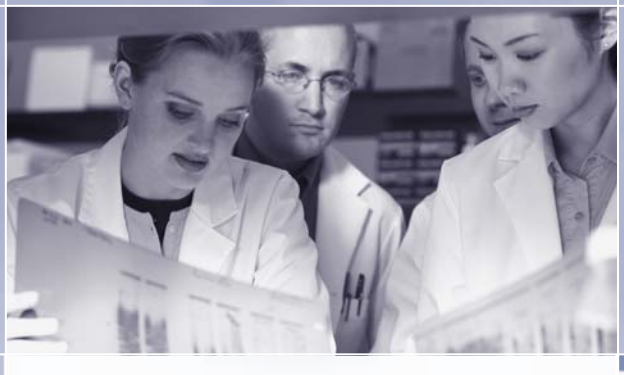
CSTA

Council of
Science and
Technology
Advisors

LINKS

Linkages in the
National Knowledge System:
Fostering a Linked Federal S&T Enterprise



A Report to the Government of Canada
February 2005

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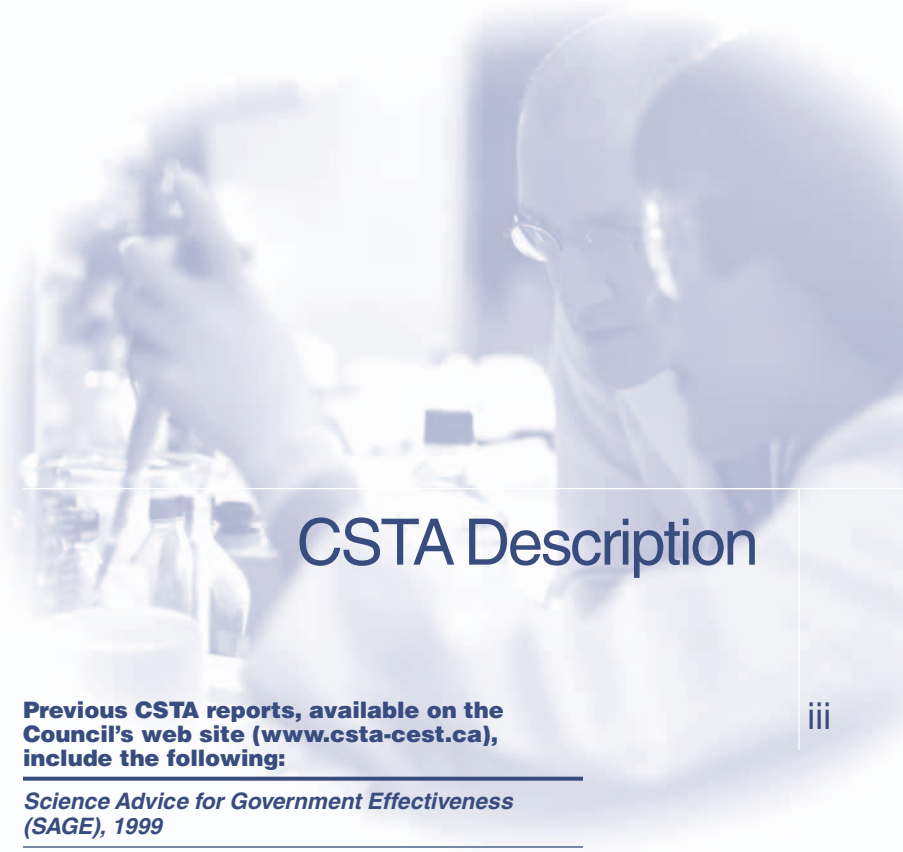

CSTA Description

The Council of Science and Technology Advisors (CSTA) is the external advisory body that provides strategic advice to the federal Cabinet on the management of the Government of Canada's internal science and technology enterprise. The CSTA was created in 1998, in response to the 1996 federal S&T strategy, *Science and Technology for the New Century*, which called for greater government reliance on external, independent advice.

The CSTA promotes excellence in the management of federal S&T by examining issues common across science-based departments and agencies (SBDAs) and highlighting opportunities for synergy and joint action. CSTA membership is drawn from the academic, private and not-for-profit sectors, and reflects the diversity of S&T-based disciplines. Appointed by the ministers of SBDAs, Council members are drawn predominantly from the science advisory bodies that advise these organizations.

The Council provides advice to Cabinet through the production of reports that seek to provide meaningful, practical solutions to federal S&T management challenges. Upon Cabinet review of the reports and approval of their release, they are shared with the public.

Previous CSTA reports, available on the Council's web site (www.csta-cest.ca), include the following:

- ***Science Advice for Government Effectiveness (SAGE), 1999***
- ***Building Excellence in Science and Technology (BEST): The Federal Roles in Performing Science and Technology, 1999***
- ***Science and Technology Excellence in the Public Service (STEPS): A Framework for Excellence in Federally Performed Science and Technology, 2001***
- ***Reinforcing External Advice to Departments (READ), 2001***
- ***Employees Driving Government Excellence (EDGE), 2002***
- ***Science Communications and Opportunities for Public Engagement (SCOPE), 2003.***

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The asterisk (*) denotes a member whose term on the CSTA expired by the time of the report's publication.

The cross (†) denotes sub-committee chairs for the linkages study.

