing access for SMEs to the latest developments in technology.

Further information on these and the other assistance programs for S&T research, which are offered by 15 government departments and agencies, can be found on Industry Canada's *Strategis* Web site **(http://strategis.gc.ca/SSG/te00954e.html)**, and in the Industry Canada publication *Your Guide to Government of Canada Services and Support for Small Business*, which can also be found on the *Strategis* Web site **(http://strategis.gc.ca/SSG/mi02983e.html)**.

The government also stimulates industrial R&D activities through other mechanisms, such as contracting out and procurement, which are important to supporting innovation in the private sector, but are often unrecognized in this role. Funding programs such as those described previously allow companies to pursue corporate objectives. Contracting out and procurement are directed primarily toward government objectives. In both cases, real synergies occur when government objectives can be pursued by the private sector, leading to the enhancement of private sector technical capabilities, and to opportunities for Canadian companies to showcase technical capabilities and new products and services in the global marketplace.

Research and Development (R&D) — Work performed to increase or enhance knowledge in order to create or improve applications of S&T.

Related Scientific Activities (RSAs) — Activities to reinforce the findings of R&D by disseminating and applying S&T knowledge. Data collection, testing, scientific and technical information services, and museum services are examples of RSAs.

1.2.2 Performing Research

The government plays an important role in the national S&T enterprise by undertaking R&D and related scientific activities (RSAs), utilizing its in-house capabilities. The government chooses to perform certain S&T activities in-house. As stated in *Building Excellence in Science and Technology (BEST): The Federal Roles in Performing Science and Technology, "*...the rationale for performing S&T within government needs to be based on a demonstration that the work is relevant to specific needs of government, that it can be done more effectively and/or efficiently in government facilities than it could be done elsewhere, and that, if the government did not do it, it would either not get done, or else would be done in a manner or a time frame that is not suitable for responding to the needs of the government." Furthermore, "the federal government needs to have a degree of scientific and/or technological capacity in order to exercise the option of outsourcing the research."

Research undertaken by federal S&T groups has a vast range of applications. The following are some examples:

- Support for Canadian industrial growth in the identification and development of marketable products, for example, in the areas of advanced manufacturing and aerospace.

Natural Resources Canada's Forest Fire Monitoring, Mapping and Modelling Program

The main objectives of this project of Natural Resources Canada (NRCan) are to monitor, map and model forest fires across Canada on a near real-time basis, using novel satellite remote sensing technologies developed under the project. The project began in 1998 as part of NRCan's ResSources program, and received a 1998 Head of the Public Service Award. In 1999, the project won two national awards: The Agatha Bystram Award and a Technology in Government Medal.

- Support for decision making, policy development and regulation, which includes stock assessments, fisheries biology needed to manage fish stocks and responses to the effects of global warming.
- The development and management of standards such as contributions to the resolution of disputes with the European Union on the pinewood nematode in Canadian softwood lumber shipments. These contributions depend on the development of nationally and internationally recognized standards that result from federally performed research.
- Support for public health, safety, environmental and defence needs. For example, the federal capacity for independent research into food quality allows the government to ensure the health and safety of Canadians.
- Enabling economic and social development such as research into health service delivery or sustainable farming practices.

Thus, in order to fulfil the mandates entrusted to it by Canadians and deliver on its priorities, the federal government has and will continue to have a critical role in performing core S&T activities and undertaking R&D for maximum public benefit.

1.3 Emerging S&T Challenges

An important role of government is to look beyond today's challenges and to identify future issues that may have an impact on the government's goals of sustainable economic growth and job creation, and improved quality of life for Canadians. As federal departments and agencies look forward, they identify issues that could have a negative impact on the government's ability to achieve its goals. They must also decide if there is a need for government intervention to address the future — or "emerging" — challenge. In many cases, the emerging challenge may not yet have captured the attention of Canadians at large, and often government must act before it is apparent to the public that an issue exists.

As previously mentioned, there is a growing need for scientific input to address these emerging challenges, both domestic and international. Increasingly, many of the most vexing emerging public policy challenges are "horizontal" ones that cross traditional departmental boundaries. Resolving these issues requires active participation, in the dual roles of S&T performer and facilitator, from a broad cross section of government. Consequently, departments and agencies are increasingly developing dynamic new partnerships, both with other federal departments and agencies and with other stakeholders, to address these emerging challenges of horizontal concern.

In *Building Momentum*, two emerging issues were identified: the need to strengthen the science-policy interface and global climate change. The first of these topics was examined by the government's Council of Science and Technology Advisors (CSTA), in the context of its study entitled *Science Advice for Government Effectiveness (see Section 2)*. The second topic, global climate change, is the subject of a major paper in that report *(see Section 3)*.

In *Forging Ahead*, a number of emerging challenges are also identified. Government departments and agencies are already tackling some of these issues to define resolutions.

Others are more newly identified challenges, and departments and agencies are still determining the best approaches to develop resolutions. It is anticipated that future Reports on Federal Science and Technology will address some of the successful outcomes of the government's efforts to deal with these emerging challenges.

1.4 The 1999 Report on Federal S&T

As touched upon in this section, S&T is no longer a solitary activity. Partnerships and collaborative activity are essential elements in advancing the knowledge needed to respond to a broad range of public policy issues facing government in particular, and society in general, and to ensure that Canadian industry is positioned to compete in a global marketplace.

The fiscal restraint of the late 1980s and early 1990s engendered an environment in which government had become less collegial in its approach to service delivery, and department-first mentalities became increasingly prevalent. This was true in the realm of government S&T as in other areas. However, in recent years, and most recently in the 1999 Speech from the Throne, the government stated its commitment to a coordinated and horizontal approach in all areas of government activity, including those related to innovation. This approach is based on partnerships between federal departments and agencies, and among levels of government, the private and voluntary sectors, communities and citizens.

The first report on federal S&T, *Minding Our Future*, highlighted the early stages of the implementation of the federal S&T strategy, which laid out a plan for increasing cooperation and collaboration in dealing with S&T issues. The second report, *Building Momentum*, illustrated how this collaborative approach to the management and conduct of federally supported S&T has contributed both to the development of Canada as one of the world's leading economies and to a quality of life that is among the highest in the world.

Forging Ahead is the first reporting of the concrete ways in which federal departments and agencies are increasingly working together and with other players in Canada's S&T enterprise to identify and respond to issues of broad horizontal concerns of government and Canadians. The following sections of this report:

- demonstrate how the federal government's advisory bodies provide advice to decision-making processes;
- provide descriptions of the horizontal efforts being undertaken to address two issues of national concern — global climate change, a topic of both national and international concern, and the federal government's mechanisms to support Canada's industrial R&D base, to ensure that Canadian companies are positioned to succeed in the global knowledge-based economy;
- identify a limited number of the full range of emerging S&T challenges that will require horizontal action on the part of federal government departments and agencies and their non-federal partners; and
- use a number of statistical indicators to provide an overview of the federal investments in science and technology.

2.0 Horizontal Advice to the Decision-Making Process: The Government's Expert S&T Committees

IN *Science and Technology for the New Century: A Federal Strategy*, the Advisory Council on Science and Technology (ACST) was committed to providing advice to the government on S&T priorities. Expert panels were constituted to examine two of those priorities: the commercialization of university research, and skills. Their activities are described below. In addition, the Minister of Industry and the Secretary of State (Science, Research and Development) committed to leading the coordination of horizontal S&T activities across the federal government. The CSTA was the vehicle chosen to aid in this coordination. Two areas examined by the CSTA — scientific advice in government decision making and the roles of the federal government in performing S&T as well as its capacity to undertake these roles — are also described in this section.

Given the relative newness of the reports of these advisory bodies, the following sections provide information on the committee process in arriving at the advice provided to the government. It is anticipated that the government's responses to the reports of these advisory bodies, as well as the implementation and outcomes of their recommendations, will be discussed in future Reports on Federal Science and Technology.

2.1 Advisory Council on Science and Technology

The Prime Minister's Advisory Council on Science and Technology is composed of 12 eminent Canadians, representing academic, voluntary and private stakeholders in Canada's S&T enterprise, whose mandate is to provide the federal government with advice on national S&T issues.

The reports of the ACST, as well as supporting information, can be found on the ACST Web site **(http://acst-ccst.gc.ca)**.

2.1.1 Expert Panel on the Commercialization of University Research

In 1998, the ACST established an expert panel to explore options to maximize the return on the public investment in university research.

The nine-member Expert Panel on the Commercialization of University Research commissioned background reports and consulted with more than 100 stakeholders prior to finalizing its report, entitled *Public Investments in University Research: Reaping the Benefits.*

The ACST has recommended to the federal government that it implement the recommendations of the Expert Panel. This would involve establishing a coherent framework for university intellectual property policy, providing incremental support for the commercialization function within universities, developing the skills required to increase the number of successful innovations created from university research, ensuring that tax policies are conducive to the growth of firms that form strategic alliances with universities, and investing in university research to fuel the commercialization pipeline.

Prior to taking any decisions, the federal government consulted with academic, provincial/territorial and private sector stakeholders under the leadership of Dr. Thomas A. Brzustowski, President of NSERC. More than 600 individuals from 101 organizations

provided feedback on the feasibility and appropriateness of the federal government implementing the Expert Panel's recommendations. The consultations took place throughout September and October 1999. In addition, individuals were invited to provide their views via the ACST Web site.

Industry Canada is developing a government response to the recommendations of the Expert Panel, which will take into account the results of the public consultation process. The Minister of Industry will subsequently seek the support of his Cabinet colleagues for a strategy to accelerate research-based innovation in Canada.

2.1.2 Expert Panel on Skills

The Expert Panel on Skills was created by the ACST in 1998 to provide advice on critical skills in sectors of industry where Canada is already strong, or where opportunities for economic growth and job creation are high. The Expert Panel specifically examined five industry sectors: aerospace; automotive; bio-pharmaceuticals and biotechnologies in agriculture, aquaculture and forestry; environmental technologies; and information and telecommunications technologies.

In its extensive research and consultations, the Expert Panel found no evidence of generalized shortages of technical skills, but a persistent shortage of opportunities for Canadians to put their skills to work. There is also a shortage of non-technical but essential skills such as management, communications and team work.

The labour market is experiencing a relatively smaller cohort of new labour market entrants. At the same time, there is a growing number of ageing workers who must re-skill continually. The tight global market for qualified workers means that Canada has to attract and retain skilled people. Learning systems, including but not limited to the formal education and training sectors, are increasingly under stress as they struggle to adapt their curriculums and delivery approaches to meet the needs of the 21st century.

The recommendations of the Expert Panel focus on improving the functioning of Canada's labour markets; leveraging our R&D capacity to create new opportunities for enterprise and employment; strengthening cradle-to-pension learning systems and improving the efficiency of "school-to-work-to-school" transitions; completing the national, state-of-the-art telecommunications infrastructure; modernizing structures for decision and action; and developing a new mind set about success and failure.

The findings of the Expert Panel were well received by the members of the ACST in October 1999. Since then, the Expert Panel has presented its report, *Stepping Up: Skills and Opportunities in the Knowledge-based Economy*, to a number of organizations and key individuals, especially those who could have an important role in implementing the proposed action items.

Science Advice for Government Effectiveness: Proposed Principles and Guidelines

- **Early identification** — early anticipation of those issues requiring science advice
- **Inclusiveness** — advice from a variety of scientific sources and from experts in many disciplines
- **Sound science and science advice** — due diligence procedures to ensure the quality, integrity and objectivity of science and science advice
- **Uncertainty and risk** — the assessment, management, and communication of uncertainty and risk to decision makers, stakeholders and the public
- **Transparency and openness** — consultations with stakeholders and the public, and transparency with respect to the findings and advice of scientists and how policy decisions have been made
- **Review** — subsequent review of science-based decisions.

Building Excellence in Science and Technology: Federal Government Roles in Performing S&T

- Support for decision making, policy development and regulations
- Development and management of standards
- Support for public health, safety, environmental and defence needs
- Enabling of economic and social development.

2.2 Council of Science and Technology Advisors

The Council of Science and Technology Advisors was established in April 1998 to provide the federal government, specifically the Cabinet Committee for the Economic Union, with external expert advice on internal S&T issues requiring strategic attention.

The CSTA consists of 22 advisors from outside government and is chaired by the Secretary of State (Science, Research and Development). The members are appointed

by ministers of science-based departments and agencies and are drawn primarily from the external science advisory boards that advise these departments. The CSTA draws these advisors into a single body to improve federal S&T management by examining horizontal issues, and by highlighting opportunities for synergy and joint action.

Initially, the Cabinet Committee asked the CSTA to consider two issues: 1) the development of a set of principles and guidelines for the use of scientific advice in government decision making; and 2) an examination of the roles of the federal government in the performance of S&T as well as its ability to fulfil these roles.

Reports of the CSTA, as well as supporting documents, can be found on the CSTA Web site **(http://csta-cest.gc.ca)**.

2.2.1 Science Advice

Recent government decisions in the areas of natural resource management (e.g. fish stocks) and public health and safety (e.g. the blood supply) have contributed to public concern regarding the government's ability to address science-based issues. Recognizing the importance of these concerns, the Cabinet Committee asked the CSTA to examine ways in which the federal government could improve its use of science advice in decision making.

In conducting its examination, the CSTA commissioned studies and received presentations by Canadian and international experts. Their report, *Science Advice for Government Effectiveness (SAGE)*, proposed a series of principles and guidelines to ensure that government decisions are informed by sound science advice and to improve public confidence through a more open and transparent process.

The SAGE report and the wealth of feedback provided through the consultations are being used to develop a government-wide Framework for Science Advice. Adoption and implementation of the framework would improve the government's ability to deal with science-based issues and restore the public's confidence in the science-based decisions of the government.

2.2.2 Roles and Capacity for Federal S&T

Building Excellence in Science and Technology (BEST), the CSTA's report on the roles and capacity of the federal government in undertaking S&T, was accepted by the Cabinet Committee for the Economic Union in late 1999 and released to the public early in 2000. Drawing on the broad experience of its members, the CSTA's BEST report provided an external perspective on a topic being examined internally by the government.

The CSTA's report explicitly recognized a number of roles for the federal government in performing S&T. It concluded that there is a requirement for the federal government to undertake in-house S&T activities, and noted that there is a wide range of challenges facing the federal government in fulfilling its role in the innovation system. The CSTA identified a number of issues related to the government's ability to be a key player in the national innovation system. These issues concern the government's capacity to perform and manage S&T to ensure maximum value for its investment.

With the new and in some cases expanding demands being placed on federal S&T, the CSTA also recognized that the federal S&T capacity issue is real. The BEST report recommends that government departments have an appropriate and robust capacity to

provide a sound scientific platform for delivering on government roles, including policy and decision making. The CSTA stressed, however, that the challenge is not necessarily to rebuild or restore capacity to historic levels. It is to identify what capacity is needed to allow the government to meet the current needs and enhance its ability to meet future challenges. Science-based departments and agencies recognize that the recommendations of the BEST report hold several implications, and that understanding the implications of change and innovation for current and future federal S&T needs is essential in determining an adequate capacity level to meet Canada's needs.

The CSTA's report will likely continue to stimulate discussion of S&T capacity issues within the federal government, and should provide a useful point of reference for addressing the in-house S&T needs.

3.0 Horizontal Issues: Working in Partnership

THERE are many areas in which the federal government establishes cooperative and collaborative arrangements to address S&T issues that support its overarching policy goals of creating sustainable economic growth and jobs and enhancing the quality of life of Canadians. In this section, two of these issues are described, together with the partnerships that have been established to address them.

3.1 Global Climate Change

In *Building Momentum: A Report on Federal Science and Technology — 1998*, global climate change was identified as an emerging policy challenge. This section of *Forging Ahead* is a report on the progress of the federal government in addressing that challenge. Detailed information on federal programs and activities and links to other Canadian and international partners can be found at **http://www.climatechange.gc.ca/english/html/index.html**

3.1.1 Introduction

Emissions of gases such as carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons (CFCs) have been increasing since the beginning of the industrial revolution. In 1988, the Intergovernmental Panel on Climate Change (IPCC) was established to study the impact on climate of these greenhouse gases. The 1990 and 1995 IPCC reports documented scientific evidence linking these emissions from human activities to the risk of global climate change; a third report is due in early 2001. In the past 100 years, average global temperature has risen 0.7 degrees Celsius — alpine glaciers have retreated, sea levels have risen and climatic zones have shifted. The best current predictions suggest average global temperatures may rise as much as 3.5 degrees in the next 100 years unless action is taken to minimize greenhouse gas emissions. The consequences of such rapid climate change have the potential to significantly disturb our social and economic well-being, as well as that of the ecosystems on which we depend. Climate change also has implications for Canada's foreign policy, international relations and security.

The 1990 IPCC report led 154 countries to join together to sign the Framework Convention on Climate Change (FCCC) in 1992. The FCCC came into force in 1994 and has now been ratified by 175 countries. In 1997 at Kyoto, Japan, countries took the first step toward quantified emissions reductions by agreeing to reduce global emissions by 5.2 percent below 1990 levels by the period 2008–12. The Kyoto Protocol will come into effect once it has been ratified by 55 countries responsible for at least 55 percent of worldwide greenhouse gas emissions. Canada's commitment is to a reduction of 6 percent. Since 1990, however, Canadian emissions have continued to increase. The challenge now is to reduce those emissions by 20 to 25 percent below current levels.

The Kyoto Protocol is only a first step. Achieving the Kyoto goal will simply help reduce the rate of future climate change. Greenhouse gases can remain in the atmosphere for decades, and even centuries. Stabilizing concentrations of greenhouse gases — and thereby stabilizing the climate — will take much larger reductions in emissions. Since

the climate is already changing — and will continue to change for some time — the second challenge under both the Convention and the Protocol is to adapt to the impacts of these changes. As some regions of Canada will be more affected by climate change than others, an additional challenge is to meet the Kyoto targets in a way that maintains inter-regional fairness.

Tackling climate change in Canada — and limiting its potential negative effects — requires two main responses: reducing emissions and managing sinks to slow the rate of increase in atmospheric greenhouse gas concentrations, and adapting to the impacts of change to protect our citizens, their health, infrastructure and economies, and our natural environment.

Canada has responded to the challenges of global climate change through significant investments in S&T research, both within the federal government and with national and international partnerships. An integrated and comprehensive management structure, centred on the Climate Change Secretariat — which has close connections to Environment Canada and Natural Resources Canada (NRCan) — has been established to ensure coordination of climate change research and other activities in Canada, including the development of a National Implementation Strategy (NIS) to meet our commitments under the Kyoto Protocol.

3.1.2 Federal/National Approaches

The Auditor General's 1998 report on the federal S&T strategy examined the management of climate change as a case study, to see whether or not the strategy's principles for horizontal management were being adequately implemented. The establishment of the Climate Change Secretariat and the development of business plans under the Climate Change Action Fund (CCAF) (*see page 17*) were seen as moving the federal government toward the kind of management structure envisioned. This section summarizes the actions of the federal government prior to and following the Auditor General's report.

The federal government has encouraged and contributed, directly and indirectly, to reductions in greenhouse gas emissions for many years. It has shown leadership by promoting energy efficiency and renewable and alternative energy initiatives, technology, and research and development, and by achieving ambitious emissions reductions in its own operations.

In 1995, the federal and provincial/territorial governments developed the National Action Program on Climate Change, which outlined the principles and strategic directions for governments and the private sector to address climate change.

Following the agreement reached at Kyoto, the National Climate Change Secretariat was established in February 1998 to serve as a focal point for developing the federal government's domestic policy on climate change and to coordinate the NIS. The CCAF, which was allocated $150 million over three years in the 1998 federal budget and is managed by the Secretariat, is the second major prong of the federal response to the Kyoto Protocol.

In terms of climate science, impacts research and the development of adaptation options, the Canadian Climate Program Board (CCPB), which brings together the federal and provincial/territorial governments, the academic community, the private sector and community interest groups, provides advice and information on climate change and variability and helps to facilitate climate-related activities in Canada.

3.1.2.1 National Implementation Strategy

The first step toward the NIS was to create 16 multi-stakeholder sector and issues tables (including government, industry, the academic community, environmental groups, scientists and non-governmental organizations). The purpose of these tables is to examine the impacts, costs and benefits of implementing the Protocol and to analyse various options for achieving the Kyoto goals. Table reports, or options papers, set out a comprehensive range of short-, medium- and long-term options, based on a consideration of the potential for emissions reduction, opportunities and barriers, time frames for implementation, competitiveness implications, and the anticipated social, economic, environmental, and health costs and benefits of each option. On the basis of a review and analysis of all the options papers, the Secretariat will develop a strategy for consideration by federal, provincial and territorial environment and energy ministers during 2000–01. The key options papers with regard to federal S&T are those on science, impacts and adaptation (SIA) and technology.

The SIA options paper, prepared by the CCPB, presents information on the current state of the scientific enterprise in Canada and proposes measures that would provide Canada with a solid scientific basis for addressing the climate change issue. The science elements of the plan focus on systematic climate monitoring to detect climate change, as well as on the improvement and validation of our climate models; key climate processes (including those related to greenhouse gas sources and sinks); and regional-scale climate modelling for impact and adaptation needs. The impacts and adaptation elements focus on the study of the impacts of climate change on Canada and the development, assessment and implementation of adaptation responses.

The technology table's task was twofold: 1) to advance the development and commercialization of cleaner and innovative technologies that will contribute to the reduction of greenhouse gas emissions; and 2) to enhance the capabilities of and opportunities for Canadian companies to provide environmentally responsive technologies in domestic and international markets. In identifying options, the table addressed the full spectrum of technology innovation challenges facing Canada (including regional considerations) and looked at all stages of development, from technology R&D through demonstration to market entry.

3.1.2.2 Climate Change Action Fund

The CCAF is by no means the main source of funds for federal or Canadian research related to climate change. Rather, it builds on existing initiatives and mechanisms wherever possible, and provides incremental funding in the following three key areas.

- Science, Impacts and Adaptation is receiving $15 million over three years to support targeted research to better understand climate processes and to assess the present and future physical, ecological, social, economic and health impacts of climate change on the regions of Canada, as well as options for adaptation to these impacts. Much of this research

involves collaboration between federal departments and universities, as well as involving industry and other stakeholders.