Contents

Executive Summary

Science and technology (S&T) affect our lives in profound ways. Canada must draw on S&T to understand and respond to a broad range of issues — whether related to Severe Acute Respiratory Syndrome (SARS), global terrorism, climate change or the productivity gap. To deal effectively with these demands, the Government of Canada must find innovative ways to advance the creation and application of knowledge and to harness the breadth of the nation's substantial S&T capacity. In this context, fostering "linkages" among key S&T players is critically important.

The CSTA was asked by the federal Cabinet to examine the subject of federal S&T linkages, to build on our previous reports in which we identified linkages as a fundamental principle that should guide the conduct of federal S&T. We are convinced that, through linkages, the government can engage the full capacity of the national science and innovation system and draw on the most appropriate expertise, experience and resources wherever they reside, in order to more effectively identify, address and resolve national issues.

We have defined the concept of "linkages" as fostering close ties among players in the national science and innovation system in the pursuit and use of S&T for mutual interest and benefit. Linkages are relevant across the broad spectrum of the S&T enterprise, including research and development (R&D), related scientific activities (RSA) and the science-policy interface. Linkages are needed across the full range of scientific disciplines (including the social sciences), among federal departments and agencies, between the federal government and the other S&T-performing sectors (industry, academe and nonprofit organizations), with other levels of government and between Canada and the global pool of knowledge. In this report, we recommend actions that the federal government can take to foster effective S&T linkages among science-based departments and agencies (SBDAs) and with the key sectors of the national science and innovation system. Although S&T linkages related to the other spheres are important, we felt that they were beyond the scope of this report and may warrant separate study.

By embracing S&T linkages, the federal government can realize many benefits, including:

- Ensuring better informed policy and regulatory decision-making;
- Facilitating the generation, dissemination and commercialization of knowledge;
- Improving its ability to remain current with the rapid pace of S&T advances;
- Enhancing the impact of programs and projects through leveraged resources; and
- Promoting a common "language" of science.

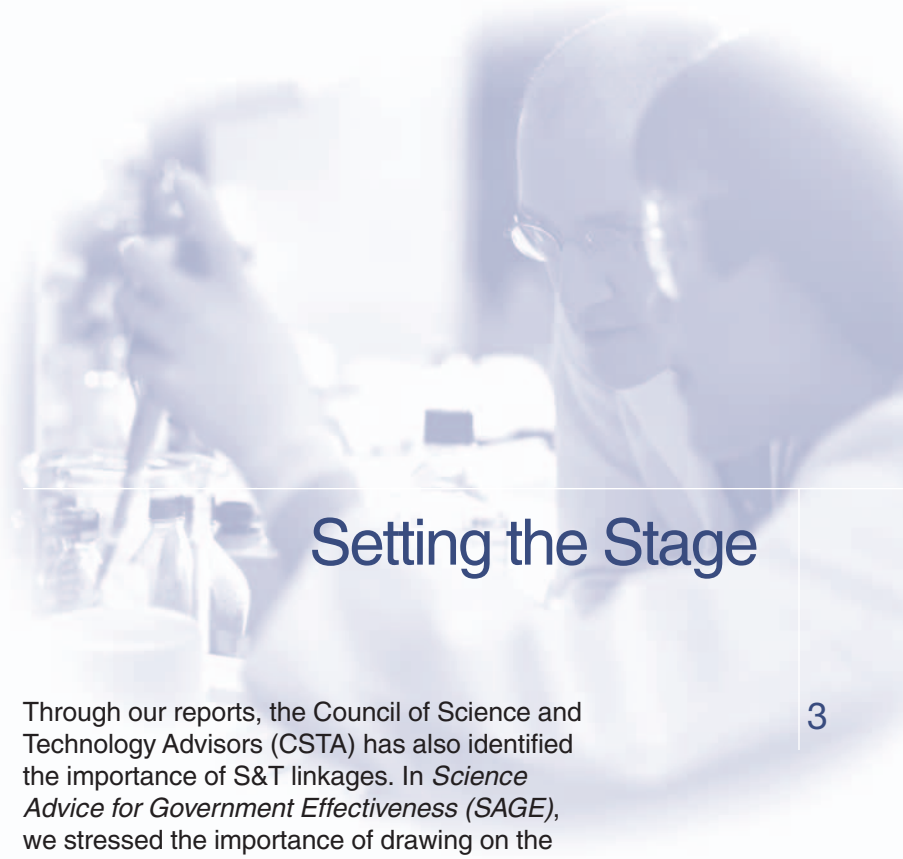
But achieving the full benefits of S&T linkages will require overcoming a number of key challenges. Chief among these is the vertical system of governance which characterizes the Canadian system. Although the world has changed significantly, the bureaucratic structures that underpin the government's management of its internal S&T have remained relatively unchanged. The federal system is still dominated by traditional vertical departments which are structured largely to provide S&T-based solutions to issues within their specific jurisdictions. The accountability, resource allocation and reward systems characteristic of this type of vertical system lack the incentives, flexibility and responsiveness that facilitate horizontal S&T.

In identifying the key elements for success, we focus our analysis and recommendations at two levels of linkages. First, we focus on the broader, more strategic level of achieving a linked national science and innovation system characterized by integration, coordination and inter-connectivity among all of the players. To achieve such a system, each of the three key sectors of government, industry and academia must be strong players in their own right and be prepared to contribute substantively to a linked system. Second, we focus on the more tactical level of individual S&T collaborative initiatives, programs or projects. While success at the tactical level will bring benefits, we believe that Canada must take strategic action towards a linked national science and innovation system if our nation is to realize its full potential.