- Technology Early Action Measures is receiving $56 million over three years to promote early action by Canadians to reduce greenhouse gas emissions through cost-shared support for the development and deployment of emission-reducing technologies. Eligible projects demonstrate innovation and assist Canadian industry to reduce greenhouse gas emissions by 2004, support community-based implementation of reduction technologies, or transfer these technologies to other countries. By the end of 1999, TEAM had allocated approximately $44 million to 47 projects, while attracting more than $400 million from the private sector and all levels of government. The projects involve companies of all sizes and virtually every sector of the economy.
- Public Education and Outreach is receiving $10 million over three years to increase public awareness and understanding of climate change and encourage and assist individual Canadians to take action through the development of tools like the Climate Change Calculator (*see the box at right*).

3.1.2.3 Other Mechanisms

Other interdepartmental research mechanisms, although not specifically oriented to climate change issues, are also contributing to Canada's responses to the challenges of climate change.

- The **Climate Research Network**, created in 1994 by Environment Canada, engages the university and private sectors and coordinates their input with that of federal departments to provide the science needed to improve our climate models. Each of the Collaborative Research Groups in the network focusses on a particular element of the climate system.
- In 1995, the four federal "natural resources" departments — Agriculture and Agri-Food Canada (AAFC), Fisheries and Oceans Canada (DFO), Environment Canada, and NRCan — established an interdepartmental **Memorandum of Understanding on S&T for Sustainable Development (5NR MOU)**; they were joined by Health Canada in 1998. In 1999, the 5NR Working Group on Climate Change and Variability completed a review of its terms of reference and developed a work plan for the next three years. A new Working Group on Ecosystem Impacts of Climate/Atmospheric Change was also established. Activities of this working group are closely connected to other government activities and the CCAF.
- The NRCan-led **Program of Energy Research and Development (PERD)** supports and complements the energy R&D activities of 11 federal departments and agencies. The energy and climate change portion, funded at $5 million per year, studies greenhouse gas cycles and storage, capture and disposal of greenhouse gas, climate change prediction and detection, and the impact of climate change on Canada's energy sector. The current strategic directions include these same fields of study, but with an expected shift toward a future emphasis on mitigation technologies. PERD also supports technology R&D in five other areas leading to reduction of greenhouse gas emissions: hydrocarbons, transportation, buildings and communities, industry, and electricity generation. Overall, it is estimated that more than three quarters of PERD's resources address climate change issues. PERD's total budget is $58 million per year.

Taking S&T Home: The Climate Change Calculator

Most greenhouse gas emissions come from commercial and industrial activities, but 25 percent are generated by individual Canadians at home and on the road. The distribution of emissions among various household activities can be viewed at **http://www.ns.ec.gc.ca/images/icons/co2.gif**

With support from the Climate Change Action Fund and others, an interactive software tool has been developed to raise people's awareness of the greenhouse gases they produce through their daily activities. The Climate Change Calculator guides users through an assessment of such things as home heating and cooling, use of appliances, transportation, and recreation. It then estimates the amount of emissions the person's activities are generating and suggests actions to reduce them.

Look for the calculator at **http://www.climcalc.net/eng/about.htm**

Domestic Activities and Achievements Since Kyoto

Climate Change Action Fund — Technology Early Action Measures (CCAF-TEAM), a three-year program (1998–99 to 2000–01) with a steering committee co-chaired by Environment Canada, NRCan and Industry Canada, has contributed $46 million in seed money to leverage $367 million from industry, federal funding programs and other governments for projects that will help to reduce greenhouse gas emissions. Projects include the sustainable development of coal-bed methane in Alberta, Iogen's Waste to Ethanol Plant, Stuart Energy Systems' fleet and personal vehicle hydrogen refuellers, Hydro-Québec's Montréal 2000 Electric Vehicles Project, Toronto Renewable Energy Co-operative's Wind Energy Project, Orenda Aerospace's Gas Turbines for Bio-oil, Questor Industries' Oxygen from Air Separation Technology; the Heating, Refrigeration and Air Conditioning Institute of Canada's Advanced Integrated Mechanical Systems Project, Union Gas' work with coal-fired power utilities and heavy industry for co-firing with natural gas, and industrial waste heat for community heating systems. For further details, see **http://www.climatechange.gc.ca/english/html/fund/techno.html**

NRCan works in partnership with its clients to develop and deploy energy-efficient, alternative energy and advanced hydrocarbon technologies. Work with Canadian steel-making companies has resulted in improved process control and has reduced energy consumption and associated emissions. With NRCan's leadership, there is growing momentum for including community heating/energy systems in municipal plans, with plants that make use of industrial wood wastes and other biomass for heating.

NRCan's capacity to develop climate change mitigation technologies is proven, and growing. For example, NRCan has assisted Stuart Energy Systems, which has operations in Ontario, Quebec and British Columbia, to further develop its hydrogen refueller. The refueller is currently servicing B.C. Transit's three new hydrogen buses in Port Coquitlam, each of which is powered by Ballard fuel cells. Advanced computer modelling simulation and design tools are another key area of interest. RETScreen™, Hot 2000™, and EE4™ are examples of these new software tools. More information is available at **http://www.nrcan.gc.ca/es/etb**

(continued on page 20)

In addition, some departments have undertaken new initiatives related to climate change.

- NRCan's **Energy Technology Futures** project, begun in 1998, aims to develop a shared understanding of the potential range of energy technologies and systems that might exist in the period 2030–50, and how the relationship between economic growth and greenhouse gas emissions might be altered. This is currently the only climate change project looking beyond the Kyoto time frame of 2008–12.
- Health Canada's **Climate Change and Health Office**, also established in 1998, ensures that the potential impacts of climate change on human health are addressed, and proposes solutions to counter the effects of climate change. In collaboration with other federal departments and agencies and the Climate Change Secretariat, the Office works in four areas: detecting climate change-related health trends; developing tools to assess, analyse and predict impacts of climate change on health; providing information to the public on the health consequences of climate change; and developing policy and risk management tools to address climate change impacts on health.
- **Ecosystem Initiatives** — led by Environment Canada and involving other federal departments, provincial/territorial and municipal governments, universities and community organizations — include the examination of the impacts of climate change in the consideration of economic and social impacts on the long-term quality of ecosystems. The Great Lakes, the St. Lawrence River, British Columbia's Georgia Basin, the Atlantic coast, and northern rivers are among the ecosystems currently being studied.

3.1.3 International Approaches

Climate change is a global challenge that can be tackled only through international collaboration. Both the FCCC and the Kyoto Protocol commit parties to cooperate in climate research and systematic observations. Parties must also take climate change considerations into account, to the extent feasible, in their own social, economic and environmental policies and actions.

Canada is a major player in international science and policy frameworks. Key areas in which we have international commitments include the monitoring of networks to support climate change detection and attribution studies, improved understanding of the behaviour of greenhouse gas sources and sinks, and improved information on regional-scale vulnerabilities and impacts in order to formulate adaptation responses. For example, we have an international obligation for climate monitoring because of our size and location as a northern country.

Canada is an active member of the World Climate Program (WCP), founded in 1979. The WCP coordinates international climate activities, mainly with respect to atmospheric and oceanographic science, and helps address climate science questions in a global context. The World Climate Research Program (WCRP) is the research component of the WCP. It addresses the dynamic and physical aspects of the earth system, with the aim of determining how climate can be predicted and the extent of human influence. Federal departments contribute to WCRP scientific programs, such as the Global Energy and Water Cycle Experiment, and are involved in the Global Climate Observing System, which is directed at enhancing our capacity to observe the atmosphere and oceans. Our

membership in the WCP allows us to focus work on issues of particular interest to Canada, such as the Arctic.

The IPCC was established in 1988 by the World Meteorological Organization and the United Nations Environment Programme to provide regular assessments of the state of scientific, technical and socio-economic information about climate change. Canadians have made significant contributions to IPCC endeavours and will need to continue to do so if we are to retain our credibility in the international arena. In addition, Canada's international activities include participation in the UNESCO International Hydrology Program and the Boreal Ecosystem Study.

Reduction targets for greenhouse gas emissions will be achieved only through the development, adaptation and adoption of new technology. No nation is uniquely endowed with the capability to achieve this on its own; international cooperation and coordination of R&D are required if we are to be successful. Consequently, Canada is an active participant in the International Energy Agency (IEA), the IEA/OECD (Organisation for Economic Co-operation and Development) Climate Technology Initiative and the Greenhouse Gas R&D Program.

As a donor of international aid, Canada must inevitably deal with the consequences if developing countries do not (or are unable to) adapt successfully to climate change. Many of these countries lack the infrastructure, resources and technology needed to adapt to the climate change problems they will face. It is in Canada's interest to assist them in the task of adaptation and the enhancement of their adaptive capacity. The Canadian International Development Agency (CIDA) supports the development of science and technical capacity in partner countries, and the transfer of appropriate technology for mitigation and adaptation.

3.1.4 Achievements Since Kyoto

Canada's actions since the formulation of the Kyoto Protocol in December 1997 have been prompt and sustained. In February 1998, the Climate Change Secretariat, the focal point for managing climate change S&T for the federal government, and the CCAF were established. By April 1998, ministers of environment and energy had agreed on the process for developing the NIS for reaching Canada's Kyoto targets, with issue tables being established a short time later. NRCan's Energy Technology Futures program and Health Canada's Climate Change and Health Office were established by the spring of 1998.

The creation of the Climate Change Secretariat and the development of business plans for its four components established a management framework, which the Auditor General had said would be essential to ensuring the maximization of Canada's investment in climate change-related activities. The Secretariat provides the focal point and the mechanisms for ensuring the coordination of activities and that duplication of effort is minimized. The work of the issues tables in support of the development of the NIS will further help in bringing together all parts of Canada's climate change response, giving federal and provincial/territorial leaders a solid foundation for setting future policy directions.

The CCAF-SIA component, intended to form the basis for a national long-term plan to be delivered by the federal and provincial/territorial governments, university researchers, and the private sector, held national workshops between October 1998 and

Domestic Activities and Achievements Since Kyoto *(continued from page 19)*

In 1999, the **National Research Council Canada (NRC)** established the Centre for Cleaner Manufacturing in its Institute for Chemical Process and Environmental Technology. One of the Centre's programs aims to develop advanced airshed modelling of urban smog to help evaluate the impact of fuel substitution mitigation technologies. Working with the Program of Energy Research and Development (PERD) and industry partners, NRC is helping develop and deploy low-energy membrane separation to reduce carbon dioxide emissions, enzyme substitutes to reduce chloro-organic waste from pulping operations, and replacements for chlorofluorocarbons.

International Activities and Achievements: Selected Highlights

CCAF-TEAM is involved with the private sector in transferring natural gas fuel-injection technology to Romania and other countries; helping demonstrate a small hydro turbine control system in China that reduces greenhouse gas emissions; and identifying agricultural products suitable for commercial drying using solar absorber technology instead of fossil fuels.

NRCan's Super E Housing program provides member companies with the tools and technical capability to export technologies that are Economical, Energy Efficient, and Environmentally friendly. A number of agreements have recently been concluded in Japan.

The **Canadian International Development Agency (CIDA)** continues to provide support to developing countries and countries in transition to strengthen their S&T capacity in climate change, through partnerships and the transfer of appropriate climate-friendly technology. For example, the Southern African Development Community Energy Efficiency project provides technical assistance to governments and industry associations in the region, allowing them to decrease their energy use in industrial processes, particularly in the mineral sector. In conjunction with the **Department of Foreign Affairs and International Trade (DFAIT)**, CIDA facilitates the participation of Canadian firms in the Kyoto Protocol's Clean Development Mechanism and the transfer of leading-edge technology.

Canada supports the development of policy in developing countries and economies in transition, involving multiple stakeholders from scientific organizations and institutions, the private sector, non-governmental organizations, and others. CIDA and **Environment Canada** are working with Ukraine to develop a national implementation strategy for climate change. CIDA and DFAIT have also contributed to workshops to help the Senegalese government establish its domestic position and policy through a multi-stakeholder process.

June 1999 to articulate knowledge gaps. The workshops were followed by calls for proposals. By late 1999, with four processes complete, 44 climate science projects ($4.5 million) and 51 impacts and adaptation projects ($3.6 million) had been approved. Each of these projects involves at least one, and usually several, partners and has obtained 50 percent of the necessary resources from other sources.

Science projects are primarily focussing on climate model improvements, greenhouse gas sources and sinks, climate monitoring, the Arctic, and support to Canadian scientists involved in the IPCC. Collaborative impacts and adaptation research projects have been completed in the Mackenzie Basin (western Arctic), the Palliser Triangle of the Prairies, and the Great Lakes–St. Lawrence Basin; these areas were selected to build on the existing base of research and data. Current research activities include a range of individual research projects in many regions and sectors of Canada, as well as case studies and two larger collaborative projects: the Georgia Basin and the Toronto–Niagara Region Studies.

Projects carried out under the CCAF-TEAM and other Canadian programs (*see text boxes*) aim to reduce greenhouse gas emissions.

Internationally, Canada is making significant contributions and playing a leadership role in the IPCC. Canadian leadership is recognized in impacts and adaptation research. Some 30 Canadian scientists are involved in the next IPCC assessment, to be completed in 2001, and a Canadian researcher is a convening lead author for the adaptation chapter. The Canadian coupled atmosphere-ocean climate model is recognized as one of the top models in the world, and is used by the United States and other countries for their own climate impact studies. Canadian scientists have also been involved in preparing a special report, requested by the negotiators who are refining the Kyoto Protocol. This report, on the complex issues surrounding carbon sinks and sources associated with land use, land use changes, and forestry; has drawn on the research and expertise of federal scientists at NRCan, AAFC and Environment Canada.

3.1.5 Future Challenges

Managing for climate change in Canada is a long-term challenge that must be addressed now. Two main responses are required: reducing emissions and managing sinks, and adapting to the impacts of change. Both responses will involve significant levels of investment; research is needed now to ensure that it is money well spent. Government resources and legislative authority (through standards and regulation) will also be required to implement both responses.

The National Climate Change Process has shown the value of federal leadership in planning and coordinating a national approach to mitigation (emission reductions). With the growing need to make adaptative decisions, a structure to address adaptation policies and mechanisms must also be developed. A research coordination mechanism is required to develop and manage a program to systematically address gaps through a consistent methodology that allows national-scale assessments of our vulnerability, and the sharing of knowledge. Such a network would facilitate the evaluation of progress as part of the NIS. A critical element of any impacts and adaptation program will be a study of the realistic options for governing the process of adaptation, as responsibilities lie at many levels.

Beyond the technical, infrastructural and attitudinal challenges to meeting the Kyoto greenhouse gas reduction target is the need to set new targets and develop even more advanced technologies that will lead to the stabilization of atmospheric greenhouse gas concentrations and co-beneficial improvements in other air issues such as urban smog and acid rain. Our ability to take advantage of greenhouse gas sources and sinks is also limited by an imperfect understanding of their potential and their behaviour under a changing climate. For example, there are gaps in our knowledge in bio-geochemical processes (required for estimating sink potential in forests, agriculture and wetlands). Better climate modelling will allow us not only to establish appropriate, post-Kyoto emission reduction targets, but also to focus adaptation strategies on those sectors and regions that will be most severely affected by climatic change.

Finally, we need to ensure that the highly qualified people capable of carrying out all these necessary policy, research, design, regulatory and risk management activities will be available and will have the intellectual and physical tools that they need to contribute to understanding and addressing global climate change.

3.2 Federal Support for Industrial R&D

3.2.1 Introduction

Sustainable economic growth and job creation are critical to maintaining and enhancing Canadians' quality of life. They are also dependent upon sustained industrial development. In turn, sustained industrial development requires companies to be competitive in the global marketplace in order to bring economic benefits to Canada. It has long been understood that to be globally competitive, companies must be innovative, both in terms of how they do business, and in terms of the products and services they offer. The latter, in particular, requires investments by the private sector in leading-edge R&D. However, R&D investments are by their very nature high-risk investments, and companies seek to mitigate the risks involved. Recognizing this fact, governments often provide mechanisms to minimize the risks to companies investing in R&D and to attract corporate investments that will lead to employment and economic benefits. Indeed, risk-reducing mechanisms have become so institutionalized that globally active companies will often base new R&D-related investment decisions on the risk-minimizing frameworks that various governments offer.

At the same time, much of the direct growth in the knowledge-based economy is based on developments made by domestic SMEs. For these companies, success in high-risk R&D investments is essential to their very survival, let alone their ability to grow. Consequently, governments establish specific mechanisms to assist research-active SMEs.

In addition, governments must act to ensure equitable economic development opportunities to all parts of the nation. As a result, vehicles are developed to assist the various regions of the country to attract and retain industrial investments that will lead to sustained jobs and regional economic development.

And lastly, to ensure that companies have the skilled work force necessary to capitalize on their R&D investments, governments provide assistance in making skilled workers available.

"There is…powerful evidence that there are huge positive spillovers from research and development... left to themselves, private firms will spend too little, because they cannot capture all the benefits that flow from these activities."

— Mr. Lester C. Thurow
Atlantic Monthly

Canadian Science Centre for Human and Animal Health, Winnipeg

In June 1999, Health Canada and Agriculture and Agri-Food Canada (AAFC) opened Canada's new world-class federal laboratories complex for human and animal health in Winnipeg. The $172-million state-of-the-art complex, equipped with the world's best technology and jointly operated by Health Canada and the Canadian Food Inspection Agency (CFIA), incorporates laboratories classified at Levels 2 and 3, and houses Canada's first Level 4 biocontainment laboratories.

The new centre will improve Canada's infectious disease and public health surveillance and strengthen our science capacity, to protect Canadians from emerging and re-emerging infectious disease. It will reinforce Canada's established reputation for world-class laboratory science and create an opportunity to become an international centre of expertise for specific human and animal diseases.

The Winnipeg complex will stimulate further collaborative surveillance, research and training. It will also provide Canadians with a home base from which to develop advanced technology for marketing to both Canadians and international customers.

Take a virtual tour of the new complex at **http://www.hc-sc.gc.ca/hpb/lcdc/fedlab/**

Consequently, although it is private enterprise that creates jobs and wealth, government has a major influence on the private sector's ability and willingness to undertake Canadian-based R&D activities that will enable it to remain competitive in the global marketplace. The government is also a significant partner in ensuring that Canadian companies have the tools necessary to succeed in the future.

The federal government's role in ensuring the success of Canadian research-active firms takes many forms: from participation in collaborative research activities, to the sharing of risk in leading-edge areas of industrial R&D, to the creation of a financial climate that attracts R&D-related investments in Canada, to support for the development of a highly skilled work force that can contribute to private sector growth.

3.2.2 Risk-Sharing Mechanisms

High-risk leading-edge R&D is critical in today's economic climate. This applies equally to established industrial sectors such as those in the resource sectors — which must find ways to create added value in their products — and to the newer industries — which are fuelling the global, knowledge-based economy. Recognizing the high levels of the investments required, as well as the high-risk factors associated with such leading-edge industrial R&D, the federal government has established mechanisms that help to mitigate these risks. Many of these mechanisms are based on collaboration between the various research-performing and -funding players in Canada's research enterprise. Although all of these mechanisms result in a sharing of the R&D risks, they also result in a net benefit, sometimes directly to the government through a repayment of the federal investment, but always through the economic growth and job creation that results from the ability of Canadian companies to compete effectively on the world scene.

3.2.2.1 Partnerships with Federal Labs

The federal government operates a network of research laboratories which collectively have a wealth of knowledge, expertise and capability of considerable value to the Canadian private sector. While the primary mission of most of these laboratories is to undertake research that specifically supports the mandates of federal departments and agencies, others have a broader role of conducting research whose application would be of value to a variety of sectors in the Canadian environment. In all cases, however, the aim is to transfer technologies developed in-house to Canadian companies with the capacity to develop commercial applications that benefit the Canadian economy as a whole.

In addition to undertaking research on their own behalf that may have broader applicability, many laboratories also undertake collaborative research with Canadian companies. In this way, Canadian firms are able to have access to state-of-the-art facilities that would otherwise be denied to them. Access to these facilities also aids in advancing the development of new technologies that have commercial applicability.

Given the often brutally competitive nature of the marketplace, the R&D focus of firms has tended to become increasingly narrow and short-term, with horizons of six months to two years being the norm. Hence, federal laboratories now often spend substantial time and effort in collaboration with firms, both in terms of helping with technology development, and in assisting firms to move further into the regime of real risk analysis.

Indeed, if there has been one change that has altered the landscape over the past decade in terms of the relationships between the federal government and the private sector, it is the significantly increased degree of R&D partnerships and collaboration that has evolved in all stages of the research spectrum, and in all industrial sectors.

While it is not possible to describe all of the federal government laboratories that support and offer collaborative opportunities to Canadian firms for industrially relevant R&D, the following examples provide a general idea.

The **National Research Council Canada (NRC)** operates the federal government's broadest-based network of research laboratories. From St. John's to Victoria, the NRC's 16 research institutes conduct strategic, multidisciplinary research with partners in industries and sectors that are key to Canada's future economic development. The NRC has focussed its technology research program on areas of strategic importance to Canada's future economic development — areas in which the NRC has strength and competence. By clustering 11 of its institutes into three technology groups — biotechnologies, information and communications technologies, and manufacturing technologies — the NRC is able to take an integrated and flexible approach to supporting multidisciplinary research programs, while the concentration of industry-specific expertise allows for better technology foresight and greater access to international S&T. In addition, through the Canadian Institute for Scientific and Technical Information, the NRC is not only Canada's premier repository of international scientific, technical and medical information, but also a world leader in providing this type of information.

Through its policies and programs, the NRC is helping to move NRC-developed technologies into the economy and promoting the establishment and growth of innovative, knowledge-based businesses. These changes in culture, approach and procedure at the NRC have resulted in improvements in technology transfer. Where no Canadian receptor exists, the NRC encourages its researchers to spin off their own companies in order to commercialize their technologies. In 1998–99, NRC researchers spun off or created nine new firms, bringing the four-year total to 27 new spin-off companies. A spin-off moves new knowledge into the marketplace and enhances the economy's capacity to receive technology. The NRC has also developed an entrepreneurship program that enables its employees, through secondments with industry partners, to provide scientific or technical support to industrial firms developing NRC technologies for the marketplace. These employees develop an in-depth understanding of the industrial work environment and how decisions regarding R&D activities are made in that particular industry. In turn, industry employees seconded to NRC get a closer look at the role that the NRC can play in supporting technology development and commercialization.