We recommend that the Government of Canada:

- Embrace a vision of a linked S&T system. Commit at senior political and bureaucratic levels and in central agencies to the importance of S&T and champion S&T collaboration as a core way of doing business.
- Promote an environment in which innovation can thrive, facilitating the health of all three S&T-performing sectors (government, industry and academia) so that each is well-positioned to contribute to a linked national S&T system. In the context of government S&T, this means ensuring that SBDAs have the capacity to deliver on their S&T roles in a healthy, supportive work environment that is conducive to the delivery of modern science.
- Demonstrate the political will to share knowledge and information and foster ongoing relationships across departments, sectors and disciplines. This means committing to transparency and openness, and exploring options that promote collaboration such as co-location of facilities and flexible work arrangements.
- Implement a new model of federal S&T to address barriers to internal and external linkages, including creating and adopting a new system of accountability and resource management that recognizes and integrates vertical and horizontal responsibilities. This may require re-examination of the Financial Administration Act and reinterpretation of existing policies, guidelines and practices to apply them in a more flexible way.
- Identify a senior individual in each SBDA responsible for the organization's S&T, with direct access to the Minister and Deputy Minister. As a group, these individuals could work with the National Science Advisor in an interdepartmental network to facilitate linkages across departments, disciplines and sectors.
- Promote the adoption of "good practices" (identified in the report) that foster effective S&T collaborative initiatives at the program or project level. These practices relate to leadership, alignment, management and relationship-building.

We believe timely implementation of these recommendations is critical if Canada is to meet the opportunities and challenges of the 21st century.



Setting the Stage

Introduction

Today, the science and technology (S&T) enterprise is vast and complex, and the results of scientific discovery and technological innovation affect our lives in profound ways. In order to succeed in the 21st century economy and enhance the quality of life of Canadians, Canada must continuously consider how best to apply S&T to address the opportunities and challenges we face. To effectively deal with a broad range of issues — whether related to Severe Acute Respiratory Syndrome (SARS), climate change or the productivity gap — it is vital that the Government of Canada find innovative ways to advance the creation and application of knowledge and to harness the breadth of national S&T capacity.

In responding to these demands, the value of fostering effective linkages among players in the national science and innovation system is increasingly being recognized. Initiatives such as the Networks of Centres of Excellence (NCEs) have created nationwide, multidisciplinary and multisectoral research partnerships among universities, industry, government and non-governmental organizations. The federal government has acknowledged the importance of linkages in its Innovation Strategy (*Achieving Excellence: Investing in People, Knowledge and Opportunity*), in Speeches from the Throne and in initiatives by the Assistant Deputy Ministers (ADMs), such as the S&T Integration Board, to improve S&T collaboration across government.

Through our reports, the Council of Science and Technology Advisors (CSTA) has also identified the importance of S&T linkages. In *Science Advice for Government Effectiveness (SAGE)*, we stressed the importance of drawing on the expertise of a variety of scientific sources, both internal and external to government, in order to enhance debate and thereby aid in achieving sound science advice. In our second report, *Building Excellence in Science and Technology (BEST)*, we identified linkages as one of three fundamental principles (along with alignment and excellence) that should guide the conduct of all federally performed and funded S&T, noting that “linkages ensure that federal performance of S&T capitalizes on the best available inputs, regardless of their source, and that overlap and duplication are minimized.” More recent CSTA reports have further supported the concept of S&T linkages.

In April 2003, the federal Cabinet asked the CSTA to build on its previous work and undertake a study of federal S&T linkages. In this report, the CSTA recommends actions that the government can take to foster federal S&T linkages, in order to marshal the most appropriate S&T talent and resources wherever they reside in Canada.

Exploring the Concept of Linkages

The concept of S&T linkages is about fostering close ties among players in the national science and innovation system in the pursuit and use of S&T for mutual interest and benefit. As we noted in our *BEST* report, the concept of linkages goes beyond the notion of "partnership". It covers a broad territory of S&T relationships. At one end of the spectrum, in their most basic form, S&T linkages can be manifested in information- and data-sharing agreements. Further along the spectrum are relationships such as individual collaborative initiatives, played out at the program/project level, and co-located facilities and equipment. At the other end of the spectrum, there is a linked national science and innovation system — a mature, sophisticated system characterized by integration, coordination and interconnectivity among the key players. Here the concept of linkages is not only about processes, structures and mechanisms; it is also about embracing an organizational culture of sharing (knowledge, resources, facilities and people) and a commitment to common goals.

There has been much activity (with varying levels of success) around promoting individual collaborative S&T initiatives at the program/project level. In the final section of this report, "Lessons Learned: Fostering Effective Collaborative S&T Initiatives", we provide some guidelines that managers may find useful in fostering success along this part of the spectrum. However, we believe it is increasingly important that the government move beyond this to seek success in fostering a linked national science and innovation system. The heart of this report, "Fostering an Effective Linked S&T System", focusses on actions to foster this type of mature, sophisticated national S&T system. Throughout the report, text boxes are used to provide examples of interesting approaches in Canadian or foreign jurisdictions which were identified through background research commissioned by the Council.

Environment Canada Science Advisors

At Environment Canada, science advisors are one mechanism by which the Department ensures that science and policy are well linked. Departmental employees are appointed as science advisors for significant issues (such as climate change, acid rain, water and wildlife) to facilitate the effective transfer of scientific information to policy makers, the general public, science audiences and others. This helps ensure that the Department's policies are based on sound science.

Linkages are relevant across the full range of the S&T enterprise — covering not only research and development (R&D), but also related scientific activities (RSA) and the science-policy interface (i.e. bringing the insights of science to bear in shaping policy and ensuring the government's policy priorities guide the federal S&T agenda). The federal government should take action to break down the traditional "stovepipes" and embrace S&T linkages across the science and innovation system. It should therefore pursue S&T relationships:

- among federal players (science-based departments and agencies and associated policy groups across government);
- with other levels of government (provinces, territories and municipalities);
- with the other sectors of the national science and innovation system (industry, academia and not-for-profit organizations);
- across the broad range of S&T disciplines (the natural, health and social sciences, and engineering and technology); and
- with the global pool of knowledge and technology.

Through these S&T linkages, the government can engage the full capacity of the innovation system and draw on the most appropriate expertise, experience and resources wherever they reside in Canada, in order to more effectively identify, address and resolve national issues that impact on society.

Because we believe it is too often overlooked, we want to draw particular attention to the linkages between the natural and social sciences. In the federal government, the social sciences consist of two key components: primary social sciences research, and policy analysis and advice. Given that the issues addressed by the federal government affect society, it is important to foster linkages among natural scientists, social science researchers and policy analysts, from the framing of the problem, through research, to analysis and policy recommendations. Too often, there seems to be a gulf between the natural and social sciences in government. Although much of this report encompasses S&T linkages relating to both the natural and social sciences, there are specific challenges relating to social science linkages that are deserving of more in-depth analysis than that offered here.

The federal government continues to be a key funder and performer of S&T in Canada, and it remains an integral part of Canada's science and innovation system.[1] In this report, we examine actions that the federal government can take to foster effective S&T linkages among science-based departments and agencies and with the other sectors of the national science and innovation system. Although linking with the global pool of knowledge and technology is fundamentally important in our increasingly interdependent world (as evidenced below), and despite the fact that Canada can play a key role in bringing its S&T resources to bear on the challenges of the developing world, the subject of international linkages is beyond the scope of this report. We believe it is a sufficiently important and complex subject to warrant separate study.

The Impact of a Changing World

Canadians are increasingly looking to S&T for responses to a wide range of challenges and opportunities that profoundly affect our social and economic well-being. S&T is fundamental to understanding and responding to ongoing pressing issues, such as toxins in fish, genetically modified foods and species at risk. S&T also plays a vital role in Canada's response to crises, such as global terrorism, extreme weather incidents, and threats to human and economic health (SARS, West Nile virus, Bovine Spongiform Encephalopathy, avian influenza). Consequently, S&T is playing an increasingly critical role in informing government policy and decision making on a wide range of issues. Increasingly, these issues are multi-dimensional in nature, crossing or transcending the traditional boundaries associated with institutions, sectors, scientific disciplines and geopolitical borders.

Not only must Canada respond to the pervasiveness of S&T-based issues, but it must also adapt to ongoing changes in the very nature of the S&T enterprise itself. The rapid pace of discovery and technological change continuously challenge our society's capacity to respond to the pressing issues of the day. Advances in S&T are leading us to places we had not anticipated, stimulating our society to grapple with novel issues unforeseen by previous generations. Our social institutions and policies — our capacity to address the social and ethical implications of new discoveries — are struggling to keep pace.

1. The four key roles of government S&T identified in the CSTA's *BEST* report are:
   - support for decision making, policy development and regulations;
   - the development and management of standards;
   - support for public health, safety, environmental and defence needs; and
   - the facilitation of economic and social development.

We are also witnessing greater internationalization of the performance and use of S&T. This is a reflection of the emergence of global problems, as noted above, that cross traditional geopolitical boundaries in an increasingly interdependent world. It is also driven, in part, by the ongoing escalation of research costs and the need for multinational facilities to conduct "big science", and by a recognition of the diffusion of S&T expertise throughout the world.

As the government grapples with the proliferation of S&T-based issues and the changing nature of the S&T enterprise, concerns have been raised about Canada's capacity to address key areas of public concern. Recent controversies have raised questions about the government's ability to make sound policy and regulatory decisions based on reliable S&T inputs, especially in areas of scientific uncertainty and those that lack scientific consensus. Questions have also been raised about Canada's ability to commercialize new discoveries, to contribute to improved competitiveness in the global economy and enhanced social benefits and quality of life at home.

The Benefits of Linkages

In this new and continuously changing world, Canada will not be able to respond effectively to the types of challenges and opportunities noted above without a mature science and innovation system characterized by S&T linkages. Given the modest size of Canada's economy and population, linkages are vital in order to be truly competitive on the global stage. By embracing S&T linkages, the federal government can realize many benefits, including the following.