Industry Canada's **Communications Research Centre Canada (CRC)** has been committed to applied and basic research in communications and related technologies since the late 1940s. A leader in the development of enabling technologies, and the transfer of these technologies to the private sector over the past 50 years, the CRC's many scientific and engineering milestones have contributed to Canada's position as a world leader in wireless and satellite communications and broadcast technologies. An institute of Industry Canada since 1993, the CRC has maintained its tradition of excellence in managing technical issues concerning the radio spectrum, the deployment of wireless communications and broadcast services, and the development of new technologies and

In 1998–99, researchers from six NRC institutes spun off nine new firms, bringing the four-year total of spin-offs to 27.

Spin-off Companies in 1998–99

- **AmikaNow!** (Institute for Information Technology)
- **Crechem Technologies Inc.** (Institute for Chemical Process and Environmental Technology)
- **IatroQuest** (Institute for Biological Sciences)
- **Iridian Spectral Technologies Ltd.** (Institute for Microstructural Sciences)
- **JenEL TVD** (Institute for Chemical Process and Environmental Technology)
- **MRV Systems** (Institute for Biodiagnostics)
- **Novo Science** (Biotechnology Research Institute)
- **ULEP** (Institute for Chemical Process and Environmental Technology)
- **Vitesse (Re-Skilling) Canada Inc.**

Federal Government Research Facilities

Collectively, AAFC, the Canadian Space Agency (CSA), Environment Canada, Fisheries and Oceans Canada (DFO), Health Canada, Industry Canada, the Department of National Defence (DND), NRC, NRCan and Transport Canada operate more than 100 research facilities in communities across the country. Most of these facilities undertake R&D work in cooperation and collaboration with private sector partners.

For a complete listing and subsequent descriptions of federal research facilities, please visit **http://strategis.gc.ca/sc_innov/tech/engdoc/2a.html**

knowledge for exploitation by Canadian industry. The CRC is the federal government's main research centre for communications technology R&D.

The **Canada Centre for Remote Sensing (CCRS)**, part of the Earth Sciences Sector of NRCan, was founded in 1971 to advance satellite-based remote sensing technology and applications; to facilitate the acquisition, processing, archiving and distribution of remote sensing data; and to support the development of a viable remote sensing industry in Canada. That industry now has more than 200 companies supplying a wide range of related value-added products and services, including half of the world's ground receiving stations and a quarter of all image analysis systems. Much of the S&T activity carried out at CCRS under internally generated projects is carried out in cooperation with industry, permitting the private sector to become involved with CCRS' S&T activities from their inception and to take advantage of technology transfer opportunities. For example, CCRS' responsibilities in receiving and archiving radar imagery from the RADARSAT satellite, and its close working relationship with the Canadian Space Agency (CSA), enable the development of RADARSAT applications with Canadian industry. Through the **Remote Sensing Data Development Program**, which provides approximately $300 000 annually in R&D funding, CCRS stimulates the evaluation and demonstration by industry of the potential of satellite remote sensing data, and the related development of demonstration products leading to operational use.

Defence R&D Branch (DRDB) of the Department of National Defence (DND) responds to defence S&T requirements and contributes to Canada's innovation system through a national network of **Defence Research Establishments (DREs)**, where staff provide leading-edge expertise in a number of defence technology areas. Last year, the department invested $170 million in R&D programs. The DRDB in turn used $90 million for the participation of Canadian industry and universities in the delivery of the defence R&D program. Working with academia provides a window on new technologies and training of the next generation of defence scientists. Partnering with the private sector maintains a Canadian defence S&T capability and facilitates transfer of technology from DREs to Canadian industry. Collaboration with allies in defence R&D gains access to international leading-edge defence technologies and helps to identify potential market opportunities for the Canadian private sector.

Mention should also be made of the three not-for-profit **forest products research institutes**: Forintek Canada Corp. (Forintek), the Forest Engineering Research Institutes of Canada (FERIC), and the Pulp and Paper Research Institutes of Canada (Paprican). These institutes have been used as a model of a different approach to public-private and federal-provincial cooperation, since 80 percent of the institutes' funding comes from private sector partners, and the remainder from contributions by the federal and provincial governments and revenue generated through research contracts. This public-private partnership approach to financing R&D benefits both government and corporate members. Companies achieve economies of scale in their R&D, while supporting a more focussed research program and greatly shortening the innovation life cycle, and SMEs gain access to new technologies. At the same time, the work of the institutes addresses specific public policy goals in areas such as environmental life cycle analysis, sustainable forest management, international market access, and building codes and public safety.

3.2.2.2 Industrial R&D Support Programs

In addition to access to the facilities available at federal laboratories, or to the results of the research conducted by these institutions, the government offers a number of more direct mechanisms for providing support to R&D-active firms in Canada. These programs offer financial support and access to business expertise and advice. Some programs are targeted to specific industrial sectors, while others are more encompassing in their scope. The following provides examples of some of the government's vehicles for supporting industrial R&D. Further details on the full scope of federal support mechanisms available can be found on Industry Canada's *Strategis* Web site at **http://strategis.gc.ca/SSG/te00954e.html**

One of the broadest-based programs offered by the federal government is the NRC's **Industrial Research Assistance Program (IRAP)**. This technology support program provides a nationwide network of more than 260 Industrial Technology Advisors — scientists and engineers chosen for their expertise and business experience. Using the IRAP network and program, SMEs (i.e. firms with 500 or fewer employees) have access to high-calibre technical assistance, resources and facilities, and financial, marketing or management services that would otherwise be out of their reach.

Other federal programs are directed toward industrial sectors that have been identified as high-growth priority areas for Canada's future economic development. These include the following.

- Through **Technology Partnerships Canada (TPC)**, a technology investment fund, the government provides repayable contributions toward research conducted in Canadian companies in areas of strategic economic importance. By partnering with research-active companies, TPC is encouraging Canadian private sector investment, and helping to maintain and grow the technology base and technological capabilities of Canadian industry. Having shared in the risk, the government also shares in the benefits. These benefits are both direct and indirect in nature: a repayment of the government's investment following successful commercialization of the research results, and economic growth resulting from a stronger industrial base.
- While not strictly an industrial R&D support program, NSERC's **Research Partnerships Program** comprises a number of grant types that have the common purpose of promoting closer collaboration between the university research community and other sectors, most notably Canadian industry. By sharing the risk with NSERC, industry can support high-quality university research and apply the results to benefit the Canadian economy and society. So far, more than 1000 companies in partnerships with NSERC have sponsored university research projects under this program. For every dollar NSERC invests in a project, an additional dollar and 70 cents is contributed by industry and others. Total private sector contributions to NSERC-supported projects over the past 10 years have topped $600 million.
- In the same vein, the **Networks of Centres of Excellence (NCE) program**, administered jointly by the three federal granting councils and Industry Canada, provides a mechanism for bringing together researchers from universities, the private sector and government to address research issues of common concern that have the potential for economic benefit to Canada.

Federal departments and agencies involved with IRAP include the following:

- the NRC and other federal science-based departments and agencies;
- Canada Customs and Revenue Agency (CCRA) (formerly Revenue Canada) — Scientific Research and Experimental Development tax credit program;
- NSERC — to develop linkages between universities and the IRAP client firms;
- Human Resources Development Canada (HRDC) and the Youth Employment Strategy;
- Business Development Bank of Canada — to provide pre-commercialization assistance; and
- DFAIT — through its S&T Counsellor Network, for access to offshore technology.

Technology Partnerships Canada — Priority Sectors

- Environmental Technologies
- Enabling Technologies (advanced manufacturing processing technologies, advanced materials processes and applications, applications of biotechnology, and applications of selected information technologies)
- Aerospace and Defence.

Networks of Centres of Excellence — 1999

- Canadian Arthritis Network
- Canadian Bacterial Diseases Network
- Canadian Genetic Diseases Network
- Canadian Institute for Photonic Innovations
- Canadian Institute for Telecommunications Research
- Geomatics for Informed Decisions
- Health Evidence Application and Linkage
- Institute for Robotics and Intelligent Systems
- Intelligent Sensing for Innovative Structures
- Mathematics of Information Technology and Complex Systems
- Mechanical Wood-Pulps Network
- Micronet-Microelectronic Devices, Circuits and Systems
- Protein Engineering
- Sustainable Forest Management
- TeleLearning.

Scientists at NRCan's Canada Centre for Remote Sensing Collaborate with the Innu First Nation

For the past two years, the Canada Centre for Remote Sensing (CCRS) has worked with the Innu Nation to develop baseline ecological surveys of lands important to the Innu way of life. Through CCRS's Local Environment Applications Program, Innu elders and CCRS scientists have pursued ways to incorporate Innu knowledge and perspectives into science-based research, including ethical and intellectual property issues. In 1999, field work in the forest and wetlands around Sheshatshui in Labrador were completed using RADARSAT and airborne hyper-spectral imager data. The Innu leadership has asked for meetings in 2001 to determine follow-up work primarily related to hydro development in the Lower Churchill River.

[NRC's Biotechnology Research Institute (BRI) in Montréal] "... is a unique space for any start-up biotechnology company. They offer a small company the opportunity to have facilities at disposal that put you on the same footing as the largest pharmaceutical companies out there. They make available the infrastructure and support that small companies, in other places, probably couldn't dream of at a reasonable price."

— Mr. Lloyd Degal
President and CEO
Caprion Pharmaceuticals

Recognizing that there is often a need to provide sector-specific support, either to help grow newly emerging industrial sectors or to assist "traditional" industries in coping with the changing global environment, the federal government has instituted programs targeted at specific industrial sectors, including the following.

- AAFC's **Matching Investment Initiative (MII)**, created as a pilot project in 1994–95, has proven to be an effective means for increasing overall investment in agri-food research. In 1998–99, with $28.5 million in AAFC funding available for matching, the MII was fully subscribed by industry. In fact, the private sector invested $31.9 million in 924 collaborative projects with AAFC and the CFIA.
- NRCan's **Industry Energy Research and Development program** increases the efficiency of energy use by supporting the development and commercialization of innovative products, processes and systems by the Canadian private sector. It supports work in all parts of the private sector, including the manufacturing and process industries, the resource industries, the transportation industry, the renewable energy industry, and the building industry. While primarily concerned with the efficiency of energy use, the program also considers other benefits to Canada such as reduced greenhouse gas emissions, other environmental benefits, job creation, investment, improved productivity, and new market opportunities for Canadian business.

3.2.3 Regional Development/Clusters

It is increasingly recognized that innovation and industrial growth is a local phenomenon, driven in communities by clusters of innovative, R&D-active firms and local entrepreneurs. Community-based technology clusters, in which innovative, technology-intensive firms working in related fields co-locate, interact, compete and grow in a dynamic, supportive environment are critical drivers of research, economic growth and international competitiveness.

Many of the cluster areas in Canada have developed around existing federal laboratories and research institutions. The presence of these laboratories, such as one or more of NRC's 16 research institutes or AAFC's 18 research centres, has been the impetus for industry sector cluster development in a variety of regions. For example, cluster development has occurred in:

- information technologies and telecommunications in Ottawa;
- agricultural biotechnologies in Saskatoon; and
- pharmaceutical biotechnologies in Montréal.

Established to promote regional economic growth in the regions of the country, the federal regional development agencies — Canada Economic Development for Quebec Regions, Western Economic Diversification Canada, and the Atlantic Canada Opportunities Agency — have identified innovation as priority themes for their activities. Through their programs targeted at business development and job creation, these agencies provide various forms of assistance to research-active firms in Quebec, the four western provinces, and Atlantic Canada, respectively. By investing in innovative companies in their regions, these agencies have also played a major role in fostering the development of regional R&D clusters.

3.2.4 Fiscal Frameworks: Provision of a World-Class R&D Tax Credit Program

One of the major issues facing firms conducting industrial research and development is the R&D tax credit regime in the country where the research is performed. This consideration has an impact on whether or not a firm will conduct R&D in a specific country and if so, how much. Recognizing this, the federal government, through the Canada Customs and Revenue Agency (formerly Revenue Canada), operates the Scientific Research and Experimental Development (SRED) tax credit program. It offers individuals, corporations and partnerships a tax deduction of up to 100 percent of qualified current scientific research and experimental development expenditures and eligible capital expenditures. The program allows eligible firms to offset tax owing; individuals and SMEs may qualify for a cash refund of tax credits. This cash refund of 35 percent of total eligible R&D expenditures is one of the strongest incentives for firms to perform R&D in Canada.

This program has long been recognized as one of the most generous R&D tax credit programs anywhere. On an annual basis, 11 000 Canadian firms, mostly SMEs, claim $1.4 billion in SRED tax credits from this program. As well, these tax credits can be augmented by a number of provincial tax credit programs. When compared with the $9.4 billion spent on R&D by the private sector last year, this program can be seen as a significant facilitator of R&D in Canada.

3.2.5 Development, Retention and Attraction of Highly Qualified and Skilled Personnel

One of the most pressing challenges facing firms in the fast-paced, knowledge-based economy is a shortage of highly qualified personnel.

The granting councils, in particular NSERC, offer a number of programs that serve to place undergraduate and graduate students, as well as post-doctoral research fellows, in the private sector. Through these programs, students and research fellows are given exposure to industrial research opportunities. At the same time, firms are able to access research expertise that they may otherwise not be able to afford.

In terms of the government research environment, the **Visiting Fellowships in Canadian Government Laboratories program**, administered by NSERC on behalf of various science-based departments and agencies provides promising young scientists and engineers with the opportunity to work with research groups or leaders in Canadian government laboratories and research institutions.

A more specific, but still broad-based program is the **NRC-NSERC Research Partnership Program**, which offers graduate students and post-doctoral fellows an opportunity to work at NRC's world-class facilities. Under this program, researchers from universities, NRC institutes and private sector partners collaborate in joint research.

On a sectoral level, the Earth Sciences Sector (ESS) of NRCan has instituted the **Science and Technology Exchange Program (STEP)**. A professional development program, STEP provides opportunities for external partners to exchange expertise, build partnerships, and share operating costs for mutually beneficial projects in earth sciences R&D. The program is based on work exchanges and research partnerships that will broaden the skill sets and experience of participating staff and organizations.

"All in all, O-Vitesse has been very successful in giving us an opportunity to fine-tune employees for positions at Mitel."

— Mr. Geoff Smith
Vice-President
Product Development and Support
Mitel Canada

Sometimes, the challenge is not a lack of experience, but rather a shortage of specialists in a particular scientific field. **Vitesse (Re-Skilling) Canada Inc.** is a non-profit organization that brings colleges and universities together with private sector companies to address critical shortages of skilled workers in high technology. Students with backgrounds in science or engineering are enrolled in a 16-month program of tailored instruction and on-the-job experience that gives them the particular skills required by the companies that select and sponsor them. To date, all Vitesse graduates have been placed in sponsoring companies.

Vitesse is poised to bring the collaborative and productive model developed in Ottawa (O-Vitesse: Ottawa-Carleton Venture in Training Engineers and Scientists in Software Engineering) to regions across Canada, and is determined to expand into other sectors such as bio-informatics. The goal is to give bright people the right training for employment in underserved sectors of our knowledge-based economy. The success of this model has been recognized by the Ontario government, which has provided $1.5 million to expand the program across the province.

3.2.6 Conclusion

The federal government plays a key role in helping Canada meet the challenges of the emerging, knowledge-based economy. Federal activities, inherent strength in S&T, and support for industrial R&D, help provide strategic assistance to many Canadian firms. These firms can then look beyond their current horizons of primarily near-term or already-available technology choices, and gain a more future perspective. Through partnerships and collaboration with the private sector, universities, and partners in other levels of government in communities across Canada, the federal government utilizes its core competencies, strengths in S&T, networking abilities and infrastructure support in innovative ways to help firms, communities and individuals realize the potential rewards the 21st century has to offer.

4.0 Emerging S&T Challenges for the Federal Government

THIS chapter is not intended to provide a comprehensive listing of all of the emerging S&T-related policy challenges facing the government. Rather, it provides brief descriptions of some of those emerging challenges that are considered to be of particular interest at this time, and for which collaborative action — often in the form of partnerships with other stakeholders — is required on the part of the federal government. Although some issues are management challenges for the government itself, others could have broad-ranging impacts on the general public.

4.1 Renewal and Retention of Scientific and Technical Competence in the Federal Government

Demographic analyses have indicated that close to 5000 federal government S&T professionals will become eligible for retirement over the next five years. This represents an unprecedented potential loss of unique skills, experience, knowledge and flexibility to adjust to new program directions, which would represent a threat to program integrity. A related problem, stemming from the same cause, is to develop and maintain an effective scientific management capability. The issue was noted by the Auditor General in his April 1999 report, which stated that the six major science departments alone need to recruit between 2500 and 3300 S&T professionals within the next five years to replace those who will retire or leave for other reasons.

To address the first of these problems — maintaining skills, expertise, knowledge and flexibility — an interdepartmental working group is examining possible strategies to assist science-based departments and agencies in undertaking anticipatory recruitment prior to the departure of senior scientists and technologists. These strategies would enable the training and mentoring of new recruits, to ensure that critical functions and knowledge are maintained after senior S&T professionals leave. They could also help science-based departments and agencies to hire people with new skills, helping to ensure a smooth transition to new ways of delivering S&T programs and to new program directions. These activities would lead to a new cadre of young S&T recruits to boost the younger-age end of the demographic curve. A further outcome would be an S&T work force that is better equipped to address the federal government's current and future S&T priorities.

A competency profile for S&T managers and an analysis of the training and development courses being used by science-based departments and agencies and central agencies in relation to these competencies have been completed. It is anticipated that within the coming year, a road map indicating training programs will be posted on an S&T Web site, which would assist entry- and mid-level science managers in identifying the management training and development opportunities available to them. It is hoped that the ready availability of this type of information would serve to demonstrate that science management is a viable career option for federal S&T employees. It would also ensure that customized training for all levels of science managers, including

"pre-management" training for employees expressing an interest in management, is made available.

4.2 Globalization of Research and Canada's Involvement in International S&T Activities

Approximately 4 percent of global scientific research is undertaken in Canada, and some 65 percent of Canada's new technology comes from abroad. Consequently, there is a need for Canada to be able to identify, understand and access cutting-edge technologies and new knowledge created in other parts of the world. This is critical if Canadian firms are to remain competitive in the knowledge-intensive, global marketplace, and if the best and most recent scientific knowledge is to be used to address domestic and international issues of concern to the Canadian public.

Although scientific research has always been inherently international in nature, the linkages that made this possible were often informal and based on personal contacts between scientists. However, cooperative and collaborative international S&T activities are increasingly being undertaken under the aegis of formal mechanisms in a wide range of areas. These include global climate change, natural disaster reduction, sustainable development in developed and developing nations, and new technology development. There is a sense that, in order to obtain maximum international leverage from our own S&T investments, Canada must develop a coherent international strategy. This would enable Canada to harvest international activities that complement domestic S&T priority thrusts; participate in the research activities necessary for the resolution of global issues; and be an effective player in global S&T networks. It would also provide access for Canadian researchers to large-scale research facilities and major international S&T programs.

Recognizing the importance of international S&T as a component of Canada's S&T enterprise, the ACST has recently formed an Expert Panel on Canada's Role in International Science and Technology, to advise the government on options for maximizing the social and economic benefits to Canada resulting from our involvement in international S&T. Further information on the Expert Panel's mandate, membership and work plan can be found on the ACST Panel's Web site **(http://acst-ccst.gc.ca/acst/intel/home_e.html)**.

4.3 Information Infrastructure Protection

New information technologies are revolutionizing the ways in which we conduct business, manage activities, and communicate with each other. Although these technologies improve efficiency and productivity, they also expose new vulnerabilities in the infrastructure services upon which our society depends, and which we increasingly take for granted (e.g. telecommunications, energy, banking and finance, water systems, government operations, and emergency services). During the past few years, several high-profile hacker incidents have raised concerns about the state, quality and integrity of networked computer systems. Commercial and government information networks must continually contend with computer viruses and other intrusions. In addition, there

is a demonstrated potential for well-organized actors — ranging from other nations to individual "cyber-terrorists" — to exploit weaknesses in the information infrastructure.

Information-intensive nations, including Australia, France, the United Kingdom and the United States, have set up coordination centres to act as focal points for network security issues. In Canada, several key stakeholders have been brought together to examine information protection under the guidance of the Privy Council Office, with the goal of developing a federal policy and action plan to deal with infrastructure protection. To address this initiative, collaborations have been formed to conduct research into technologies and techniques that contribute to information security.

The Communications Security Establishment is the lead government agency in protecting the information infrastructure. The NRC and DND are assessing the effective use of commercial technology, including the security of distributed systems and network infrastructures. The CRC is contributing to this effort by investigating practical issues associated with securely managing networks that are under threat or under network-based attacks. Université Laval is also helping to develop methods of detecting malicious embedded code in commercial software objects to ensure that these objects do not include "features" that could compromise the network. Through its granting programs, NSERC helps fund research into the security of networks and data protection at various universities.

The growing reliance on secure electronic transactions requires an understanding of the dynamic interactions of complex systems. New techniques and tools are required to prevent hostile activity, detect network intrusions and recover from attacks. Since information infrastructures are deeply intertwined, the threat of "soft" attacks in cyberspace on information networks needs to be addressed through expanded partnerships and a more concerted research effort from the commercial sector and all levels of government. More proactive information protection measures will not only strengthen the ability to protect information, but will also assure privacy and promote Web-based commerce.

4.4 Managing Ecosystems for Ecological Integrity

Protected areas everywhere are under threat from many human-made stresses impinging on wildlife populations that need diverse habitats for their long-term survival. Affected wildlife include wide-ranging species such as the grizzly bear to migratory species such as the Monarch butterfly. Other stresses are global in scale and impact, such as the long-range transport of acid precipitation, climate change, and the transport of exotic species in the ballast water of the world's shipping fleet. These and other environmental stresses share at least one major attribute: they are not limited by jurisdictional boundaries.

Consequently, effective ecosystem protection requires partnerships among all concerned and implicated stakeholders — from local and national governments to international organizations, from family-based primary producers to multinational corporations, and from academia to environmental non-governmental organizations. The long-term survival of most species and ecosystems also requires large and interacting populations to ensure diverse genetics, health and reproductive success, and large areas

to provide habitats and nourishment. This further supports the need for partnerships to protect and manage biodiversity.

The common management goals for sustaining natural ecosystems are to restore and maintain lands and waters so that ecological structures and functions are unimpaired by anthropogenic stresses, and biodiversity and supporting processes are likely to persist. This concept, known as ecological integrity, depends on an S&T toolkit that integrates and brings to bear a vast range of disciplines and activities.

The goals of ecological integrity can apply to several classes of protected areas that fall within the responsibility of a variety of federal departments and agencies, including Parks Canada, Environment Canada, DFO, DND, the CFIA and Indian and Northern Affairs Canada. Non-federal partners include regional ecosystem planning and management authorities in provinces and territories, community and corporate stakeholders in regional resource development, and sustainable development and biodiversity conservation interests worldwide.

Under the *National Parks Act*, ecological integrity is the first priority for park management. Consequently, Parks Canada is developing ecological integrity goals for each park, and applies ecosystem restoration, management and protection techniques in support of those goals. A set of indicators has also been defined to form the core of park monitoring. The indicators range from growth rates, reproduction rates and population dynamics of indicator species, to species diversity and nutrient budgets of natural communities, to climate and habitat fragmentation across landscapes.

Parks Canada calls upon a wide range of stakeholders to cooperate in the application of ecological integrity sciences. Many parks are members of national applied science partnerships, such as model forests, biosphere reserves, and the Environment Canada-led Ecological Monitoring and Assessment Network, while others catalyse their own regional science partnerships. Whether part of a network or not, these regional, ecosystem-based partnerships unite the efforts of land managers and research institutions to better understand environmental issues, and to develop joint management guidelines to mitigate or remedy environmental stresses in their domain.

The federal government also has an interest in applying ecological integrity principles to other areas outside its immediate control. For example, the Species at Risk Accord calls for national recovery strategies and action plans for certain species. The Habitat Stewardship Program for Species at Risk will support activities that conserve, enhance and protect critical habitat for those species. The program will also implement activities that maximize conservation benefits across the landscape, and encourage landowners and resource users to take actions that prevent species from becoming "at risk" in the first place. All these elements of species protection depend in some measure upon the disciplines and technologies in the ecological integrity toolkit.

However, effective application of ecological integrity principles for ecosystem protection will require collaboration and partnerships among federal science-based departments and agencies, and between the government and its non-federal partners. These partnerships are being developed.

4.5 Maximizing the Use of Government Information — Provide Free or for a Fee?

An emerging challenge for science-based departments and agencies is to facilitate access to and use of the government's data, information and knowledge. The federal government, and especially its science-based departments and agencies, are home to a large volume of information that represents a major knowledge asset for Canada. This asset covers a wide range of sectors and interests, in all parts of the country, and includes resource-based data, socio-demographic and economic statistics, and archives of national climate information. Access to the information supports informed decision making, to help build a better quality of life for Canadians. With the increasingly knowledge-based, global economy, ready availability and use of information are key to promoting the competitiveness of Canada's private sector.

While new technology and the growth of the Internet create a new means of public access to these important information holdings, there is considerable discussion within government and the private sector on user fees and the pricing policy that could maximize the benefits from this important asset. An objective of the current user-fee policy, as developed by Treasury Board, is to promote fairness by shifting costs for services from taxpayers at large to those specific users who benefit most directly from these services (where appropriate). The spectrum of pricing possibilities for government information ranges from the "public good" model, where government makes data freely available, to a full cost-recovery model. Many argue that access to free data would be a catalyst to stimulate the development of value-added products by Canadian industry, and that the lack of free data hampers the growth of the private sector. Others point out that the problem with the public good model is that providing access to quality data requires resources, and that the quality and utility of data will suffer if fees are not collected. There are also other factors to be considered, such as the impact of pricing policies in other countries, market size, and effects of globalization.

A consistent pricing policy for government information is considered to be essential in fostering the development of vibrant, internationally competitive private sector enterprises that will make use of and add value to this government asset. To this end, federal government departments and agencies are working cooperatively to encourage the development of policies at departmental, federal and national levels, and supporting the open discussion of issues and achievement of consensus.

4.6 Systematics Research and Bio-informatics

The continuing worldwide decline of expertise in systematics, and especially taxonomy, is an issue of concern within the biological research community. Even though contributions from systematics research are basic to making informed decisions in land-use planning, wildlife management, bio-prospecting, pest management and international trade, and in understanding how to monitor changes in the environment, interest in this type of science has waned. There are many international programs attempting to change this situation, for example the Global Taxonomy Initiative (sponsored by the parties to the United Nations Convention on Biological Diversity, which includes

Canada), BioNet and the Global Biodiversity Information Facility. However, the decline in domestic expertise remains a challenge for Canada.

Systematics is the study of the diversity of organisms, their evolutionary and genetic relationships, their similarities and differences, and their classification. Taxonomy and systematics are strongly related in terms of attaining knowledge of the diversity of life; in fact, the terms are often used interchangeably. Systematics research provides the most basic information needed to place a value on natural resources. Its strength lies in linking the data available from widely dispersed sources, and making them accessible through new and developing informatics technologies. When applied to the biological sciences, these advances in informatics are driving the new and rapidly growing field of bio-informatics, which draws heavily upon the results of systematics research. The term "bio-informatics" is also used to describe information obtained about gene sequences.

The Federal Biosystematics Partnership (FBP) is a focal point for systematics research and bio-informatics in Canada. Since late 1998, the FBP has brought together the AAFC, DFO, Environment Canada, NRCan, and the Canadian Museum of Nature (CMN); it is currently chaired by the CMN. This cooperative partnership recognises the importance of systematics and facilitates research and applications. FBP activities in 1999 included conducting a needs assessment of systematics expertise and research capacity (involving all partners); supporting the Integrated Taxonomic Information System (ITIS*ca) in Canada (led by AAFC); representing Canada on the Bio-Informatics Working Group of the OECD's Megascience Forum, and in formulating the Canadian position for the Global Biodiversity Information Facility (led by AAFC). In addition, all partners were involved in the development of the Biota of Canada Information Network, which is a distributed network of interoperable biodiversity data bases (led by AAFC under the 5NR MOU).

To address this issue on a national level, there is a need to ensure that Canada has an appropriate number of systematics experts; that comprehensive biodiversity information is easily accessible; and that scientists, decision makers and the public understand the utility of this field of research.

4.7 Bio-terrorism

In many areas of the world, the threat of chemical and biological attacks has added a new dimension to terrorism. Highly lethal agents can be created with minimal equipment and space in covert facilities, and at relatively low cost. Many of these agents are difficult to detect: some are tasteless and odourless, and others have a delayed effect, ranging from several hours to several days. Moreover, the development of technologies and materials used to manufacture and deliver lethal chemical and biological agents may not be readily visible, since they may have legitimate everyday uses, as well as applications in the medical, pharmaceutical, food, cosmetic and pesticide industries. Advances in biological sciences and biotechnology, and the proliferation of ways to apply them, have combined to make these agents all the more dangerous.

In the hands of terrorists or "rogue states," chemical and biological agents pose a threat to public health and safety, as well as to the nation's infrastructure (including crops, food

and water supply). The notorious nerve gas attack in the Tokyo subway system demonstrated the devastating effects of these agents, and the vulnerability of cities and states to this type of terrorism. In the realm of agro-terrorism, the CFIA has categorized and ranked potential anti-crop and anti-animal agents of concern.

Coordination of research to counter bio-terrorism threats, both across government and with other nations, is essential to ensure that Canada has access to the best capacity to respond to such threats. A number of collaborative activities are under way to protect and defend Canadians against chemical and biological agents. For example, a multi-sectoral and multinational initiative to develop and provide vaccines to protect and defend against biological agents is being launched by DND, in partnership with the Canadian defence and biotech industrial sectors, the United States and United Kingdom. In the realm of law enforcement activities against bio-terrorism threats, the Solicitor General and the U.S. State Department are discussing mechanisms to undertake collaborative research of benefit to law enforcement agencies of both countries. Collaborative efforts in this field by the Royal Canadian Mounted Police and the military, under the coordination of a Joint Nuclear, Chemical and Biological Response Team, have already led to positive results: in conjunction with Canadian industry, a unique, portable system, called "Blast Guard," has been developed to provide a foam-based containment and decontamination unit to help emergency personnel deal with chemical and biological hazards. In addition, DND is set to begin collaborative research with the Health Protection Branch of Health Canada, aimed at countering chemical and biological threats.

Although many of these initiatives are still in their initial stages, they are steps toward a comprehensive approach to the problem. Cooperative and collaborative research into detection, diagnostics, countermeasures and vaccines, undertaken with domestic and international partners, will play an important role in developing means to effectively mitigate the consequences of a bio-terrorist act.

4.8 Application of the Precautionary Principle in Public Policy

In recent years, the "precautionary principle" has become a point of focus in public debates concerning a wide range of health, environmental and trade issues. The presence of statements invoking the precautionary principle in international treaties, in domestic legislation, and in policy statements related to public risk management, without a clear and broadly accepted understanding of what the principle means and how it is to be applied, has raised important questions about its use.

At all levels of government, decision makers are expressing a need for a framework that provides a common understanding of and guidelines for the implementation of the precautionary principle in domestic and international commitments. The precautionary principle has most recently been embodied in Canadian legislation, in the *Canadian Environmental Protection Act* (CEPA 1999), as "...where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures...."

A number of important considerations are shaping the application of the precautionary principle.

- Its application in decision making must be within a modern risk management framework, i.e., decision making based on the recognition of all possible facts and repercussions, whether of a scientific, social, economic or political nature.
- The phenomenal pace of industry-generated research, science and technology raises the larger question of the government's capacity to understand the S&T advances, and dictates a need for ongoing government evaluation of decisions in light of new scientific information.
- Pressure for coherence and cohesiveness is rising as governments are being driven to articulate policy positions, often in reaction to urgent issues in the international arena with important long-term trade implications.
- Public opinion on the precautionary principle, even though it is largely undefined, parallels somewhat the opinion on risk management in decision making: wariness and scepticism, leading to lack of confidence about the integrity of the process for its application, and concern about consumers' interests being considered paramount.
- Consultation and communications strategies must be integrated in the implementation of the precautionary principle and, in all sectors, the protection of the health and safety of citizens must be seen to be paramount in dealing with serious risks. Cost-effectiveness issues or trade imperatives are factored into decisions to the extent that they do not compromise the public safety consideration.

Given the significant horizontal implications of applying the precautionary principle in public policy decision making, an interdepartmental process, led by the Privy Council Office, has been initiated to address these challenges.

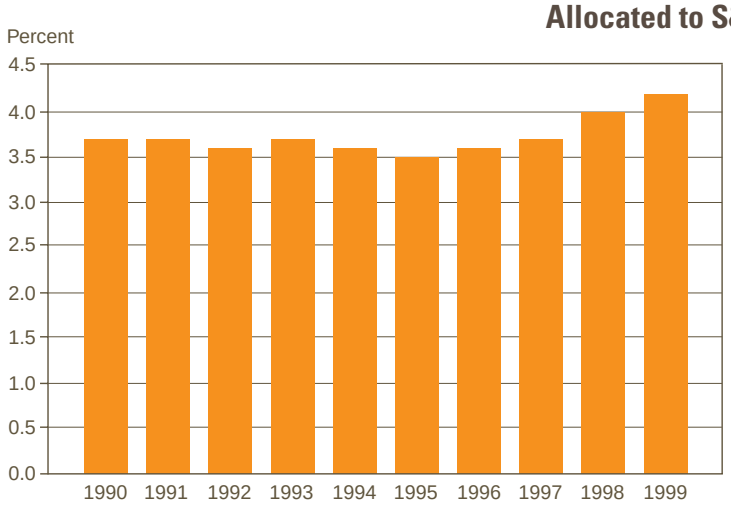
5.0 Federal Investments in S&T: Statistical Indicators

5.1 Highlights

IN 1999, the federal government strengthened its role as a facilitator of Canadian S&T activities with the coming on-line of the CFI, and increases in funding for the three granting councils — the MRC, NSERC and SSHRC. The CFI was established in 1997 to award funding to universities, research hospitals and private non-profit organizations to support research infrastructure. It emerged as the largest single federal source of funds for S&T at $605 million in 1999–2000. The federal budget of February 1999 allocated a further $200 million to the CFI for the year 2000–2001.

Two of the federal government's industry research support programs also received increases in funding in 1999. Industry Canada's TPC program received an additional $50 million per year for three years, and NRC's IRAP was allocated an additional $5 million per year for each of the next three years. As a result of these increases, together with changes in S&T spending in other departments and agencies, total federal expenditures on S&T grew by $465 million to $6.3 billion, a new high point. The proportion of the $152 billion total federal planned expenditures that are allocated to S&T (4.2 percent) is now the highest ever (*Figure 1 shows data for the past decade*).

Figure 1: Proportion of Federal Expenditures Allocated to S&T



Source: Statistics Canada. 1999. *Science Statistics*, Vol. 23, No. 5, Cat. No. 88-001-XIB, October 1999. Ottawa, Canada.

Note: The CFI funds were allocated in the 1997 federal budget, but show up as S&T expenditures in 1999, since that is the year in which the CFI distributed the funds. Planned expenditures are taken from the Main Estimates early in the fiscal year. Data are revised the subsequent year to reflect actual expenditures.

The proportion of federal funds allocated to funding external activities has reached an all-time high of 48 percent. That is, $3 billion of the total $6.3 billion S&T budget is used to fund S&T in universities, the private sector or foreign performers. The remaining $3.3 billion is used to fund S&T conducted by the 29 000 people engaged by the federal government to conduct S&T activities.

International comparisons show that Canada's R&D environment is more globalized, collaborative and specialized than that of most OECD countries. Analysis of scientific publications shows that the federal government is a major contributor to scientific knowledge, especially in the fields of biology, and earth and space sciences.

5.2 Federal S&T Activities

The federal government acts both as funder and performer of S&T activities. At the all-time high of $3 billion, extramural expenditures on S&T have increased by $584 million over the previous year, which is largely attributable to the CFI. Of this $3 billion, more than one third is allocated to Canadian business enterprises, $1.6 billion to Canadian higher education, $240 million to foreign S&T performers, $98 million to private non-profit institutions, and $33 million to other Canadian S&T performers, including provincial and municipal governments.

Of the major federal S&T funders, nine departments and agencies increased their S&T budgets by a total of $678 million (*see Figure 2*). Seven departments and agencies collectively reduced their S&T budgets by $213 million.

Figure 2: Federal Expenditures on S&T

Department/Agency	1998–99	1999–2000	% change
	$ million		
AECL	135	120	–11.1
AAFC	355	310	–12.7
CFI	70	605	764.3
CIDA	323	347	7.4
CSA	343	306	–10.8
Environment Canada	444	424	–4.5
DFO	196	205	4.6
Health Canada	213	225	5.6
IDRC	75	81	8.0
Industry Canada	407	411	1.0
MRC	277	309	11.6
DND	305	305	0.0
NRC	570	553	–3.0
NRCan	363	359	–1.1
NSERC	501	540	7.8
SSHRC	104	121	16.3
Statistics Canada	457	419	–8.3
Other*	705	668	–5.2
Total	**5843**	**6308**	**8.0**

Source: Statistics Canada. 1999. *Science Statistics*, Vol. 23, No. 5, Cat. No. 88-001-XIB, October 1999. Ottawa, Canada.

*Consolidates data on 39 federal departments and agencies, including Parks Canada, HRDC, DFAIT, the CFIA and Transport Canada.

In fiscal year 1999–2000, the federal government expects to spend $3.3 billion on intramural S&T activities. This is lower than any year during the current decade.

Despite the drop in intramural expenditures, in 1999 there were 185 more civil servants engaged in S&T activities, for a total of 29 050 (*see Figure 3*). This represents the first increase of S&T personnel since 1991–92, when the federal S&T contingent was one sixth larger than it is today.

Figure 3: Federal Personnel in S&T

Department/Agency	1998–99	1999–2000*	% change
	Full-time equivalents		
AECL	1 195	1 160	–2.9
AAFC	2 575	2 627	2.0
CFI	16	19	18.8
CIDA	193	193	0.0
CSA	379	363	–4.2
Environment Canada	2 801	2 838	1.3
DFO	2 092	2 159	3.2
Health Canada	1 517	1 600	5.5
IDRC	172	174	1.2
Industry Canada	973	983	1.0
MRC	86	88	2.3
DND	1 424	1 424	0.0
NRC	2 932	2 966	1.2
NRCan	2 756	2 782	0.9
NSERC	204	215	5.4
SSHRC	107	118	10.3
Statistics Canada	4 983	4 956	–0.5
Other**	4 460	4 385	–1.7
Total	**28 865**	**29 050**	**0.6**

Source: Statistics Canada. Science, Innovation and Electronic Information Division.

*Preliminary figures.

**Consolidates data on 39 federal departments and agencies, including Parks Canada, HRDC, DFAIT, the CFIA, and Transport Canada.

The federal S&T budget is allocated to either R&D or RSAs. The federal S&T expenditures allocated to RSAs have remained relatively stable between $2.2 and $2.4 billion during the 1990s. The amount allocated to R&D activities has grown from $2.9 billion in 1990–91 to more than $3.7 billion in 1999–2000.

The largest component of RSAs has always been data collection, which accounted for $985 million (or 43 percent of the RSA budget) in 1999–2000. Statistics Canada is the federal government's major spender of RSA funds ($419 million). Other major RSAs take place in Environment Canada ($306 million) and CIDA ($290 million).

5.3 National R&D

The federal government's S&T budget contributes to a vital national system of research and development that also includes private industry, universities, provincial governments and private non-profit organizations. One index of this national system is the Canadian gross expenditures on R&D or GERD. GERD, which measures actual expenditures on R&D rather than transfers of funds, increased by $500 million over 1998 to reach $14.9 billion in 1999.

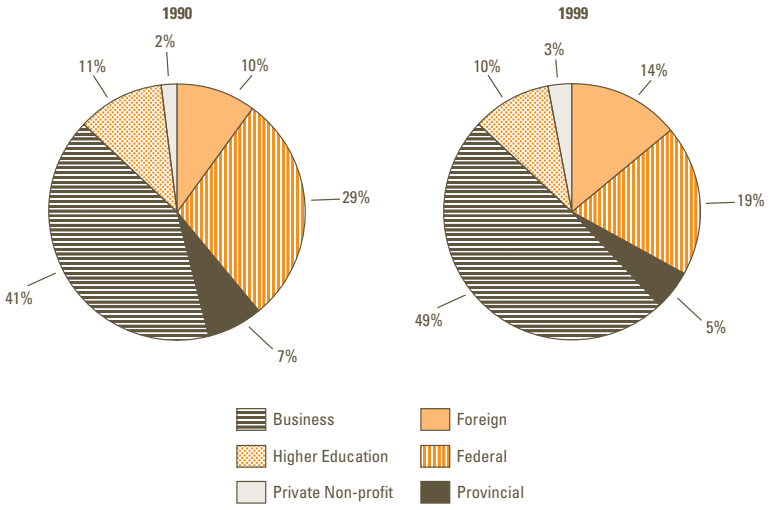
Federal Roles in S&T Funding

The 17 federal S&T funders have differing roles.

- The CFI, MRC, NSERC and SSHRC are funding agencies that allocate federal funds to support research in universities and colleges.
- The NRC and Industry Canada support research in industry through IRAP and TPC, respectively.
- CIDA and the International Development Research Centre (IDRC) support research overseas.
- Departments and agencies such as AAFC, Atomic Energy of Canada Limited (AECL), NRCan, DFO, Environment Canada, Health Canada, the NRC and Statistics Canada conduct most of their own S&T activities.
- The CSA conducts much of its S&T activities through contracts and partnerships with Canadian industry and universities.
- In addition to collaboration with other nations and in-house activities, DND conducts about 50 percent of its R&D through industrial and university contracting.

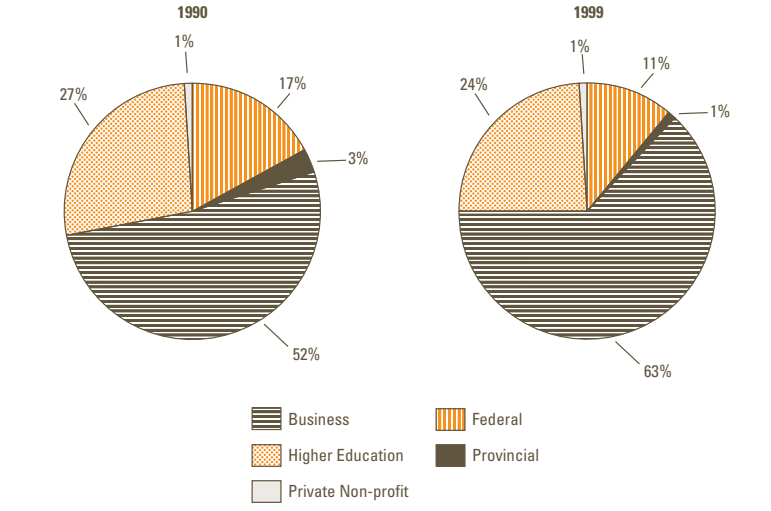
The contribution of the federal government to GERD has been dropping over the past decade. In 1990, almost 30 percent of all R&D performed in Canada was funded by the federal government. This proportion has dropped to below 20 percent with the difference being made up by business, funding from which has grown from 41 percent to 49 percent of all R&D performed in Canada. The contributions of the provinces, the higher education sector, and private non-profit organizations have remained relatively stable, while the proportion of GERD financed by foreign organizations increased from about 10 percent in the early 1990s to its current 14 percent (*see Figure 4*).

Figure 4: Sources of GERD, 1990 and 1999



Source: Statistics Canada. 1999. *Science Statistics*, Vol. 23, No. 6, Cat. No. 88-001-XIB, November 1999. Ottawa, Canada.

Figure 5: Performance of R&D (GERD), 1990 and 1999



Source: Statistics Canada. 1999. *Science Statistics*, Vol. 23, No. 6, Cat. No. 88-001-XIB, November 1999. Ottawa, Canada.

As demonstrated by R&D performance measures, the federal government currently conducts 11 percent of the R&D performed in Canada, compared with 17 percent in 1990 (*see Figure 5 on page 41*). As with the funding of R&D, the decrease in federal R&D performance has been made up by a relative increase in that conducted by business.

5.4 International Context

Canada is unique in many respects: our R&D activities are more globalized, collaborative and specialized than those of most OECD countries.

- Canada's GERD as a proportion of GDP, at 1.6 percent, is well below the OECD average of 2.2 percent.[1] The United States, Japan, Korea, Sweden and Finland invest more than 2.7 percent of their GDP as GERD.
- Canada's investment in knowledge[2] is estimated at 8.8 percent of GDP. This is higher than the OECD average of 7.9 percent and higher than the United States' investment of 8.4 percent.
- Canada has one of the highest levels of foreign investment in R&D (14 percent in 1997). Only the United Kingdom can claim a more globalized R&D environment, with a 15 percent foreign contribution in 1997.
- Canada ranks as the highest of all OECD countries in terms of the proportion of government R&D expenditures devoted to health and to the environment. At 28 percent of the government R&D expenditures in 1997, only New Zealand (at 25 percent), the United States, United Kingdom and Norway (at about 20 percent) have similar levels of priority for these areas.
- Canada has one of the most collaborative R&D environments, as shown by the proportion of business investment in university R&D. For OECD countries, on average in 1997, business funded about 6 percent of R&D in universities. In Canada, this proportion was almost double at 12 percent.