- **Better informed government policy and regulatory decision making:** Ministers are accountable for decisions that impact on the lives of Canadians (and potentially on the lives of others beyond our borders in this interdependent world). The public expects these decisions to be made on the basis of the best available information. As we noted in our *SAGE* report, responsible decision making draws on advice, expertise and experience from a variety of sources. Linkages help ensure that ministers can draw on a broad spectrum of sound scientific information and advice to inform policy and regulatory decisions.
- **Generation, dissemination and translation of knowledge:** Linkages support "knowledge mobilization" — the sharing of information that not only transmits knowledge, but also creates opportunities to generate new knowledge, translates knowledge into new applications, and facilitates the dissemination and commercialization of results. Collaboration brings a wealth of experience to the table, and provides an opportunity to benefit from the synergistic aspects of discovery.

Tacit knowledge and knowledge of technique are often best conveyed through collaboration. In many cases, collaboration is the key mechanism for mentoring graduate students and postdoctoral researchers, enhancing the productivity of individual scientists, as well as preparing the next generation of scientists and engineers.

- **Currency with S&T advances:** Remaining current with the latest S&T developments is difficult for any participant in the S&T enterprise. It is a particular challenge for the Canadian government, since the majority of S&T is conducted external to government and, indeed, external to Canada. Linkages can help the government keep pace with S&T advances, while still allowing it to focus its own S&T efforts on those tasks that federal S&T is uniquely equipped to deliver.

- **Enhanced impact through leveraged resources:** Linkages can result in a more coordinated and coherent effort, bringing the "right" expertise and resources to bear on challenges and opportunities. Effective linkages can help leverage resources and enhance the quality and impact of S&T programs and projects.
- **A common "language" of science:** Linkages can facilitate the coordination and synthesis of scientific results and the development of consistent standards, definitions and protocols for reporting data across organizations and disciplines.

Key Challenges to Fostering Federal S&T Linkages

Although the world has changed significantly, the bureaucratic structures that underpin the government's management of its internal S&T have remained relatively unchanged. The federal S&T system is still dominated by traditional vertical departments, which are structured largely to provide S&T-based solutions to issues within their specific jurisdictions. This rigidity in the vertical structure presents serious impediments to horizontal cooperation, resulting in a working environment that is not conducive to effective S&T linkages.

In this structure, departments tend to compete for resources to service their mandates. They may also compete for credit for delivery on key issues, since sharing the credit can result in diminishing departmental budgets, as resources are spread across a greater number of organizations. Ministers and public servants may therefore be inclined to resist initiatives that they perceive as potentially circumscribing their control over their mandates and resources. This challenge is compounded when an organization has traditionally enjoyed sole responsibility for an issue. Departments may tend to maintain their own interests at the expense of a more comprehensive, integrated perspective that would better meet national needs.

Dutch EET Program

The Dutch Economy, Ecology and Technology (EET) program suffered from a "territorial tendency", where each ministry developed its own strategy, set its own research agenda and had a limited number of preferred research partners. Inter-departmental programs, such as EET, are on the fringe of departmental mandates; this compromises their sustainability.

Furthermore, the accountability and resource allocation systems characteristic of this type of vertical structure are not conducive to resource sharing, as they lack the flexibility and responsiveness that facilitate horizontal S&T. The *Financial Administration Act* (FAA) and Treasury Board of Canada Secretariat (TBS) policies and guidelines which interpret and enforce the Act do not offer the type of mechanisms that easily facilitate a linked S&T system. Indeed, the FAA and TBS policies and guidelines can inhibit S&T collaboration, whether among government departments and agencies or between government and the other sectors of the national science and innovation system.

Government performance accords, whether at the political level (ministerial mandate letters) or the bureaucratic level (public servant work plans and appraisals) are also designed to reflect this vertical system and, thus, do not typically recognize collaboration as a core means of delivering on mandates. Historically, government has not been alone in this. Universities traditionally did not reflect the value of collaboration in researchers' performance assessments, although more recently they have redressed this gap.

Complicating the issue are the differing organizational cultures among government, industry and academia; across departments and scientific disciplines; and among fundamental research, applied research and related scientific activities (RSA). It is difficult to manage, much less overcome, cultural differences. Large organizations and established disciplines are typically reluctant to change their values and operating norms. Organizations and individuals tend to simply continue what they have historically done, which makes fostering linkages all the more challenging. Also, cultural differences can impede mutual understanding, which can generate lack of trust among partners.

Some of the differences apparent in various organizational cultures include the following:

- **perspectives and responsibilities regarding communications, transparency and openness;**
- **criteria and measures of excellence;**
- **time horizons for outcomes;**
- **management styles and hierarchical structures;**
- **accountability structures and responsibilities; and**
- **tolerance levels for risk.**

On a final note, it is important to realize that a linked national science and innovation system is only as strong as each of its constituent parts. Linkages are most effective when each of the three key sectors of government, industry and academia are strong players in their own right and are prepared to contribute substantively to a linked system.

Fostering an Effective Linked S&T System

The government must address the challenges outlined in the previous section, if it hopes to succeed in fostering effective federal S&T linkages to respond to the challenges and opportunities Canada faces. In identifying the key elements for success, we examine two levels of S&T linkages as defined earlier in this report: the broader, more strategic level of a linked national science and innovation system; and the narrower, more tactical level of individual collaborative S&T initiatives at the program/project level. In this section, the heart of our report, we look at what the federal government can do to facilitate an effective linked science and innovation system.