5.5 Knowledge Production

Publishing is an important means of disseminating scientific knowledge. After researchers in universities and hospitals, federal scientists and engineers are Canada's largest contributors to international scientific and technical literature. In 1997, for example, they published 3133 papers (down from 3365 in 1995), notes and reviews in the world's most prestigious journals and periodicals. About one in nine S&T publications published between 1990 and 1997 had at least one author from the federal government.

Federal scientists and engineers published in all of the major research disciplines and in almost every one of their sub-fields. They were particularly active in the disciplines of biology, and earth and space sciences, where they authored more than one third of

1. *OECD Science, Technology and Industry Scoreboard*, 1999. OECD, Paris, France.
2. The OECD calculates this as the sum of all expenditures on R&D, public expenditures on education, and all expenditures on software. Certain components were subtracted to avoid double counting and to focus on intangible aspects:
   - the equipment component of R&D expenditures;
   - the R&D component of higher education; and
   - purchases of software by households and operational services in firms.

Further Reading

More details on Canadian and international S&T activities are available on the Internet.

Current budget information, as well as special features on S&T, is available on Finance Canada's Web site at **http://www.fin.gc.ca/access/budinfoe.html**

Departmental performance reports, which often contain statements of the impact of the department's S&T spending, can be found on the Treasury Board Secretariat's site at **http://www.tbs-sct.gc.ca/rma/dpr/dpre.asp**

A summary chart of important results shows specific program-related plans and results at **http://www.tbs-sct.gc.ca/rma/communic/prr99/mfr99/ckre2.htm**

Statistics Canada publishes many documents related to S&T on its Web site at **http://www.statcan.ca/english/research/scilist.htm**

Service bulletins are located at **http://www.statcan.ca/english/IPS/Data/88-001-XIB.htm**

The *Innovation Analysis Bulletin* can be downloaded from **http://www.statcan.ca/english/IPS/Data/88-003-XIE.htm**

Most of the OECD S&T statistical publications can be ordered from their site at **http://www.oecd.org**

The *Innovation and Technology Working Papers* are available free at **http://www.oecd.org/dsti/sti/s_t/inte/prod/online. htm**

all Canadian publications. These are the two fields in which Canada is the most specialized internationally.[3] In sub-fields such as agriculture and food science, environmental science, meteorology and atmospheric science, and oceanography and limnology, federal researchers accounted for almost half of the Canadian papers. In dairy and animal science, entomology, nuclear technology, marine biology and hydrobiology, and analytical chemistry, federal researchers authored approximately one third.

Bibliometric data also show that federal scientists and engineers are engaged in a relatively large number of collaborative efforts, both among themselves and with partners in the university and industry sectors, provincial governments, and internationally. About half of their papers are written with authors from outside the federal government. Almost a third of the papers with a federal government author are international collaborations.

5.6 Conclusion

The renewed commitment of the federal government to S&T is only starting to appear in the indicators. Additional funding allocated during 1999 will be evident in next year's indicators when the funds filter through the system and are actually spent on R&D by the performers.

5.7 A Note on Measurability and Outcomes

This review of the federal investment in S&T has focussed largely on expenditures. Our ability to measure the inputs to the S&T system has been developing for the past two decades, but measuring the outcomes is a novelty.

It is clear that measuring the inputs to S&T gives only a partial picture. However, even this partial picture comes with a cost. Surveys of government, business, higher education and private non-profit organizations are conducted to complement administrative information. Respondents take their time to provide as much information as they can. Therefore, even for this seemingly simple set of indicators, there is a need for substantial harmonization and estimation.

Going several steps further to answer the question "What is the *impact* of all this spending on S&T?" would require more information than is currently collected. Statistics Canada's surveys would have to be more detailed, and would require more time on the part of the respondent and more effort to harmonize and analyse.

Two initiatives have been undertaken over the past two years to examine some outcomes of S&T spending in the federal government. One is the bibliometrics information reported above. At its core is the intensive work required to validate hundreds of thousands of science citations. The second initiative is a pilot survey conducted to obtain information on intellectual property generated in federal departments and agencies. Last year's *Building Momentum* reported some preliminary data from this survey. The survey is being conducted for the second time this year.

3. *Knowledge Flows in Canada as Measured by Bibliometrics*, Cat. No. 88F0006-XPB, No. 10, 1998. Statistics Canada, Ottawa, Canada.

6.0 Conclusion

RECOGNIZING the need for improved coordination of federal S&T activities to maximize the benefits that Canadians derive from the government's investments in S&T, the 1996 federal S&T strategy, *Science and Technology for the New Century*, provided a framework for enhanced cooperation and collaboration among science-based departments and agencies, and between Ottawa and its non-federal partners, on horizontal issues of concern to Canadians. Since the release of the strategy, federal departments and agencies have made significant improvements in the ways in which they interact with other partners in the Canadian, as well as in the international, research enterprise.

Forging Ahead is the third report on federal S&T, providing information on progress made to implement the goals set out in the strategy. It has described the activities of the government's horizontal expert S&T committees to identify and provide recommendations on S&T issues of broad concern to the government. It has also used two examples to demonstrate how the government's S&T investments are being used to foster, facilitate and implement cooperation and collaboration among science-based departments and agencies, and between the government and its non-federal partners, to advance the overarching goals of enhancing economic growth and job creation, and improving the quality of life for Canadians. The report has also highlighted a number of emerging S&T policy challenges that will require concerted action on the part of federal departments and agencies, and their non-federal partners, to ensure that the government is well placed to assure the continued economic and social well-being of Canadians.

Although considerable progress has been made since 1996, there remains scope for improvement in the federal S&T enterprise to ensure current and future federal S&T investments continue to provide the maximum benefits to Canadians. Future reports will provide continuing information on the federal government's actions to secure these investments.

Annexes — Highlights of Departmental and Agency Performance

Individual ministers set priorities and direct their S&T activities in order to deliver on departmental and agency missions. Details on the mandates of the various science-based departments and agencies, and the ways in which they use S&T to deliver on their mandates, were provided in *Building Momentum*, the 1998 report on federal S&T. The following material provides highlights of the major ongoing S&T activities of the individual departments and agencies, and the significant achievements in 1999.

Agriculture and Agri-Food Canada

Major S&T Achievements

Agriculture and Agri-Food Canada's (AAFC) Return-on-investment (ROI) studies research in specific commodity areas indicate the value of federal agri-food research to the nation. Extensive ROI studies have been done on selected commodities, showing the following net annual benefits:

- Potatoes: $220 million
- Hogs: $590 million
- Wheat: $377 million.

The ROI study on wheat conservatively shows that the net benefits accrued to the Canadian economy each year from AAFC wheat research alone exceed the typical annual expenditures for all the department's R&D activities. About half of wheat fields on the prairies in 1998–99 were sown to AC Barrie, which offers higher grain yield and protein content over previously leading varieties. This translated into up to $20/acre more in the pockets of producers.

Conserving the environment is one of AAFC's key research priorities. A few examples of achievements in this area follow.

- *The Health of Our Air* was published after six years of research. This publication joins *The Health of Our Soils* to demonstrate how increased agricultural productivity and taking care of the environment are compatible objectives.
- An improved manure treatment system that increases the take-up of nitrogen by the plant was recently developed. This new system lowers the risk of phosphorus buildup and nitrogen run-off. In addition to improving fertilizer value, the system allows for the recuperation of methane that can be used as an energy source similar to propane and natural gas.

Many new barley cultivars feature improved resistance to stresses and have reduced the need for expensive fungicides. New durum wheat cultivars have increased gluten strength, a desirable, marketable feature. Yield and quality increases have been attained with similar management practices. A few highlights follow.

- Winter wheat, which is planted in the fall and must be hardy enough to survive the winter, has a number of advantages. It can produce a high-quality feed grain that matures three to four weeks earlier than normal varieties. It helps conserve soil and air quality by reducing wind and water erosion. AC Bellatrix, a new variety, contributed to the further expansion of winter wheat planting in the prairies, which has increased by 40 percent in the past year.
- The reduced-stature or semi-dwarf cereal corn was tested from Alberta to Newfoundland. It is under one metre high and can be planted and harvested using conventional farm machinery, thus eliminating the need for specialized corn equipment. Rapid development also makes cereal corn a cropping option outside the current corn production regions.

Animal research is done in eight research centres across the country. Highlights of achievements in this area include the following.

- The Hog Environmental Management Strategy is a partnership among the federal and provincial governments and the hog industry to help address environmental problems associated with the industry's rapid expansion.
- Phosphorus excretion by poultry, which is implicated in eutrophic algal growth in surface waters, is a serious concern for the sustainability of the industry. A new production process resulted in a nearly 50 percent reduction of phosphorus excretions.
- Live animal assessment of quality and yield grade is of immediate value to the production and processing sectors by enabling the segregation of animals prior to slaughter. A Windows-based computer vision system using ultrasound technology captures cross sectional images of live cattle. These images are used to predict back fat thickness and rib-eye marbling.

Although food research is carried out across the country, a new food research program was established in Guelph, Ontario, to concentrate federal expertise in an innovation cluster alongside industry, university and provincial partners. Some achievements in this key area include the following.

- An award-winning project undertaken jointly with Caldwell Bio Fermentation Canada Inc. to preserve fermented vegetables that can be marketed without pasteurization or preservatives. The resulting food products are unique in the world.
- The blueberry harvest in the Northern Hemisphere lasts from August until mid-October. Production from the Southern Hemisphere does not begin until late December. An improved storage technique allows Canadian producers to take advantage of this global window of opportunity by extending the fresh product marketing season.

AAFC's Matching Investment Initiative (MII) has proven to be an effective means for increasing overall investment in agri-food research. With projects co-funded by the department and industry, market signals are brought to bear on research priority setting and technology is transferred efficiently from government labs to industry. In 1998–99, with $28.5 million in AAFC funding available for matching, the MII was fully subscribed by industry. In fact, the private sector invested $31.9 million in 924 collaborative projects undertaken with AAFC and the CFIA.

AAFC continues to help increase the productive capacity of agricultural lands while ensuring that the agriculture sector growth does not have a negative impact on the environment. The Prairie Farm Rehabilitation Administration (PFRA) accomplishments in this area include assessing and managing land and water capabilities for continuing sustainable use and developing and transferring to rural people new information about environmentally sustainable practices and technologies.

- PFRA's Rural Water Development Program provided technical information and $5.6 million to rural residents to plan and develop reliable and sustainable water supplies.
- PFRA collaborated on a three-year study to determine the prevalence of cryptosporidium and giardia in the North Saskatchewan River basin. These organisms are very small parasites that can infect and reproduce in the digestive tract of animals, including humans.
- Field test results of a new technology aimed at extending the life of water wells by counteracting the plugging effect of groundwater bacteria were promising and may be useful for treating biofouled wells.

Strategic Directions in S&T

AAFC's S&T efforts will focus on the following long-term goals:

- increasing production from existing crops;
- developing and introducing new, higher-yielding, more resistant, better-quality crops;
- expanding livestock production and quality;
- introducing new value-added food and non-food products and processes;
- helping protect the Prairie's fragile marginal lands and maintaining biodiversity; and
- protecting and improving the quality of water in rural areas.

Included in these challenges is the Canadian Agri-Food Marketing Council's target of 4 percent of the global market share for agricultural and agri-food exports by 2005. Canada's share now stands at 3.3 percent.

Agricultural biotechnology can shorten product development cycles, reduce research costs and introduce crops that are more resistant to disease, insects, and changing climate conditions. For farmers, it can mean plants that require fewer chemical pest control products. For consumers, it can mean new choices in the marketplace, such as products with health benefits and health care products. Biotechnology provides important research tools at all 18 AAFC research centres. The Department is a recognized leader and sought-out partner in research and technology development with countries around the world.

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Atlantic Canada Opportunities Agency

The Atlantic Canada Opportunities Agency (ACOA) places a high priority on innovation and technology as tools through which to advance regional and community economic development in Atlantic Canada. The Agency seeks to increase SME productivity, diversity and revenues generated from technology development, commercialization and diffusion. ACOA's Innovation and Technology Strategy has four elements:

- providing project-specific financing and advisory support for projects involving SME development, use and commercialization of technology, as well as infrastructure support to research facilities servicing SMEs;
- supporting technology development and commercialization alliances;
- undertaking technology initiatives with partners; and
- facilitating innovation in strategic sectors.

ACOA delivers financing to support innovation through its program instruments. The "Innovation" element of its Business Development Program (BDP), provides repayable financing for firms engaged in innovation activities. For fiscal year 1998–99, $9.1 million was authorized in assistance to SMEs under this element. Beyond this, BDP assistance was provided to support non-commercial organizations, research centres and associations engaged in innovation activities. ACOA's COOPERATION Program provides for joint establishment and funding, with the Atlantic provinces, of broadly based economic development agreements. These agreements provide for collaborative federal-provincial investments in strategic areas of the Atlantic economy through the funding of technology development projects and initiatives. ACOA's COOPERATION Program has also been the main source of matching funds for Atlantic Canadian universities, hospitals and not-for-profit organizations under the programs of the CFI. Without the COOPERATION Program funds, or alternative provincial sources, it is unlikely that Atlantic Canadian research institutions would have been able to benefit from the investments in research infrastructure made by the CFI.

Major S&T Achievements

ACOA has supported a number of international and domestic partnerships for technology development and commercialization. These include alliances between research institutions and companies, as well as partnerships between private sector firms.

- At the international level, ACOA's initiatives to link Atlantic Canadian firms with international partners resulted in the formation of six new partnerships. The following are examples of the types of initiatives under which these partnerships were formed:
  - — ACOA's alliance with the **Canada–Israel Industrial Research and Development Foundation** to promote R&D partnerships and market outreach between companies in Atlantic Canada and Israel; and
  - — **Swedepark**, a project geared to develop investment opportunities between Nova Scotia and 26 S&T parks throughout Sweden.
- Domestically, ACOA has supported a number of research facilities and organizations that have a significant role in fostering partnerships between the private sector and research facilities. In 1998–99, a total of 27 new R&D partnerships were formed. A notable example is the **AAFC/ACOA/NRC Joint Technology Commercialization Initiative**, a commercialization service designed to move innovative technologies from AAFC research stations out into the marketplace. Another excellent example is the **Telecom Applications Research Alliance (TARA)**, a telecom research facility located in Nova Scotia, which has affiliations with universities, the NRC, and 42 local, national and international private sector members. In 1998–99, nine new partnerships were formed under TARA alone.

Strategic Directions in S&T

Enhancing Atlantic Canada's capacity for innovation and technology development will remain a priority for ACOA. A recent planning exercise within the Agency has re-affirmed ACOA's Innovation and Technology Strategy, and suggested the following three areas for concentrated focus:

- Systems of innovation — initiatives to strengthen the region's innovation network, including linkages between key innovation players
- SME innovation capacity — to enhance the capacity of clients and partners to assess and manage innovation projects
- Electronic commerce — to encourage awareness and use of e-commerce by SMEs in Atlantic Canada.

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Canada Economic Development for Quebec Regions

Major S&T Achievements

Since April 1, 1995, Canada Economic Development for Quebec Regions (CED) has provided contributions totalling $83 million, under the Innovation, Research and Development component of its IDEA-SME Program and the technological components of its Regional Strategic Initiatives (RSIs).

To maximize the impact on Quebec SMEs, CED partners with other federal departments, Canadian research councils and private organizations.

CED supports an initiative of the NRC to provide research assistance to SMEs through the Industrial Research Assistance Program (IRAP). CED has also agreed to participate with the NRC to promote a new program to Quebec SMEs, the Precommercialization Assistance (PA) Program. CED provides funding for the preparation of projects submitted by research institutions to the CFI when the projects have significant structural impacts for SMEs. CED has a partnership agreement with Environment Canada to assist SMEs in technology demonstration and environmental marketing projects by facilitating access to technology specialists.

CED's partnership with financial institutions encourages the funding of R&D, innovation and market development projects for technology firms. In addition, through the IDEA-SME Program, CED is continuing to support the projects of SMEs that aim to integrate new technologies in their manufacturing processes. CED is continuing the Operation SME program, initiated by the *Ordre des ingénieurs du Québec*. Also, after an evaluation of the economic impacts of a network of technology incubators, CED is assisting technology entrepreneurs in the preparation of the pre-launch and launch phases.

CED will contribute $12.5 million to enlarge the laboratory facilities of the *Institut national d'optique* [National Optics Institute] as well as for its research program.

CED will invest $3 million to implement the Angus Environmental Technopole in East Montréal, an initiative that will contribute to the revitalization of East Montréal.

CED has launched RSIs that are intended to have a structural impact on the regional economy. For example, one RSI aims to develop the Eastern Quebec region as the Maritime Technopole of Quebec. A sum of $11.3 million will be devoted to this purpose over the period from 1998 to 2003. Another RSI, for the Abitibi-Témiscamingue region, will devote $5 million between 1999 and 2002 to foster technological entrepreneurship and create synergy between the research centres and SMEs in order to assist enterprises in adopting new technologies and developing new value-added products. A third RSI, for the Estrie region, will invest $8.5 million from 1999 to 2004 to develop the region's technological capacity and support innovative enterprises.

Strategic Directions in S&T

- To encourage the implementation of five projects that promote modernization, growth and the creation of research centres that establish business links to increase research and technology transfer with SMEs in Quebec.
- To contribute to the launch of some 30 technology SMEs over three years in the technology incubators that CED funds.
- To contribute to the pre-launch of 15 enterprises in the multimedia sector and to new media over three years.
- To support the launch of five technology SMEs in the Québec City/Chaudière Appalaches region to achieve a total of 15 SMEs since the launch of the TechnoRegion initiative.
- To provide access to the services of a qualified engineer for some 100 manufacturing SMEs per year.

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Canadian Food Inspection Agency

The Canadian Food Inspection Agency (CFIA) was created in April 1997, consolidating the delivery of all federal food, animal and plant health inspection programs. Its mandate is to enhance the effectiveness and efficiency of federal inspection and related services for food, and animal and plant health. The Agency contributes to Canadian food safety and consumer protection through its science-based inspection and enforcement activities, utilizes national and international S&T standards to develop effective food safety, and animal and plant health policies. In 1999, the CFIA continued to build on its scientific capacity to enhance its policy development, program design, and risk analysis activities, and to improve animal and plant health- and inspection-related services to Canadians.

The CFIA's S&T activities are divided into three broad components:

- utilizing expert scientific information and advice to ensure that sound science advice is integrated into decision making and policy development;

- contributing to the food safety system, to the health of animals and plants, and to regulatory and inspection services through 21 CFIA laboratories; and
- establishing R&D programs directed toward the development of risk profiles on food hazards, pests and food-borne diseases, and the development and adaptation of new technologies and methods to meet immediate domestic and international analytical/testing needs.

Major S&T Achievements

The CFIA's Science Evaluation Unit (SEU) was established in 1998. The Unit has coordinated science activities within the Agency, reviewed the CFIA's overall science strategy in partnership with other science elements, and represents the Agency on numerous national and international science-based, policy- and standard-setting organizations to assist in harmonizing health and food safety requirements. Through the SEU, the Agency enhanced its involvement in a consolidated federal approach to S&T, through participation in groups such as advisory councils and the Federal Partners in Technology Transfer.

The CFIA has recently established two senior panels to further the Agency's S&T objectives. These panels will be instrumental in fulfilling the needs highlighted in Canada's science strategy and in taking advantage of opportunities evolving in the S&T sector. In particular, they will provide oversight for the implementation and integration of the recommendations of the CSTA's reports (*Science Advice for Government Effectiveness* and *Building Excellence in Science and Technology*) into the CFIA's priority-setting and decision-making processes.

The consolidation of the Agency's 21 laboratories into a single reporting structure is the first step toward developing a strategic plan to enhance the CFIA's internal S&T capacity, including programs for quality assurance, partnership and collaborative arrangements, identification and maintenance of core skills and expertise, and targeted R&D initiatives that support program needs.

The CFIA's National Centre for Foreign Animal Diseases, situated at the Canadian Science Centre for Human and Animal Health in Winnipeg, commissioned its facilities and is now in a position to undertake analytical activities. The new centre is only one of a few Level 4 facilities in the world able to diagnose viral diseases of animals that pose a serious threat to Canadian livestock.

The CFIA finalized an agreement with the Standards Council of Canada (SCC) on laboratory accreditation. The agreement requires all laboratories that provide analytical testing required by federal legislation covering food, animal feeds and fertilizers, to be accredited by the SCC to ISO/IEC Guide 25 (*General Requirements for the Competence of Calibration and Testing Laboratories*).

The CFIA's research program has been redesigned to improve client involvement in AAFC's MII program. The objectives of the MII are to increase the participation of the private sector in collaborative R&D activities; strengthen agri-food technology development; and accelerate the process of technology transfer. In 1998–99, MII funds for CFIA research projects matched $1.6 million in industry contributions for collaborative research.

Four CFIA laboratories in Quebec created a network to provide better support services for Food Safety and Animal Health programs in Quebec. Resource pooling enabled them to provide better management of quality assurance programs, and more effective and efficient training, development and administration services.

Strategic Directions in S&T

The CFIA has set the following S&T priorities:

- to maintain the core skills and expertise required to provide the best service and sound, science-based advice to its clients, and to acquire the latest and best available science;
- to strengthen science capabilities in areas that are new, emerging or increasing in importance to the CFIA, including biotechnology and better consolidation of evaluation activities;
- to implement and integrate the principles and guidelines recommended by the CSTA in *Science Advice for Government Effectiveness* and *Building Excellence in Science and Technology*, to enhance the effectiveness of the CFIA's S&T capabilities;
- to develop and implement a framework for the delivery of laboratory-based S&T to support the CFIA's research and technology development programs, and other program needs; and
- to participate actively and contribute to the formation of partnerships, linkages and networks with federal and provincial science-based departments and agencies, academia, the private sector, and international colleagues; these partnerships will facilitate the sharing of technical knowledge, expertise and other related information to resolve common problems and issues that threaten consumer health and well-being.

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Canadian Museum of Nature

The Canadian Museum of Nature (CMN) is Canada's national museum for natural history, providing care for a comprehensive collection, new knowledge through systematics research, and educational media, displays and programs. The results of CMN research are directly applicable to resource use and planning, such as through the Canadian Biodiversity Strategy (and the various organizations that partner through the leadership of Environment Canada), the deliberations of the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), and the mining industry. CMN research staff provide scientific advice to or are present on the governing committees of COSEWIC, the Ecological Monitoring and Assessment Network (EMAN), the Aquatic Environmental Effects Monitoring Program, the Biological Survey of Canada, the Pan-Arctic Flora Project, and the International Mineralogical Association. The efforts of CMN research, as well as research undertaken by others, is publicized through a major display facility in Ottawa, the Victoria Memorial Museum. The collection of natural history specimens is in a state-of-the-art facility, the Natural Heritage Building, in Aylmer, Quebec, and is available to researchers from the CMN's laboratories and elsewhere.

Major S&T Achievements

The CMN chairs the renewed Federal Biosystematics Partnership (FBP), a cooperative effort between AAFC, Environment Canada, NRCan, the CMN and DFO. The FBP is a focal point for systematics research in Canada and ensures that this kind of expertise is recognized, emphasized and supported.

The CMN is an active partner in the development of the Biota of Canada Information Network, a distributed network of interoperable biodiversity data bases (led by AAFC under the 5NR MOU).

The CMN implemented Multi-MIMSY, a collections data base, began converting existing electronic formats to this new system, and planned future data entry and the means to make information available.

The CMN organized the Natural Science Collection and Research Special Interest Group through the Canadian Museum Association. This national network will assess the importance of museum facilities to scientific research in Canada, produce an ongoing dialogue of research activities at Canadian natural history museums, and work toward forming a national collection strategy. This group communicates through the cooperation of the Canadian Heritage and Information Network.

Major Ongoing S&T Activities

Dr. Joel Grice continues in his second three-year term as Chair of the Naming Committee for New Minerals of the International Mineralogical Association. Having the committee office in Canada is a privilege and recognition of our expertise in this area. All new mineral names, everywhere, are scrutinized and approved by this professional body.

Dr. Claude Renaud is a co-chair of the Freshwater Fishes Species Specialist Group of COSEWIC, and Dr. Robert Anderson is a COSEWIC committee member. Dr. Lynn Gillespie is a member of the Biodiversity Science Board of EMAN.

The CMN continues to support the Biological Survey of Canada (terrestrial arthropods — insects and their relatives) as it has for more than 15 years. The survey, led by Dr. Hugh Danks and guided by a widely representative scientific committee, promotes the study of systematic and faunistic entomology and enables national initiatives to be developed with the collective consideration of the Canadian scientific community. It serves as a catalyst to coordinate work, developing selected scientific projects, synthesizing scientific knowledge, and acting as a clearing house for information on personnel and other resources.

The CMN is committed to its involvement with the IUCN (the World Conservation Union). Recently, a memorandum of understanding was undertaken with the IUCN Species Survival Commission to host the Secretariat for the Commission's Medicinal Plant Specialist Group (led by ethnobotanist Dr. Danna Leaman). A member of IUCN since 1976, the CMN has been host to the Secretariat of the Canadian Committee for IUCN since 1991, and is the focal point for the Committee's activities, and a key link between Committee members and Canadian IUCN members. It facilitates exchanges with the IUCN Canada Office and the IUCN Headquarters in Gland, Switzerland.

Through its Canadian Centre for Biodiversity (CCB), the CMN participates in the Canadian Biodiversity Forum (federal/provincial/territorial representatives) and the Interdepartmental Biodiversity Committee led by Environment Canada, and continues to be an active participant in Canadian delegations to the Subsidiary Body on Scientific, Technical and Technological Advice, advising the parties to the Convention on Biological Diversity.

The CMN continues to employ 16 research scientists and 18 collection experts in support of collection-based research projects in systematics in the areas of biodiversity (botany and zoology), paleobiology and mineralogy, and on the conservation and management of natural history collections, who produced 37 refereed scientific publications and 57 non-refereed scientific publications in 1998–99. The scientific staff take an active role in educational programming (at the

CMN facilities, through university courses and through the CMN's formal affiliation with the Bamfield Marine Station), media events and individual consultations with the public to help interpret and present the natural world. Experts from the CMN identified 2527 specimens and answered 1547 inquiries from students, school teachers, researchers, consultants, government agencies and the general public.

The CMN undertook extensive planning and made a proposal to renovate its educational display facility, the Victoria Memorial Museum. The capital plan for building renovations is integrated closely with a separate fundraising strategy for dynamic, new science exhibits.

The CMN coordinated the formation of a partnership of seven natural history research facilities, to encourage graduate students to study systematics, through an NSERC supplement program.

The CMN's CCB was an invited participant at the "First Meeting Toward the Establishment of a Network of Museums and Environmental Education Centres in the Valley of Mexico City," in Mexico City. The CCB, in collaboration with the Université du Québec à Montréal and the *Institut de l'Énergie et de l'Environnement*, organized biodiversity-training workshops in Morocco and Tunisia. The institute is a subsidiary body of the *Agence de la Francophonie*. The CCB also provided its expertise to the government of Burkina Faso, to assist this West African country with the implementation of the Convention on Biological Diversity.

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Canadian Space Agency

Major S&T Achievements

The Canadian Space Agency (CSA) celebrated its 10th anniversary in 1999. Since its creation in 1989, the Agency has pursued a mission committed to leading the development and application of space knowledge for the benefit of Canadians and humanity.

In the 1999 federal budget, the government provided the CSA with additional funding of $430 million over three years starting in 1999–2000, and an envelope of $300 million annually thereafter. The government also approved the new Long-Term Space Plan and accompanying management framework. This provides the Agency with stable, ongoing funding, a solid base for planning and an ability to adapt programs to the rapidly evolving environment.

CSA astronaut Ms. Julie Payette became the first Canadian to board the International Space Station as part of Mission STS-96. The purpose of this mission was maintenance and resupply to outfit the space station for future flights and occupants.

Important milestones of the International Space Station program were met. Space qualification testing of the Space Station Remote Manipulator System (SSRMS) at the CSA's David Florida Laboratory (DFL) was completed. The SSRMS was officially handed over to the CSA by the Canadian industrial team that built it, and the SSRMS was subsequently delivered to NASA at the Kennedy Space Centre. Work started on testing the Special Purpose Dexterous Manipulator at DFL.

A Canadian space science instrument called MOPITT (Measurement of Pollution in the Troposphere) was launched on NASA's Earth Observing System (EOS) satellite. This instrument will provide the first long-term, global measurements of carbon monoxide and methane gas levels in the lower atmosphere. EOS and MOPITT will produce a unique data base that will be used to predict the long-term effects of pollution, understand the increase of ozone in the lower atmosphere, and guide the evaluation and application of shorter-term pollution controls. MOPITT was conceived by Dr. Drummond of the University of Toronto, and built by Com Dev International of Cambridge, Ontario.

The joint United States–Canada–France space telescope known as FUSE (Far-Ultraviolet Spectroscopic Explorer) entered into operation in 1999. Canada's part is a pair of FES (Fine Error Sensor) cameras built by Com Dev International, with project leadership from Dr. Hutchings of the NRC. The FUSE telescope measures starlight in a far-UV range undetectable using the Hubble Space Telescope, and will thereby augment our understanding of the universe.

A major milestone was achieved in 1999, with the selection of the Atmospheric Chemistry Experiment (ACE) as the scientific payload for SCISAT-1, the first all-Canadian scientific satellite in nearly 30 years. ACE's mission is to measure and understand the chemical processes that control the distribution of ozone in the stratosphere and upper troposphere with a particular focus on Arctic winter stratosphere. Analysis of ACE data will contribute to an informed assessment of existing environmental policy such as the Montréal Protocol for the phase-out of CFCs. The leader of the science team is Dr. Bernath of the University of Waterloo with members from a range of Canadian, U.S. and European universities. ABB Bomem of Québec City has been selected to provide a key part of the ACE instrument.

Canada's Earth observation satellite, Radarsat-1, produced its first complete view of Canada. The 276 images used in the mosaic were captured over a seven-day period, producing a near instantaneous snapshot of the entire country. This unique feat is not practical with other imaging satellites. Radar images can be acquired day or night regardless of the weather, whereas other imaging systems would take an inordinate amount of time to completely capture such a vast territory due to cloud cover and darkness.

In the fall of 1997, over an 18-day period, Radarsat had acquired images of the entire continent of Antarctica. Previously, it had taken five satellites 13 years to take images that were incomplete and less accurate. In 1999, these images were formed into a map of the continent, an achievement recognized by Discovery Channel as one of the top 10 science stories of 1999. The images were augmented by a technique known as interferometry, to create a valuable research tool aimed at bringing new insights into the dynamics of the vast Antarctic ice sheet. Antarctica, as the world's largest freshwater reservoir, has a major role in regulating the world's climate and sea level.

More than 30 000 Canadian youths participated in Embrace Space Day, an international celebration of achievements in the exploration and use of space. They participated in the Embrace Space Webcast with Senator John Glenn, enjoyed a Space Day teleconference with CSA astronaut Mr. Chris Hadfield, and were treated to space-related hands-on activities at various CSA sites and at science centres and museums across the country.

The government passed Bill C-4 to formally recognize and enable Canada's membership in the International Space Station. As a member, Canada agrees to a framework for mutual international cooperation in relation to the detailed design, development, operation and utilization of a permanently inhabited civil international space station for peaceful purposes.

Canada has had a cooperation agreement with the European Space Agency (ESA) since 1979. A new agreement with the ESA was negotiated and approved by both parties in late 1999. This new agreement continues to give Canada the right to participate in the ESA programs of its choice, and to participate in all relevant ESA decision-making bodies. Moreover, it has the added benefit of more stringent guarantees concerning industrial return to Canada. The ESA relationship will lead to benefits in key areas of mutual interest, such as broadband satellite telecommunications and Earth observation from space, sustained development of commercial alliances between Canadian space suppliers and European firms, and sustained diversification in Canada's international space relationships.

Strategic Directions in S&T

Facing new opportunities, with a fresh focus and a stable budget, the CSA is planning and implementing programs for each of its service lines, toward the following objectives:

- to understand, monitor, predict and protect the Earth through enhanced upper atmospheric and environmental research;
- to maintain Canadian industry leadership in radar-based technologies, by completing Radarsat-2 and strengthening satellite data-receiving infrastructure and application developments;
- to advance knowledge about space microgravity and life science, and participate in new international space astronomy and planetary exploration missions, thereby offering new challenges to the scientific community and industry;
- to secure Canada's leadership in space robotics, through participating in the construction and use of the International Space Station, and provide regular flight opportunities for Canadian astronauts;
- to contribute to the national effort in making Canada the most connected nation in the world and ensure that Canadians will continue to develop and have access to the world's most advanced satellite communication technologies;
- to develop innovative and emerging technologies for the space program that stimulate the Canadian space industry, and maximize the commercialization of space technologies in both space and non-space applications;
- to enhance Canada's international visibility in S&T and instil a sense of pride among all Canadians; and
- to promote scientific literacy and inspire the younger generation to pursue careers in S&T.

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Department of National Defence

Major Ongoing S&T Activities

The objective of the Defence R&D Branch (DRDB) is to ensure that the Department of National Defence (DND) and Canadian Forces remain technologically prepared and relevant. The key challenges being addressed are asymmetric threats (e.g. attacks on the information/communications infrastructure), and rapid advances in technology (e.g. smart materials, genetic engineering and novel energetic materials). DRDB is responding to these challenges through a forward-looking Technology Investment Strategy with increased effort in several emerging technology areas:

- Network Information Warfare
- Psychological Performance
- Simulation and Modelling for Acquisition, Rehearsal and Training
- Space Systems.

In consultation with Canadian Forces clients, the Defence R&D Program is delivered through a structure of 26 thrusts, delivery "packages" managed by projects, covering the three broad areas: combat systems, human systems, and sensors and information technologies.

These R&D activities are carried out at five Defence Research Establishments (DREs) with national and international partners:

- DRE Atlantic (DREA) in Dartmouth, Nova Scotia
- DRE Valcartier (DREV) outside Québec City, Quebec
- DRE Ottawa, Ontario (DREO)
- Defence and Civil Institute of Environment Medicine (DCIEM) in Toronto, Ontario
- DRE Suffield (DRES) near Medicine Hat, Alberta.

The Defence R&D Program covers the spectrum of research, from technology investigation to application. More than half of the Defence R&D Program is extramural. Although Canadian industry is a key partner, activities in the international arena provided an estimated benefit of $28 million to Canada. The Technology Investment Fund set aside $6 million annually for staff and external research collaborators to pursue innovative ideas. The Defence Industrial Research Program continues to be an important way of soliciting from industry innovative R&D proposals that have potential defence applications. Technology demonstrations are being used to validate technological solutions for new and emerging operational systems without having to go to full development.

Major S&T Achievements for 1998–99

A symposium entitled "Canadian Defence Beyond 2010" brought together stakeholders from DND, allied nations, universities and industry to discuss Canada's response to the revolution in military affairs (RMA). Driven by the innovative application of new technologies, the RMA is having a significant impact on the character and conduct of military operations. The resulting concept paper, *Canadian Defence Beyond 2010: The Way Ahead* **(http://www.vcds.dnd.ca/dgsp/dda/rma/wayahead/intro_e.asp)** put forth several recommendations to help prepare Canadian defence for the future.

The Joint Intelligence Information Management System (JIIMS), which automates many of the steps in data collection, has been designed to meet specific requirements by providing an easily searched, structured data base. A prototype version of JIIMS has been fielded and used in Bosnia and East Timor. It forms the basis for future intelligence analysis tools and is a step toward effective knowledge management.

DCIEM researchers and Fullerton Sherwood Division of Carleton Life Support Technologies Limited received a Federal Partnership for Technology Transfer award for development, transfer and commercialization of diving life-support equipment technology.

The successful completion of the CA/UK Low Frequency Active (LFA) Sonar trial represented a major step forward in Canadian sonar technology. It provided an opportunity for naval and maritime air staffs to experience the potential impact that LFA systems will have on future operations. The trial provided proof of impressive detection performance, achievable through platforms working in close cooperation with LFA sonar-equipped ships.

Effective and safe DNA-based vaccines are being developed with a novel delivery mechanism in "nose drop" form that have potential use against biological agents.

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Environment Canada (April 1998 – December 1999)

S&T Management

S&T accounts for more than 80 percent of departmental spending, so managing S&T is itself a significant activity for Environment Canada.

- Environment Canada, primarily through its Nature, Clean Environment, and Weather and Environment Prediction business lines, has been involved in assessing S&T infrastructure and human resource capacity, as well as developing a long-term capital plan for infrastructure maintenance and replacement. A strategic research agenda has been developed for the Nature business line. Research agendas are also being developed by the other S&T business lines. The Department has also been engaged in interdepartmental S&T capacity issues.
- Environment Canada continues to strive to develop a more systematic approach to managing S&T in the Department. *S&T Management: Principles and Practices* provides overall guidance for S&T managers. More detailed support is found in companion documents: *Collaborative S&T Positions Policy* (for adjunct professors); *Framework for the External Review of Research and Development in Environment Canada; Science and Technology Partnering: Principles and Practices*, and *Manager/Employee Guide on Data and Copyright Ownership*.
- The Science and Technology Advisory Board has helped the Department move its agenda forward in key areas, including science advice, environmental S&T capacity, science communications, R&D priority setting, and the integration of social sciences into its planning processes.

S&T Activities

Since Environment Canada is the single largest contributor to environmental and meteorological sciences in the country, the examples highlighted below were chosen primarily to reflect activities involving significant collaboration with other federal departments or partnerships outside of the federal government.

- **Ecosystem Initiatives (EI)** — Led by Environment Canada in partnership with provincial and municipal governments, local communities, business, industry, organizations, and individuals, EIs aim to achieve environmental results and sustainable development. They respond to the unique problems of targeted areas and communities and address environmental, economic, and social concerns — recognizing the interrelationships between land, air, water, wildlife and human activities. For more information, see **http://www.ec.gc.ca/ecosyst/infodoc.html**
- **The Toxic Substances Research Initiative** — Established in 1999 by Environment Canada and Health Canada, TSRI will invest $40 million over four years to promote scientific research into the links between toxic substances, environmental damage and human illness. Much of Environment Canada's expanded research activities are conducted in partnership with other federal departments, universities, the private sector, and non-governmental organizations. For more information, see **http://www.hc-sc.gc.ca/tsri**
- **Species at Risk** — In 1999, Environment Canada made public its three-part strategy for species at risk, including implementation of the 1996 federal/provincial/territorial Accord for the Protection of Species at Risk. The accord is a commitment to a broad national program, including monitoring, species assessment, recovery, stewardship and public awareness to achieve the goal of preventing species in Canada from becoming extinct as a consequence of human activity. The accord complements the work of RENEW (Recovery of National Endangered Wildlife), a strategy developed by the federal and provincial governments and environmental non-governmental organizations. Under the strategy, 28 RENEW teams undertook extensive recovery activities for species such as whooping crane, spiny soft-shell turtle and red mulberry. For further information, visit **http://www.cws-scf.ec.gc.ca/es/endan_e.html**
- **National Radar Project** — To be completed by 2003, the project will establish a system of advanced doppler radar weather stations, by upgrading some existing radar facilities and adding some new stations, the first of which opened in Regina in late 1998. The system will improve public safety by assisting meteorologists in the earlier detection and prediction of severe weather. For more information, see **http://www.msc-smc.ec.gc.ca/doppler/index_e.htm**
- **Metals in the Environment (MITE) Working Group** — Part of the 5NR MOU on S&T for Sustainable Development, MITE focusses on further understanding the impact of metals on ecosystems and human health. Collaborative efforts among departments and with university researchers have examined the sources, fate and effects of metals in the environment, particularly in relation to mining and smelting activities. Members have also helped to develop science programs for the MITE Research Network, a five-year joint program funded by industry and NSERC.
- **Environmental Technology Centre** — The centre participated in 10 emergency science technology joint projects, six with external organizations, such as the U.S. Environmental Protection Agency, Exxon, and a Venezuelan company, and four with other federal government agencies. Partners contributed more than $800 000 to these projects.

Strategic Directions in S&T

Environment Canada is charged with ensuring that the environment is protected, respected and conserved, as well as with making sustainable development a reality. Challenges facing the Department in 2000 and beyond are many.

Some of the key S&T issues the Department will face include:

- implementing the renewed *Canadian Environmental Protection Act* (CEPA 1999);
- developing plans and programs to fulfil Canada's obligations under the Biosafety Protocol of the Convention on Biological Diversity;
- rapidly developing the scientific and technical capacity to better identify, protect and recover species at risk within the framework of the federal/provincial accord and federal endangered species legislation, and continuing and expanding its work;
- incorporating into departmental practices the policies and guidelines adopted by the federal government in response to the CSTA reports *Science Advice for Government Effectiveness (SAGE)* and *Building Excellence in Science and Technology (BEST)*; and
- securing sufficient S&T capacity (internally or through partnerships) to be able to fulfil the Department's mandate.

Meeting these challenges will require Environment Canada to continue to develop the strategic vision necessary for meeting its overall mandate. Preparation of a comprehensive departmental research agenda and implementation of effective S&T management policies and practices to enable that agenda to be delivered effectively will provide a foundation for the future, an integrated framework for setting priorities, and a basis for seeking the new resources that will be necessary for meeting these goals.

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Fisheries and Oceans Canada

Fisheries and Oceans Canada's (DFO) stated S&T priorities during this period fell under three categories: fisheries and oceans science, habitat management and environmental science, and hydrography.

At DFO, science is used to achieve an important public policy goal, understanding how to conserve and wisely manage Canada's ocean resources for this generation and for the generations to follow.

This is demonstrated by a reliable scientific basis for fisheries resource conservation and the sustainable development of aquaculture, by scientific understanding of ocean and coastal waters and of aquatic ecosystems, and by technology transfer from aquaculture research projects to industry.

This commitment is also illustrated by healthy and productive aquatic ecosystems, improved scientific understanding of aquatic habitats, and effective integrated habitat management.

The picture would not be complete without mentioning the input necessary for safe and efficient navigation by the scientific understanding of water depths, tides, currents, water levels, and the geographic relationship between Canadian waters, adjacent waters and the Canadian landmass and improved access to hydrographic information.

DFO has many examples of science at work and science making a difference, including the following.

- The control of sea lamprey population in the Great Lakes has been a long-standing commitment by DFO. The St. Marys River remained a major trouble spot, producing more sea lamprey than all of the Great Lakes tributaries combined. These lamprey migrate downstream and feed on large numbers of fish in Lake Huron and northern Lake Michigan. The selected application of a lampricide, Bayluscide, eliminated 45 percent of the sea lamprey larvae. In combination with an extremely successful trapping and sterile male release initiative, the reproductive potential of sea lamprey in the St. Marys River has been considerably restricted.
- As part of the National Hydroacoustics Program, a demonstration trawl and acoustic survey was performed in May 1998. The demonstration successfully performed real-time echo integration. It also allowed the execution of several protocols on signal classification, multi-beam ensonification of cod, avoidance of trawl by fish, fish reaction to vessels and vertical distribution of groundfish. A paper was written as a result of this demonstration, and received the Best Paper Award for 1999 by the International Council for the Exploration of the Sea.
- DFO in Newfoundland is working in partnership with industry (Lotek Marine Technologies Inc.) and academia (University of Waterloo and Memorial University of Newfoundland) to develop

a new, advanced acoustic telemetry system. This system relies on an advanced coding and modulation scheme to provide precise localization of fish in high noise marine coastal environments. This coding scheme also enables discrimination of a large number of individual fish, without the use of multiple frequency channels, permitting simultaneous code searching to enhance temporal resolution of positioning.

This telemetry system has been used in a three-year study of the movement and habitat use of juvenile Atlantic cod (*Gadus morhua*) in inshore habitats in Newman Sound, Newfoundland. Data on fish position are coupled to high resolution (< 1 m accuracy) habitat mapping and bathymetry to permit the association of position with components of habitat. Diurnal patterns in juvenile cod habitat use were evident in the summer, but not in the fall. The frequency of occurrence of fish at various depths indicated a summer nocturnal movement to shallow inshore areas. These results have confirmed the potential of this "state-of-the-art" telemetry system in the study of habitat requirements and use by fish in juvenile life stages. These types of study are essential to provide the knowledge to support the Department's habitat responsibilities under the *Fisheries Act* and new conservation responsibilities under the *Oceans Act*.