Vision and Commitment

Success in achieving a linked S&T system begins with commitment, at senior political and bureaucratic levels and in central agencies, to the importance of S&T and to linkages as a legitimate means to pursue national policy objectives. Senior political officials and public servants need to ***embrace a vision of a linked S&T system and champion collaboration*** to ensure that it is adopted as a fundamental component of government S&T culture. Leading by example, they should demonstrate that collaboration is not a "corner of the desk" endeavour constituting "extra" work. Instead, collaboration is a *core* approach to doing business, a legitimate means of achieving the objectives of the organization. The government will not be successful in addressing the complexities around S&T collaboration without this vision and conviction.

Innovation Environment

As indicated earlier, the effectiveness of a linked science and innovation system is directly related to the independent strength of each of the three main contributing sectors: government, industry and academia. In order for linkages to flourish, each of the key participating sectors must be strong in its own right so that each can "carry its weight" as a viable partner in a linked system. The government should contribute to this by ***promoting an environment in which innovation can thrive, facilitating the health of all three sectors so that each is well positioned to contribute to a linked national S&T system.***

In the context of government S&T, promoting an environment in which innovation can thrive requires that the government commit to its role in the national science and innovation system at a level commensurate with its mandated responsibilities and emerging S&T priorities. This means ensuring that science-based departments and agencies (SBDAs) have the capacity to deliver on their S&T roles, as we noted in our *BEST* report, in a healthy, supportive work environment that is conducive to the conduct of modern science. Sufficient capacity includes a dynamic, high-calibre S&T work force; modern facilities, platforms and equipment; and predictable, adequate financial resources.

As we noted in the *BEST* report, this does not necessarily mean rebuilding or restoring capacity along historical lines, but rather identifying the capacity needed to address current needs and evolving challenges and opportunities.

Promoting an environment in which innovation can thrive in academia means that, among other things, government funding support must continue. We welcome the government's investments in universities and other academic and related institutions, through initiatives such as the granting councils, the Canada Foundation for Innovation (CFI), the Canada Research Chairs program, the Networks of Centres of Excellence (NCEs), Genome Canada and the Canadian Health Services Research Foundation (CHSRF).

As part of the efforts to promote an industrial environment in which innovation can thrive, the government can use the tax system and other mechanisms to encourage Canadian pools of private capital (venture capital and institutional funds) to invest in the domestic innovating community. This community consists not only of the relatively few large, research-intensive companies, but also a significant population of small and medium-sized enterprises (SMEs) that, with infusions of management expertise and capital, have the potential to make significant contributions to Canada's national science and innovation system. As the private sector is the principal actor in the final stages of the innovation cycle, ensuring its robustness is vital to Canada's continued prosperity. The government needs to foster a national climate in which S&T innovation is perceived by investment managers as a profitable, high-growth opportunity.

The government can also support an innovative environment for Canadian companies through continued efforts to support R&D through tax incentives, direct grants and subsidies, and industrial support programs such as the Industrial Research Assistance Program (IRAP) and the Defence Industrial Research Program (DIR). Funding support, like departments, tends to be structured vertically, administered by a number of organizations, with each subject to unique rules, regulations and monitoring processes. Breaking down the compartmentalization of federal support for industrial innovation would be more consistent with the vision of innovation as a single, flexible and seamless process from research to commercialization. So-called "one-stop shopping" for industrial innovation support could help relieve the administrative burden on SMEs.

By promoting a vibrant national innovation environment, the government can contribute to expanding and strengthening the innovation base in the public, private and academic sectors, and ensure that all three sectors are well positioned to contribute to a linked national S&T system.

Communication

An effective linked S&T system is characterized by a broad, deep and regular flow of information and knowledge within and among the key sectors and disciplines. The government is better positioned to pull together the "best and the brightest" to respond to emerging national crises and opportunities in a timely, coherent way in a system where information and knowledge sharing is already routine. Recent S&T-related crises in this country have highlighted the importance of this.

Coordinated SARS Research

The Canadian SARS Research Consortium (CSRC) is a new partnership among funding agencies, government, industry and researchers that seeks to mobilize Canada's health research community to address new pathogens research in a coordinated, focussed manner. The CSRC will develop and coordinate the implementation of a national research agenda on SARS, establishing research priorities, coordinating funding, facilitating collaboration among researchers (both nationally and internationally), and facilitating the integration of the funded research projects.

The government must ***demonstrate the political will to share S&T information and knowledge***. In previous reports, we have stressed the importance of transparency and openness; this is particularly important to the success of a linked S&T system. Leading by example, senior political officials and public servants must foster a culture that embraces the concept that *sharing* knowledge is power. We encourage the government to examine means by which it can enhance communication across departments, disciplines, levels of government and sectors on an ongoing basis, to ensure that S&T information and knowledge is shared in an open and transparent manner.

One such mechanism for consideration is integrated "foresight" exercises across sectors and disciplines on an issue-specific basis. The government could convene interested parties around a particular issue (e.g. water resources, emerging diseases or genetically modified organisms) to share information and ideas about emerging scientific and societal challenges and opportunities around that issue and to explore how Canada as a country can respond. The roles of existing bodies could be enhanced to fulfil this function. Such foresight exercises could be expanded to include international S&T players where the issues cross traditional geopolitical borders. Communication would be an important part of this foresight process, to ensure that the information resulting from these exercises is shared broadly within the Canadian S&T community.