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Health Canada

The long-term sustainability of the national health system is dependent on health-related S&T. Health Canada's S&T activities are mainly RSAs in natural sciences, engineering, social sciences, humanities, and R&D. Natural science activities are mostly in the health protection area, and social science activities support mainly population health and well-being, and the promotion of good health. A strong S&T base is required for anticipating, preventing and responding to new threats from emerging and re-emerging diseases. On the social sciences and humanities side, research is the pillar of the children's well-being, seniors', women's, and Aboriginal health programs.

Major S&T Achievements

Health Canada produced many studies and reports on factors affecting the health of Canadians, many of which are available on the Web site. The following were some significant reports.

- *Particulate Matter Science Assessment* — the re-examination of particulate matter air pollution and its possible consequences on human health and the environment.
- *Assessment and Management of Cancer Risks from Radiological and Chemical Hazards* — the assessment and management of ionizing radiation and genotoxic chemicals.
- *Persistent Environmental Contaminants and the Great Lakes Basin Population: An Exposure Assessment* — a scientific and technical report of human exposure to 11 priority contaminants in the environment.
- *The Health and Environment Handbook for Health Professionals* — basic environmental health concepts for health professionals and more experienced users.

Strategic Directions in S&T

The Health Protection Branch (HPB) transition exercise is intended to strengthen Health Canada and its partners and to better manage risks to the health of Canadians into the next century. A report published in 1998, *The Way Forward: More Effective Health Protection Laboratory Science and Testing*, concluded that HPB laboratories need to be redefined, streamlined and integrated, both to make more effective use of laboratory resources and to better meet the needs of Canadians. Three of the report's eight recommendations will affect the future direction of the S&T program. These recommendations are to implement internationally recognized quality management systems, to establish formal working partnerships with external laboratories and other sources of expertise, and to integrate the management and facilities of the laboratories.

The national strategy for a Canadian Health Infostructure uses information technology extensively to enhance the sharing of health knowledge and expertise. The Canada Health Infoway will become the key information and communications foundation for our health care system and for improvements to the health of Canadians. Important new services will emerge that will build on capacities for communication over long distances and for creating, analysing and accessing information. These information resources and communication technologies will help determine the quality of health care delivery in the

21st century. Researchers will benefit from a supportive environment that offers easy access to current information, as well as mechanisms for collaboration with their colleagues and other people involved in health care. The Canada Health Infoway will offer the channels to collect, analyse, extract and share information.

Research activities in Health Canada are re-orienting in response to the changing nature of health issues in Canada and the world. Health research involves many different organizations: from those that fund research, through those that perform it, to those that use it. Financial support comes from the federal and provincial/territorial levels of government, as well as the private and the voluntary sectors. Health research is conducted in universities, hospitals, research institutes and centres, and industrial and government facilities. Health research has been re-examined in the light of concerns about the rising costs of health care delivery, the recognition that the health status of Canadians is dependent on factors other than health care, and that the most effective policy is prevention rather than cure. A national task force on health research reported in 1998 that, despite the excellent health research work being carried out, there is significant room for improvement, as underfunding, fragmentation and lack of coordination of health research needed to be addressed. The task force recommended the establishment of the CIHR. The federal government committed itself in the February 1999 budget to the launch of the CIHR and to an increase (almost double) in resources for health research to nearly $500 million over a three-year period. The CIHR will replace the Medical Research Council on April 1, 2000.

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Industry Canada

Technology Partnerships Canada supports and advances government initiatives by investing strategically in R&D and innovation in environmental technologies, enabling technologies (advanced manufacturing and processing technologies, advanced materials processes and applications, applications of biotechnology, and applications of selected information technologies), and aerospace and defence. These investments are aimed at encouraging private sector investment to maintain and grow the technology base and technological capabilities of Canadian industry. Technology Partnerships Canada also supports the development of SMEs in all regions of Canada.

The CRC is a founding partner in the new National Capital Institute of Telecommunications (NCIT), along with the University of Ottawa, Carleton University, NRC, Nortel, Newbridge, Bell Nexxia, QNX Software Ltd. and the Regional Municipality of Ottawa-Carleton. NCIT's headquarters in a new building at CRC, which also houses Industry Canada's Certification and Engineering Bureau, will allow professors, students and other researchers to work closely with CRC researchers on leading-edge R&D. Notable achievements at CRC have included demonstrations of real-time transmission of 3D video using CRC-developed equipment; DND's deployment of CRC-developed equipment and systems; the graduation of seven high-tech start-ups from the Innovation Centre; and the signing of collaboration agreements with labs in Japan, India and Singapore.

Industry Canada also promotes private sector innovation by facilitating the development of Technology Roadmaps to identify the critical technologies required by an industry to meet future market demands. The Department is also involved in developing high growth opportunity sector strategies to build knowledge-intensive sectors such as aerospace, biopharmaceuticals, biotechnology in agriculture, fisheries and forestry, environmental technologies, and information and telecommunications technologies, including new media learning solutions and telehealth. In addition, Industry Canada works toward developing sector innovation strategies to identify technology priorities and projects that will strengthen Canadian knowledge-based manufacturing, contribute to improving productivity and reduce the innovation gap.

The Minister of Industry has a horizontal policy coordination role for S&T in the federal government. In this context, Industry Canada monitors implementation of the federal S&T strategy, and provides secretariat support to the ACST and the CSTA.

Industry Canada develops and applies state-of-the-art information technologies for the collection and dissemination of information on science, technology and innovation opportunities **(http://strategis.gc.ca)**, as well as for the promotion of a strong science culture in Canada.

Major S&T Achievements

- SchoolNet — Canada became the first nation in the world to connect all of its schools and libraries to the Internet on March 30, 1999. Results of a national on-line survey and estimates from provinces

indicate that there are approximately 229 737 connected computers in Canadian schools.

- The Community Access Program — Some 4544 community access sites have been established in rural and remote communities since the program began and an urban element of the program has been launched.
- Computers for Schools — More than 70 000 computers were delivered to schools and libraries across Canada during the past fiscal year, bringing the total to approximately 195 000 since the program began.

Since 1996, TPC has invested $972 million in 105 R&D projects, which will leverage $4.5 billion of innovation spending. These contracted projects, if successful, are forecasted to create or maintain more than 22 000 jobs.

The National Fuel Cell Research and Innovation Initiative was announced on August 10, 1999, at the NRC Innovation Centre in Vancouver by the Honourable John Manley, Minister of Industry, the Honourable Ralph Goodale, Minister of Natural Resources Canada, and Secretary of State Raymond Chan representing the minister responsible for British Columbia. This $30-million, five-year national initiative was funded equally by the NRC, NSERC and NRCan.

The Canadian Biotechnology Strategy (CBS), a multi-department initiative, stimulated significant funding in the 1999 budget for biotechnology research on genomics. This strategy also resulted in the creation of an expert scientific panel, under the Royal Society of Canada, to examine developments in food biotechnology, the work of the Canadian General Standards Board on voluntary labelling of genetically modified foods, and resource allocations under the CBS Fund from 1999 to 2002.

The Automotive Competitiveness Review (ACR) was completed in June 1998. In August 1999, the High Growth Opportunity Sectors (HGOS) initiative picked up on the ACR results, taking them one step further, by identifying elements of growth in the industry and by proposing a framework for government action. Its focus was primarily on the parts sector and on the initiatives required to position this sector to become a global competitor. The HGOS examined four areas in which government could introduce measures to stimulate growth in the sector: technology, human resources, standards and regulations, and marketplace development. However, the initiative's primary focus has been on raising the R&D capability of the Canadian automotive parts sector, and the consequent effects on skills development.

The ACST received the reports of two Expert Panels, on Commercialization and on Skills. The ACST met with the Cabinet Committee on the Economic Union twice to present recommendations based on these reports. The ACST formed an Expert Panel on Canada's International Science and Technology that will report in 2000.

In 1999, the CSTA presented two reports to the Cabinet Committee for the Economic Union that addressed 1) principles and guidelines for the effective use of science advice in government decision making, and 2) the roles of the federal government in the performance of S&T and its capacity to fulfil those roles. Cabinet received the CSTA's reports and has asked it to undertake an examination of excellence in federally performed S&T.

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Medical Research Council of Canada

The Medical Research Council of Canada (MRC) is the federal agency with primary responsibility for funding, promoting and sustaining basic, applied and clinical research in the health sector. In 1998–99 the MRC and a broad range of partners and stakeholders in health research came together to promote a common cause: a new vision for health research in Canada. This vision is predicated on the belief that an increased investment in extramural health research is an indispensable step in improving the health of Canadians. Further, this investment must be delivered through a system in which the funders, performers and consumers of research, in every area of health, have jointly developed strategic priorities and work in concert to deliver research results to Canadians, as efficiently and effectively as possible. This is the vision for the CIHR.

Major S&T Achievements

For the MRC, 1998–99 will be remembered as the turning point at which the federal government recognized the importance of national health needs and gave the go-ahead for the establishment of the CIHR. The CIHR will transform the Canadian health research enterprise, improving the rate, depth and focus of our research efforts by

creating an environment of unprecedented collaboration, and partnership in support of health research.

In 1998–99, the MRC funded more than 3000 research projects, through a variety of mechanisms that ranged from individual research grants to Networks of Centres of Excellence. These projects covered the full spectrum of health research questions, from those that probe the structure of molecules to those that ask about the relationship between community behaviours and health.

The MRC invested $23.4 million in programs directly targeted at the training of more than 1350 promising students and post-doctoral fellows, an increase of more than $5 million over 1997–98. In addition, the MRC invested $22.2 million in career awards for more than 475 of Canada's most outstanding health researchers.

MRC continues to invest in research focussed on health issues that have been identified as special threats to the health of Canadians, such as AIDS, breast cancer and diabetes. The MRC and partners earmarked more than $18 million for research in those areas. The MRC also invested in a genome research program in recognition of the need to ensure that Canada is fully prepared to participate in the expanding field of genome science.

In accordance with the CIHR vision, the MRC has been working to diversify and strengthen Canadian health research through partnership with others. The MRC undertook the following new partnerships and joint projects in support of excellence in health research.

- **Partnership Challenge Fund** — Twenty-four health charity and non-profit organizations partnered with the MRC to create an investment of up to $3.4 million over two years. This fund will provide for the training of about 80 young people in all fields of health research, in accordance with the objectives of the partner organizations. The Partnership Challenge Fund expresses, in a tangible way, the shared values of the MRC and non-governmental organizations that seek to improve the health of Canadians through new knowledge generated by research.
- **Canadian Neurotrauma Research Program** — Eight organizations, including the MRC, the NeuroScience Canada Foundation and the Rick Hansen institute, have joined forces to support neurotrauma research activities. The Canadian Neurotrauma Research Program will foster the exchange of ideas and innovation in research with a view to providing better treatment for brain and spinal cord injuries.
- **Research Chairs in Women's Health** — Canada's first clinical research chairs in women's health were created through partnership with Wyeth-Ayerst Canada Inc., a member of Canada's Research-based Pharmaceutical Companies.
- **Regional Partnerships Program** — Eight health researchers at the University of Saskatchewan were the first to benefit from a new research program aimed at strengthening the health research community in Saskatchewan. The Saskatchewan Regional Partnerships Program is a joint initiative of the MRC and the government of Saskatchewan that will provide $10 million for health research in Saskatchewan over five years. Similar partnership agreements are under way or under discussion with the governments of Manitoba, New Brunswick, Prince Edward Island, Nova Scotia and Newfoundland.

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National Research Council Canada

On April 27, 1999, the Chief Justice of Canada, Antonio Lamer, presented the Canada Gold Medal for Science and Engineering to Dr. Keith Ingold. A scientist at the National Research Council Canada (NRC), Dr. Ingold was honoured for pioneering a new field of chemistry and discovering the importance of Vitamin E in medicine and health. Vitamin E deficiency is thought to lead to cholesterol buildup, hardening of the arteries, muscle damage and heart diseases. This can occur when oxygen reacts with unstable molecules called free radicals to produce peroxy radicals associated with heart disease and stroke. NRC research revealed that small amounts of the vitamin act as an antioxidant, blocking the reaction of oxygen with free radicals.

Saskatoon-based MicroBio RhizoGen Corp. (MBR) is a leader in the development, production and worldwide distribution of legume inoculants, which are naturally occurring bacteria that enhance biological nitrogen fixation in legume and forage crops. By refining long-standing inoculant technology based on liquid and peat delivery systems, MBR saw its annual sales increase from $30 000 in 1989 to $3.5 million in 1998. MBR President Mr. Murray Trapp credits a 12-year alliance with NRC's IRAP for much of his company's accomplishments. Most recently, MBR accessed financial support for the launch of their

granular inoculant through the Precommercialization Assistance (PA) Program, a joint venture of IRAP and Industry Canada's TPC program. The PA Program is designed to allow companies to take new technologies from the lab to the marketplace.

IatroQuest Corporation, an Ottawa company spun off from the NRC, has made significant advances in developing rapid sensing and diagnostic systems for the detection and identification of chemical and biological warfare (CBW) agents. The company's directions were highlighted this past December at the 6th Annual Ottawa Life Sciences Council National Conference. IatroQuest co-founders, Dr. David Armstrong and Dr. Martine Lafrance, spoke of the ever-increasing global need for CBW agent detection technology. The company's focus is on developing next generation bio-sensing and ultra-high throughput diagnostic systems for the defence, medical and occupational health sectors. Less than a year old, IatroQuest has already captured the attention of major players in industry and government.

The Canadian Centre for Housing Technology (CCHT) was officially opened in October 1999 in Ottawa. Consumers, home builders and manufacturers will benefit from research taking place at this unique, new housing research facility. The CCHT will encourage the development and use of innovative Canadian technologies in both domestic and export housing markets. The Centre is a $1.5 million partnership of the NRC, Canada Mortgage and Housing Corporation, and NRCan. The research houses will evaluate the performance of innovative products and building techniques. Testing products under realistic conditions provides manufacturers and home builders with a more accurate picture of the effectiveness of new products and techniques.

The NRC's Institute for Information Technology hosted two events this past October at the NRC's Sussex Laboratories: the First International Workshop on Agents for Telecommunications Applications (MATA '99) and Multimedia Modelling '99 (MMM '99). MATA '99 provided an opportunity for researchers, software and application developers, and computer network technologists to discuss new developments on mobile agent technology, which have applications that include intelligent information retrieval, network and mobility management, and network services. This workshop was the result of a multi-year collaboration on network management with *Centre National de la Recherche Scientifique* and *Université Paris 6* in France. MATA '99 was organized in conjunction with the University of Ottawa, a partner in the "Mobile Agents Alliance," which also includes local companies, Mitel and Tanager software. MMM '99 was an international conference, co-sponsored with the University of Ottawa, that provided a unique opportunity for researchers, software and application developers, and computer graphics technologists to discuss new developments in multimedia modelling technologies and applications to virtual reality, speech and music modelling, and education.

The Virtual Environment Technologies (VET) Centre of the NRC's Integrated Manufacturing Technologies Institute was opened in September by the Honourable John Manley, Minister of Industry. The VET Centre operates under a unique relationship between the NRC and its industry collaborators and contributors — SGI Canada, Electrohome Limited/Fakespace, Inc., the Diesel Division of General Motors, and the University of Western Ontario. It houses the world's most extensive and innovative collection of virtual reality equipment — an immersion room, immersive design rooms, immersive power walls, work stations and head mounted displays — all driven by powerful graphic computers and visualization devices. "The most advanced and comprehensive research and design facility of its kind in the world, the VET Centre offers leading-edge tools and techniques that increase the competitiveness and efficiency of a wide cross section of Canadian industries," said Minister Manley. "A national facility, this Centre acts as a catalyst in southwestern Ontario, the most highly concentrated manufacturing area in Canada."

The NRC plays a lead national role in reducing technical barriers to trade, helping Canadian companies and emerging industries compete in the global marketplace. This is done largely through the NRC's Institute for National Measurement Standards participation and leadership on more than 150 international metrology committees working on international agreements. These agreements led our trading partners to recognize the equivalence of measurement standards as the basis for expanding international trade. A notable recent example of groundbreaking international cooperation was the signing of the Mutual Recognition Agreement in October 1999.

The Canadian-European Research Initiative on Nanostructures (CERION) establishes Canada as a major collaborative partner in European nanostructure research. It is coordinated by the NRC Institute for Microstructural Sciences in Canada and involves eight Canadian and 17 European nodes, participating in research on nano-electronics, nano-optics and the technology of advanced nanostructures. Two industrial firms, Nortel and Thompson, are participants in the initiative. Building on partners' complementary knowledge, expertise and facilities, CERION coordinates research, fosters collaboration, and reports on new developments.

In 1998, the NRC's Biotechnology Research Institute (BRI) signed a collaborative agreement with the Biological Engineering Division of the German Federal Biotechnology Research Institute. Expected benefits include an increased number of researchers working in Bioprocessing in Canada, and increased industrial investments and revenues in Canada as the collaboration could serve to attract German

investors to Canada using the Bioprocess Sector as a technological and scientific magnet. In addition, the BRI and other members of the Canadian biotechnology establishment will gain added visibility, and Canadian companies, in particular SMEs, will gain easier access to the German biotech market.

Through its ongoing collaborations with Dr. Carolyn Mountford of the Royal North Shore Hospital in Sydney, Australia, the NRC's Institute for Biodiagnostics in Winnipeg is developing a breast-specific Magnetic Resonance Imaging coil. Using this unique coil, clinicians will be able to visualize a lump, compare the spectral data from the lump with that in its data bank, and identify whether the lump is benign or malignant — all within a 20- to 30-minute hospital appointment. Multi-site clinical trials are just beginning at the Beth Israel Hospital (Boston, U.S.A.), the Karolinska Hospital (Stockholm, Sweden), the Royal North Shore Hospital (Sydney, Australia) and the Health Science Centre (Winnipeg, Canada).

Analysts worldwide rely on the NRC's Institute for Marine Biosciences Certified Reference Materials Program to provide quality instrument calibration standards and certified materials; trace elements in marine sediments, biological tissues and seawaters; and shellfish toxins. Laboratories use IMB's products to monitor seafood safety, study environmental hazards and develop quality assurance programs.

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Natural Resources Canada

Major S&T Achievements

The following are examples of Natural Resources Canada's (NRCan) latest S&T achievements.

- **National Forest Health Assessment** — The report, *Forest Health in Canada: An Overview 1998*, the first national synopsis of the health of Canada's forests, was published with contributions and the advice of experts in Canadian governments, universities and industry. The report represents a new approach to assessing forest health in that Canada's eco-zones are used as the basis for the assessment.
- **Risks of Exotic Forest Pests** — The growing threat of the entry of non-indigenous or "exotic" forest pests poses serious risks to native trees and forest ecosystems and has major economic implications to Canada. The Department took the lead in establishing collaborative research and monitoring programs with the CFIA, the U.S. Forest Service, the U.S. Department of Agriculture, and with researchers in China and Russia.
- **Climate Change Forest Research** — NRCan produced a new three-year climate change forest S&T framework that will more than double resources directed at research and monitoring activities to enable Canada to meet its international reporting requirements related to Canada's forest carbon cycle, and to plan for broad-scale adaption strategies.
- **Community Energy Systems** — The CANMET Energy Technology Branch of NRCan was selected for the implementation of a project for waste heat recovery, based on novel concepts in district heating and cooling applications in the Hamilton district. The feasibility study identified a possible 114 MWt of heating and up to18 MWt of cooling for the city core.
- NRCan's **Photovoltaic Program** — The program focusses on the development and implementation of photovoltaic technologies in domestic and international markets where it is economically feasible. The majority of the projects are conducted in partnership with industry, universities, research organizations, utilities and other levels of government. Some of the key activities were three demonstration systems in Iqaluit, Inuvik and Nahanni Park, and the development of new technologies such as the snow removal system.
- **Super E** — NRCan has entered into a joint venture agreement with a Japan-based company to build a Super E™ demonstration home in Sapporo, Japan. This project involves the demonstration of a number of Canadian energy-efficient and healthy products adapted and integrated with Japanese building components and practices. NRCan has provided specific design recommendations that promise to result in approximately $10 000 of additional value-added Canadian energy-efficient products and services incorporated into the pilot project.
- **Canada Centre for Remote Sensing Fire M3** — This is a national system that automatically monitors, maps and models forest fires across Canada. Satellite technology detects and positions hot spots, which are then entered into a geographic information system that allows automated mapping and measuring. The Fire M3 was developed by a team from the Canadian Forest Service and the Earth

Sciences Sector (Canada Centre for Remote Sensing) and has been recognized recently with two prestigious national awards: the bronze award for Excellence in the Management of Information and Technology in the Public Sector, presented during Technology in Government week; and the Agatha Bystram Award for Leadership in Information Management by the Council of Federal Libraries.

- **Tactile Atlas of Canada** — A prototype of the Tactile Atlas of Canada was demonstrated at the ICA '99 Conference and was tested in schools for blind persons. It resulted in a tangible order of a set of atlases for use at the W. Ross Macdonald School. Based on a Canadian invention of a special raised ink powder, high quality tactile maps can be produced. A map of Ottawa was presented at Showcase of Canadian Assistive Technology in May 1999.
- **Toporama** — The Centre for Topographic Information (Sherbrooke) has developed a new method of accessing geographical information, called "Toporama." Toporama is a representation of the centre's national data base of topographic images and has been available free via the Internet since December 1, 1999.
- **Downhole Seismic Imaging Consortium** — NRCan's integral participation with industry and academia is developing and refining techniques to minimize the need for costly exploratory drilling programs. A new, digital generation of geophysical tools, developed by NRCan for improved measurement of rock properties in land-based and marine exploration boreholes, was transferred to Canadian industries. As a result, Canada's resource exploration and environmental industries are afforded a competitive edge on the global scene.
- Iqaluit-based **Canada–Nunavut Geoscience Office** — With the inauguration of Nunavut and in collaboration with Indian and Northern Affairs Canada and Nunavut Sustainable Development, NRCan established this office to support sustainable development in the new territory, geoscience capacity building and education and training for the residents. The newly compiled Geology of Nunavut poster map was distributed to all Nunavut schools and Member of the Legislative Assembly offices. Current studies of bedrock and surficial geology, geochemistry and glacial history are revealing new mineral resource potential for Nunavut, and have stimulated increased activity by the private sector during the past exploration season.
- **Gold Processing** — NRCan was instrumental in creating national research consortia to improve gold processing through the development and implementation of technology innovations. Impressive results from the research of these consortia have resulted in further collaborative projects with AMIRA (the Australian Mining Industry Research Association). This newest member attested to a 2-percent increase in gold recovery, for an additional revenue of $988 000 per year; this follows on the productivity improvements realized by earlier members.
- The **Canadian Lightweight Materials Research Initiative (CliMRI)** — With an initial suite of 11 projects, the CliMRI will help Canadian companies play a key role in developing lightweight and high-strength materials for vehicles. The program started in April 1999, and is supported by the Panel on Energy Research and Development (PERD) and by industry, to a value of about $1.2 million. The main goals of CliMRI are to reduce greenhouse gas emissions through improved vehicle efficiency, and to improve the competitive position of Canadian operations involved in the vehicle manufacturing chain.

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Natural Sciences and Engineering Research Council of Canada

The Natural Sciences and Engineering Research Council of Canada (NSERC) invests in people, discovery and innovation to build a strong Canadian economy and to improve the quality of life of all Canadians. It supports research in universities and colleges, research training of scientists and engineers, and research-based innovation. The Council promotes excellence in intellectual creativity in both the generation and use of new knowledge, and it works to provide the largest possible number of Canadians with leading-edge knowledge and skills to help Canada flourish in the 21st century. NSERC fulfils its mission by awarding scholarships and research grants through peer-reviewed competition, and by building partnerships among universities, colleges, governments and the private sector. NSERC is committed to institutional innovation in achieving its mission.

Major S&T Achievements

- In 1998–99, nearly 13 000 university students and post-doctoral fellows were supported by NSERC. Another 2900 university

technicians' salaries were paid from NSERC grant funds awarded to university researchers. In total, NSERC created or sustained more than 15 000 high-technology jobs in which people are learning the most advanced knowledge. Further, research spending from NSERC grants on goods and services (e.g. materials, scientific equipment and travel) indirectly created or sustained roughly another 1500 jobs this year.

- Annual surveys of former holders of NSERC post-graduate scholarships show that 65 percent of respondents are active in R&D, using their training for one of the primary purposes of the program. The unemployment rate for respondents is estimated to be less than 2 percent, with 70 percent of respondents indicating that their graduate training was "critical" to their careers. Furthermore, 96 percent of the respondents completed the degree (master's or doctorate) for which they received NSERC funding.
- NSERC's Industrial Research Fellowships (IRF) program has contributed significantly to the number of doctoral graduates working in Canadian labs. More than 15 percent of Canadian industrial researchers with a PhD have been funded by NSERC through its IRF program. Seventy-five percent of former IRFs from 1980 to 1998 are still working in Canadian industries. Seven percent have taken to academic positions in Canadian universities, and a similar percentage of IRFs have left the country.
- University researchers produce most of Canada's natural sciences and engineering (NSE) publications. Of the 15 000 university papers produced annually, more than 80 percent can be attributed to NSERC-funded researchers. Furthermore, Canadian researchers in the NSE are collaborating with international partners at an increasing rate and benefiting from the globalization of R&D. In 1997, one third of Canadian papers in the NSE were written with international partners. A recent survey showed that 85 percent of NSERC-funded researchers in the earth sciences collaborate with colleagues in 66 countries.
- One of the more tangible outcomes of NSERC-funded research is the creation of a company. A survey conducted this year found that at least 111 spin-off companies have been started from the results of research partially funded by NSERC over the past 21 years. They employ more than 7500 Canadians and generate an estimated $1.3 billion in annual revenue.
- Since the beginning of NSERC's university-industry research programs, more than 1200 companies have participated, increasing from fewer than 50 companies in 1983 to more than 500 businesses participating in 1998. On average, 100 new firms are working with NSERC every year. NSERC is well known to companies heavily involved in R&D. Thirty-seven of the top 50 Canadian R&D companies (as ranked by *The Globe and Mail*, 1998) have funded university research jointly with NSERC.
- Over the past 11 years, contributions from NSERC's partners, mainly industrial, have grown tremendously. From just over $23 million in 1988–89, contributions in 1998–99 reached $83 million, for a growth rate of 260 percent over the 11-year period. The ratio of partner contributions to NSERC funding has been steadily increasing over the last 11 years. From a low of 1.13 in 1988–89, this ratio now stands at 1.7. Put another way, for every dollar NSERC puts on the table for a university-industry research grant, its partners contribute $1.70.
- Canadian universities are increasingly using licensing to commercialize their research. Revenue to Canadian universities from licensing has jumped from about $5 million in 1991 to almost $25 million in 1997. Most of these revenues can at least be partially attributed to funding from NSERC and the MRC.

Strategic Directions in S&T

NSERC undertook a year-long review of its strategy. NSERC's previous strategy document was published in 1994 and, since then, the research environment has changed dramatically.

The most important conclusion reached was that the environment within which the Council operates is changing so rapidly that publishing a strategy document every few years will no longer suffice. Rather, NSERC's strategy must become an ongoing planning process. NSERC must be flexible, innovative, strategic and responsive to meet the changing needs of Canada and the natural sciences and engineering research community. At the same time, NSERC will preserve its core priorities of investing in discovery and innovation and the people who make it happen.

Two other conclusions of the strategy review are worth noting. First, NSERC has expanded its eligibility to include colleges. Shifting from the current practice, college professors in partnership with their university colleagues are now eligible for project research funding. NSERC will review this change in two to three years and consider expanding college eligibility to other NSERC program funding.

The second conclusion relates to NSERC's influence. Although NSERC is already influential in areas beyond its program reach, there are several ways in which NSERC plans to become more influential. One example is by entering into partnerships with agencies responsible for elementary and secondary education to help improve early education in math and sciences. In addition, NSERC is becoming actively engaged in science promotion, by assuming the responsibility for the Michael Smith Awards for Science Promotion and creating a new Science for Youth program.

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(Searchable data base of grants and scholarships awarded by NSERC since 1991)

Parks Canada

Parks Canada plays a leading role in federal government activities related to recognizing places representative of Canada's natural heritage and places of national historic importance, and in protecting and presenting these places to the public. The legislation mandating Parks Canada activities includes the *Parks Canada Agency Act*, the *National Parks Act*, the *Historic Sites and Monuments Act*, the *Heritage Railway Stations Protection Act* and the *Department of Transport Act*.

Parks Canada's S&T focusses on mission-oriented research and related scientific activities. To the extent that its mandate allows, Parks Canada facilitates pure and applied research by universities and other agencies. Where circumstances and resources warrant, the Agency may provide secure sites and logistical support for short- and long-term studies.

Canadian National Parks

Comprehensive resource inventories and analyses are conducted at each of Canada's 39 national parks and two national marine conservation areas. The inventories provide maps, data and reports based on systematic mapping of ecosystem components like soils, vegetation and landforms, monitoring of climate, wildlife populations and hydrology, and ecological land classification. The analyses use remote sensing, geographic information systems (GIS), statistics and laboratory techniques to identify key features and the links between ecosystem components, assess the socio-economic impacts and benefits of park establishment and visitor activities, assess sensitive resources for zoning and planning, and help in the development of interpretive programs. Many of these data sources and techniques are also used to identify the potential national parks and marine conservation areas needed to complete the park systems, and assess boundary options.

Specialized studies are also conducted to understand particular issues, such as the population dynamics and habitat relationships of a species, the environmental impacts of a park development or visitor activity, or fire history to help design a fire management program. Some applied research is also conducted to solve multi-park or long-term problems, often in association with other government or university partners. One example is the creation of a DNA tissue bank to help understand the genetic diversity of selected species for conservation and forensic purposes. Another example is the development of an integrated national data base of environmental maps and species lists to support periodic assessment of the state of the parks as required by Parliament. A third example is the research at Pukaskwa National Park on the effects of human-induced stress and landscape disturbance on the population demographics and predator/prey relationships among wolves, moose and caribou. A fourth example is the information being collected in the mountain parks to find ways to mitigate the impact of the highway and railway corridor on wildlife populations.

Canadian National Historic Sites

Parks Canada is one of the principal cultural resource management organizations in Canada. Places of national historic significance are identified and designated as Canadian national historic sites on the basis of research and analysis carried out by historians, architectural historians and archaeologists. Parks Canada administers 144 Canadian national historic sites (CNHS) and advises on more than 700 CNHSs owned and operated by others. Parks Canada manages a vast range of cultural resources such as buildings, structures, landscapes, archaeological sites and specimens, and historic objects. It provides professional and technical advice on federal heritage buildings, archaeological resources on federal lands, shipwrecks and heritage railway stations.

Historians, archaeologists, cultural resource managers, architects, engineers, curators and material researchers work in a multidisciplinary setting to ensure the commemorative integrity of Canadian national historic sites and the protection of cultural resources on lands that Parks Canada administers. These specialists build on science-based knowledge to safeguard the cultural resources in Parks Canada's care and to communicate their historic value. Data bases, GIS and other recording tools, historical and archaeological research, condition assessment and on-site monitoring are used to ensure preventive care, maintenance, and conservation treatment of resources showing degradation. Architects and engineers seek new ways to extend the life cycle of historic structures and assess risk associated with various conservation interventions. Assessing the residual strength of timber using non-destructive testing technology is an example of this kind of

specialized study. In another example of science applied to protecting and presenting Canada's national historic sites, specialists are involved in a metallurgical study of samples associated with iron working and assaying at the 16th century Frobisher Site CNHS on Kodlunarn Island, Nunavut.

Major S&T Achievements

Due to the mission orientation of Parks Canada's S&T, it is inappropriate to highlight any specific item in any given year. Parks Canada's more significant role is to provide a platform and anchor for long-term, multi-partner science activities. Major examples include providing an integrated monitoring site at Kejimkujik National Park for the study of long-range transport of air pollution, and the inclusion of 18 parks in the national Ecological Monitoring and Assessment Network coordinated by Environment Canada. In total, there are more than 1000 research and monitoring studies in progress across the 39 national parks.

Strategic Directions in S&T

The March 2000 report to the Minister of Canadian Heritage, from an Expert Panel on the Ecological Integrity of Canada's National Parks, made a number of recommendations calling for enhanced links to the S&T community and a greater internal science capacity, in order to enhance scientific input into park management. In response, the Minister identified a wide range of actions to be undertaken, including the development of a national parks science strategy focussing on staffing requirements within Parks Canada, and on partnerships with government, university and other stakeholders. The Panel's recommendations and the Minister's subsequent action plan resonate strongly with the CSTA's reports on science advice and capacity: the SAGE and BEST reports. Other S&T-related recommendations of the Panel included better management and quality control of data, and an enhanced program of appropriate ecological integrity training for all staff. The Panel also recognized the value of traditional knowledge in ecosystem management, so that naturalized knowledge might complement Western science in guiding ecosystem management decisions and environmental education. Not only will the Panel's recommendations and Minister's responses guide park management for years to come, the report also provides a blueprint for the maintenance of protected areas with the aid of science. The report and the Minister's action plan can be viewed at **http://ecolog.org/**

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Social Sciences and Humanities Research Council of Canada

The Social Sciences and Humanities Research Council of Canada (SSHRC) is the key national agency responsible for supporting university-based research in the social sciences and humanities and to chart directions for the Canadian research effort in these fields. SSHRC supports basic research, targeted research on issues of national importance, the training of highly qualified personnel, and the broad dissemination of knowledge for the benefit of Canadian society. Its programs and strategies promote research excellence, innovation, productivity and partnerships with users of research in public, private and community sectors.

Major S&T Achievements

SSHRC is implementing its Innovation Scenario, a three-year action plan to address knowledge gaps in key policy areas, to train youth for employment, and to sustain a strong innovation capacity through basic research and training.

The following are examples of SSHRC's achievements in 1998–99.

- Invested $37.8 million in 1800 research projects and $31.4 million to help train more than 1600 graduate students in the social sciences and humanities.

- Implemented three new themes to generate strategic, policy-relevant knowledge on Social Cohesion in a Globalizing Era; Society, Culture and the Health of Canadians; and the Challenges and Opportunities of a Knowledge-based Economy.
- Concluded four new joint initiatives to co-develop and co-fund research with external partners:
  — Federalism and Federations, with Intergovernmental Affairs;
  — Valuing Literacy in Canada, with the National Literacy Secretariat and HRDC;
  — The Canadian Tobacco Research Initiative, with the National Cancer Institute of Canada; and
  — Relationships in Transition, with the Law Commission of Canada.
- Implemented the Community-University Research Alliances Program to develop knowledge and expertise geared to community development through innovative alliances between universities and organizations in communities across the country. More than 175 applications were received from universities across the country and more than 300 organizations participated in the first competition under this new program.
- Developed the Canadian Initiative on Social Statistics, in partnership with Statistics Canada, to maximize the use of social statistics in support of effective policy making on key national issues.
- Mobilized the social sciences and humanities research communities to help design the CIHR.
- Organized a major awareness event on Parliament Hill to profile the contribution of human science research on key issues of importance for the government and Canadians.

Strategic Directions in S&T

SSHRC will continue to build knowledge and skills that help sustain innovation, competitiveness and quality of life through the implementation of its Innovation Scenario.

In line with the Scenario, SSHRC is developing new initiatives to enhance strategic training opportunities for youth, to promote research on theme areas and joint initiatives that respond to emerging socio-economic issues, and to reinforce the research and training base. SSHRC will continue to expand its partnerships with the private, public and voluntary sectors and to enhance its knowledge brokering capability to make the results of SSHRC-funded research widely available.

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Statistics Canada

Historically, Statistics Canada's program has been structured to provide macro-economic, micro-economic and socio-demographic statistics, and statistical information in public institutions and programs. Such information continues to be relevant. However, emerging issues prompt demands for new kinds of data. For example, needs have been expressed for improved information on education and the transition from school to the workplace, the health of Canadians and the systems that support it, the effects of globalization, the functioning of Canada's economy, the factors affecting Canada's competitiveness in world markets, the impact of S&T, the outcomes of government programs, and the status of various subpopulations within Canadian society.

Maintaining the relevance of the Statistics Canada program by meeting information needs such as these will always be a primary goal. To maintain a high level of program relevance, Statistics Canada relies on two pivotal instruments. These are the advice and guidance it receives from external consultative bodies; and the Agency's rigorous planning and performance monitoring system and processes. The external consultative bodies are the National Statistics Council; professional advisory committees (including the Advisory Committee on Science and Technology Statistics); bilateral relationships with key federal departments; and the Federal-Provincial Consultative Council on Statistical Policy. As part of ensuring the relevance of its products, the Agency coordinates the Data Liberation Initiative, which provides affordable access to statistical files and data bases in support of social science research and teaching (*see* **http://www.statcan.ca/english/Dli/dli.htm**).

As well as being the largest social science department or agency in the federal government, Statistics Canada maintains a growing program

of S&T statistics as part of the Information System for Science and Technology Project. It includes surveys of the activities of R&D, invention, innovation, technology diffusion and related human resource development, measures and analyses of linkages among actors in the S&T system, and analyses of outcomes. The program is progressing towards the analysis of the impact of S&T activity and it is guided in this by the document *Science and Technology Activities and Impacts: A Framework for a Statistical Information System 1998* (Cat. No. 88-522-XIB).

The survey of federal science activities provides information on what the government spends on S&T, where it spends its S&T resources (sector and region), and on what its resources are spent (socio-economic objective). A longer-term objective of this and the rest of the S&T statistics program is to demonstrate what the government gets for its S&T spending. (*For more information, see* **http://www.statcan.ca/english/research/scilist.htm**)

Recent findings include the relationship between advanced manufacturing technology and competitiveness, the rates of adoption of the Internet and electronic commerce in the financial services industry, the rates of use and planned use of biotechnology in firms. This work has been in support of the federal ACST, and the Canadian Biotechnology Strategy. Recent findings are summarized in a newsletter, the *Innovation Analysis Bulletin*, available free of charge on Statistics Canada's Web site.

Strategic Directions in S&T

Strategic planning is one mechanism for ensuring the relevance of programs. In the case of S&T statistics, Statistics Canada has prepared a *Five-Year Strategic Plan for the Development of an Information System for Science and Technology* (Cat. No. 88-523-XIE). The plan takes the program from its developmental stage, funded by Industry Canada from 1996 to 1999, to a new level as an integral and ongoing part of the work of the agency. The funding for this strategic development is part of a $20-million-a-year package, coordinated by the federal Policy Research Committee, to reduce gaps in the statistical system.

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Transport Canada

Major S&T Achievements

The Joint Winter Airport Runway Friction Measurement Program, initiated in 1996, continues to expand its data base on the many factors that affect runway friction. Canadian participants are Transport Canada groups, the NRC and DND; international members include the U.S. Federal Aviation Administration, NASA, the U.S. Air Force, the International Civil Aviation Organization, the European Joint Aviation Authority, French and Norwegian civil aviation authorities, aviation industries and equipment manufacturers. Two important findings of the 1998–99 winter work are that, contrary to earlier theories, aircraft groundspeed has a negligible effect on braking coefficients, and vertical load is a primary influence on friction measurements.

Transport Canada's Marine Safety Directorate, the U.S. Coast Guard and the NRC's Institute for Marine Dynamics began work to validate a water forces analysis capability computer program for assessing the effectiveness of life jackets. The validation tests are based on the performance of a newly developed Sea-Water Instrumented Mannequin (SWIM). SWIM mimics the movement and dynamics of a person in water, and allows testing over a much broader range of sea states and environmental conditions than was possible with human subjects.

Performance trials of a new steered-frame freight car truck took place in 1998–99 in British Columbia. Parallel tests with standard freight car trucks provided a baseline for comparison. Instrumented wheelsets on each truck measured wheel-rail forces and lateral-vertical force ratios, while the angles of attack of wheel to rail were measured on the curves of the winding test track. The trials demonstrated the superiority of the steered-frame freight car truck on all counts.

Two innovative intermodal initiatives began this year. The first involves analysis of business processes and information interchange among Port of Montréal stakeholders (trucking, rail, shipping, and port authorities) and development of Web-based Electronic Data Interchange services at the port. The system will eliminate paperwork and reduce communication delays and congestion at the terminal. The second project will integrate data from automatic equipment identification tags and state-of-the-art optical character recognition technology to allow automated identification of rail cars and containers at the port.

The long-term Transport Canada-U.S. security R&D program tripled in value in 1998–99. The cooperative program's first priority is the development and effective use of explosives detection systems for carry-on and checked baggage.

Canada's Aging Population: Transportation Safety and Security, a report released in July 1998, is a valuable reference for policy makers, rehabilitation professionals, transit authorities, researchers and advocate groups. Based on an extensive literature review and input from experts in the field, it covers current initiatives in all transportation modes. Its recommendations for best practice in each mode stress the importance of consulting with elderly travellers before implementing changes.

Strategic Directions in S&T

S&T is essential to advancing Transport Canada's mission, achieving its strategic objectives and developing the innovations and technologies needed to improve the transportation system. R&D activities undertaken by Transport Canada will advance the Department's strategic objectives as outlined in the department's business plan for 2000–03. An R&D Strategic Plan will be developed in 2000 to provide direction for decision making in support of emerging priority areas, including modern safety management systems, sustainable transportation, climate change, efficiency, accessibility and the potential of new technologies.

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Western Economic Diversification Canada

Since its inception, Western Economic Diversification Canada (WD) has been involved in innovation-related programming as part of its mandate. Its current reliance on federal-provincial cooperation, strategic partnership and flexible delivery mechanisms position it well to engage the West in realizing its potential as a strong innovation player within the national economy. Science, technology and innovation have horizontal application that affects all of WD's service to business through the following:

- support for the development and commercialization of leading-edge technologies;
- WD information services;
- the facilitation of financial support through WD's investment funds (in partnership with financial institutions), which provide debt financing to high-growth technology SMEs;
- the provision of targeted business services, including developing business plans, and export-readiness services to technology SMEs; and
- partnership with other stakeholders in providing services to technology start-ups through innovation centres.

Major S&T Achievements

In addition to providing services to technology SMEs through its Western Business Service Network, efforts have been directed at strengthening Western Canada's innovation system through initiatives such as the following.

- **Senior Officials Forum on Innovation** — Senior officials (ADM level) from provincial, federal and territorial governments meet regularly to develop a vision for innovation in Western/Northern Canada.
- **Western Economic Partnership Agreement (WEPA)** — WEPA initiatives have directed funding into economic development programs relating to growth sectors such as high technology and telecommunications.
- **Climate Change** — WD has a very substantial pan-Western role to play in supporting initiatives in the area of climate change technology, and will cooperate with Alberta in ensuring appropriate Western leadership.
- **Fuel Cell Initiative** — WD's proposed Technology Demonstration program would support demonstration projects in fuel cell and related technologies.
- **Telecommunications Research Laboratories (TRLabs)** — TRLabs is a not-for-profit applied telecommunications research consortium, with laboratories in Edmonton, Calgary, Regina, Saskatoon and Winnipeg engaged in pre-competitive research in network systems, network access, fibre optics and photonics, data networking, and wireless communications.
- **WestMOST** — Established in 1996, WestMOST is a not-for-profit consortium of nine Western Canadian universities and five software technology companies to enhance the international competitiveness of software workers and to promote and develop educational courses for software development.

- The **Western Medical Technologies Strategy (WMTS)** — Announced in 1997, WMTS is developing an integrated medical technologies cluster in Manitoba with strong links to other Western locations.
- **First Jobs in Science and Technology (FJST)** — WD's FJST program provides businesses with access to funding for salaries of recent graduates in order to work on related projects.

Strategic Directions in S&T

- Innovation Pillar — WD will place a strong emphasis on innovation by developing new program elements and will expand its program delivery instruments to establish innovation as a major strategic pillar within the Department. It will work with the provinces in the coordination of innovation strategies in Western Canada. It will take a leadership role and act as a catalyst in building the effective linkages among innovation players and to global markets in order to strengthen the Western innovation system. The Innovation Pillar identifies three program areas that are targeted at strengthening Western Canada's innovation system.
- Technology Demonstration — WD will explore establishing a more generic program in which WD would try to find ways to help reduce the perceived risk in early procurement. Essentially, this would provide a funding capacity to offset part of the risk involved in technical and commercial demonstration of new products and services developed by Western SMEs.
- Technology Assessment/Benchmarking — WD will develop a preliminary framework for a program that would have the capacity to assist firms in benchmarking their production technology use against state-of-the-art processes, and to assess the potential of technologies against the needs of groups of firms working in similar business areas. The program could also advise and support SMEs seeking to become certified against ISO standards.
- Technology Bid Support — WD will continue to play a role in ensuring that Western firms and organizations are positioned to access innovation related opportunities available through public sector programs.

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