Fostering ongoing individual and institutional relationships across departments, sectors and disciplines is an effective way to encourage the sharing of information and knowledge. To this end, the government should explore options for co-location of S&T facilities, both among government departments and between government and academic or industrial organizations. Co-location can be pursued as a general operating principle, in the absence of immediate, specific collaborative initiatives. The act of co-location itself can foster a physical environment conducive to information and knowledge sharing and the promotion of personal and institutional relationships, on which specific collaborative initiatives can be built in the future.

There are other mechanisms that can facilitate individual and institutional relationships on an ongoing basis, both within government and among government, industry, academia and not-for-profit organizations. Some of these we identified in our *EDGE* report, in the context of recommendations to improve S&T human resource management in government. They include the following:

- promoting greater mobility for scientists, both within government and among government, industry, academia and not-for-profit organizations, through more flexible human resource policies and programs such as interchanges;
- supporting the attendance of government scientists and policy analysts at key national and international multisectoral conferences to facilitate informal networking; and
- seeking out more opportunities for flexible work arrangements for government scientists, such as dual appointments (e.g. adjunct professorships) and joint appointments with other bodies, especially universities.

Accountability and Funding

Tension between vertical accountabilities and horizontal responsibilities is a key issue relevant from the ministerial level down through the ranks of the public service. As noted earlier, the structure of the federal S&T system is characterized by vertical departments focussed on their specific organizational missions and jurisdictions. In Canada's parliamentary system, each minister is individually accountable to Parliament for his or her department's activities and for the decisions made (and not made) related to the department's mandate. Departmental officials, in turn, are accountable to the minister. Reconciling this vertical accountability with the collective, horizontal responsibility of a linked S&T system is one of the biggest hurdles to fostering an effective linked national science and innovation system.

Accountability is manifested in large part through the allocation, management and reporting of resources. As described earlier, the FAA and TBS policies are not conducive to effective S&T linkages. Real success in promoting linkages requires that the federal government ***create and adopt a new system of accountability and resource management that integrates vertical and horizontal responsibilities***. This new system of integrated accountabilities must be flexible, responsive and simple. This may require legislative changes to the FAA.

In the immediate term, while the FAA is under review, the government can re-assess existing interpretations of the current legislation, policies, guidelines and practices. Such a re-assessment may allow central agencies and departments to use the existing mechanisms and instruments in a more flexible and "collaboration-friendly" way. For example:

- Mandate letters for ministers and deputies could be used to stress the importance of collaboration and integration on horizontal S&T-based issues.
- Management and employee performance accords (work plans and appraisals) could be used as a tool to encourage S&T linkages by incorporating incentives and rewards for the use of a collaborative approach.
- TBS policies and guidelines could be re-interpreted to focus on the *outcomes* of initiatives, allowing more flexibility for partners in collaborative S&T initiatives to determine how best to pursue shared goals.

Collaborative Water Management in Australia

The Murray Darling Basin Initiative, a collaborative water management program in Australia, explicitly recognizes "partner relations" as a function of the commission responsible for the initiative. This is reflected in the job descriptions of individual commission staff members.

Accountability and resource management are not just issues of government structure, laws and policies. They are also related to political culture and traditions, to a belief system around responsibilities, resources and rewards. Changing the culture of government can be even more difficult than changing its structure. It requires the type of vision and commitment at senior levels that we described above.

We want to make it clear that we are not suggesting that the government abrogate ministers' and departments' responsibility to account to Parliament and Canadians for their activities and their expenditures. Accountability is a core value upon which our democracy and our Westminster system rest. But, in the current environment of complex, horizontal challenges and opportunities that demand S&T linkages, we must acknowledge that the existing systems of accountability and resource management do not best serve our interests. We must find new models conducive to S&T linkages that strike the right balance between vertical and horizontal accountabilities and resource management.

Governance

The key to governance of a complex, linked S&T system is flexibility. Our understanding of the world is constantly changing. The emergence of new technologies and the advancement of scientific knowledge can dramatically impact on priorities, policies and programs, so that active science itself contributes to the evolution of the government's agenda. The government requires flexibility, agility and responsiveness in S&T governance, whether related to governance of its own internal system or to its contribution to broader governance of a linked national science and innovation system. This flexibility allows the latitude to re-assess priorities and re-allocate resources accordingly in an inclusive, timely, coherent way, and to respond effectively to emerging crises or opportunities.

We welcome the creation of the new position of National Science Advisor (NSA) to the Prime Minister. The NSA can serve as a champion, both symbolically and practically, to promote greater linkages across government, across disciplines, among sectors and with the international S&T community.

To complement the creation of the NSA at the national level, we recommend that, on a department-specific basis, each SBDA ***identify a senior individual responsible for S&T in the organization***. The precise manifestation of this position may vary from one department to another, due to differing departmental structures. However, it is important that this individual be positioned to exercise significant influence over the management, conduct and use of S&T in the department, and that he/she enjoy direct access to the deputy minister and the minister. This individual would perform the following roles:

- ensure that the organization's S&T is aligned with the government's priorities and with the department's mandates, as we described in our *BEST* report;
- ensure that the organization's S&T is managed and conducted consistently with the characteristics of federal S&T excellence that we described in our *STEPS* report (quality, relevance, transparency and openness, and ethics);
- ensure that the science-policy interface functions effectively to contribute to superior science advice (as per our *SAGE* report); and
- raise the profile of the organization's S&T and its contribution to the department's and the government's agenda.

These individuals could prove invaluable in facilitating S&T linkages across departments, disciplines and sectors. Working with the NSA, they could form an excellent network for discussing horizontal government S&T; generating consensus on shared or complementary S&T priorities; identifying ways and means of cooperating on these issues; and exploring opportunities to share infrastructure, facilities, personnel and data. In the service of external linkages, each could function as a readily identifiable first point of contact in his/her respective department and, on a more proactive basis, communicate with external players to raise the profile of the department as an active and interested S&T partner.

Network of Chief Scientists in the U.K.

In the United Kingdom, the approach to S&T linkages across the government revolves around the Chief Scientific Advisor, who reports to the Prime Minister, and the chief scientists in each of the major departments. Meeting informally on a regular, ad hoc basis, this informal network appears to provide a powerful vehicle for planning horizontal initiatives.

Lessons Learned: Fostering Effective Collaborative S&T Initiatives

We now turn to the more tactical level of specific collaborative S&T initiatives at the program/project level. In investigating the topic of federal S&T linkages, we looked at a variety of institutions in Canada and abroad that were involved in collaborative S&T initiatives. Our intent was to learn lessons from their experiences that would be relevant to Canada's SBDAs as they pursue collaborative S&T programs/projects among themselves and with the private sector and academia. In this section of our report, we share with managers and scientists some of these "lessons learned" to foster success at the level of individual collaborative S&T initiatives.

It should be noted that, although pursuing S&T through a collaborative approach brings many benefits, as noted previously, collaboration is a means to an end, not an end in itself. The collaborative process brings its own challenges and administrative costs. A collaborative approach is best pursued when an assessment of the situation concludes that collaboration is a productive means by which to achieve an organization's goals.

Leadership

A collaborative S&T initiative requires one decisive authority, whether that authority is invested in an individual or in an executive committee composed of representatives from participating organizations. Leadership of a collaborative S&T initiative need not be centred in government. Depending on the purpose of the collaboration and the requirements it serves, leadership can also be located in or shared with industry and academia. Some guidelines include the following.

- Where the initiative is led by an executive committee, ensure that all committee members have the authority to make decisions on behalf of their respective organizations, including decisions related to resources.
- Ensure that leaders are committed to the practice of collaboration and to the collaborative S&T initiative itself, not just to the interests of their own organizations. They must devote dedicated time and attention to the collaborative initiative, as opposed to approaching it as an additional activity to be managed from the "corner of the desk".
- Establish legitimate leadership, which requires both intellectual status and credibility in the S&T community, as well as management skills to deal effectively with administrative and human resource issues. The personal characteristics that make a good leader are not necessarily the same as those that make a good scientist. Effective leadership in a collaborative S&T initiative is also characterized by an appetite for intellectual experimentation and a willingness to take risks.

Alignment

In our *BEST* report, we noted the importance of alignment: "Federal S&T efforts must be focussed where they will have the most benefit to Canada. Federally performed and funded S&T must be demonstrated to be aligned with departmental mandates and the overall priorities of the government. Departments and agencies should only be performing the S&T that is needed to support their mandate and that cannot be obtained more effectively from other sources." (p. 24)

This principle of alignment holds true for collaborative S&T initiatives: the collaborative initiative should be consistent with the mandate, objectives, requirements and interests of each participating organization. Specific guidelines include the following.

- Ensure that the collaborative initiative is relevant to the policy interests and objectives of the participating SBDA and the government more broadly. Collaborative S&T, like S&T itself, must support policy and regulatory decision making, address program and operational needs, or support related scientific activities.
- Generate a clear, commonly understood definition of the problem/question at issue among all participants, covering objectives, desired outcomes and expectations.
- Avoid "mission drift", following available resources or pursuing scientific questions or new issues to the point where the participating organization inadvertently moves beyond its mandate. Perfect alignment is not necessary, especially in emerging issue areas that traditional departmental mandates did not foresee or in cases of overlapping mandates among SBDAs. However, some of the goals of the collaborative initiative must be consistent with the participant's mandate, and the participant's core responsibilities in the partnership must align with its mission. "Mission shift" can be appropriate, where an SBDA explicitly and deliberately adjusts its interests and priorities, permitting involvement in a collaborative initiative, in order to respond to emerging opportunities/challenges and evolving advances in technology or knowledge.

Management

Efficient and effective management and administration are fundamental to success. This requires strong project management skills. Some guidelines include the following.

- Maintain work plan flexibility and adaptability. A collaborative initiative can be designed and modified in ways that collaborating institutions cannot. Flexibility and adaptability can allow efficient and timely alterations in program goals, structures, approaches and resources to respond to evolving advances (or barriers) in the science or to problems in the collaborative relationship.

Canada's Northern Contaminants Program

One of the identified strengths of the Northern Contaminants Program (NCP) design is the active participation of both researchers and the clients and beneficiaries of the program. Under this management structure, the program has evolved from an early focus on environmental contaminants and their transport mechanisms to its current primary focus on the implications for human health in the Eastern Arctic, ensuring that the program's products continue to have clear relevance to the affected communities.

- Ensure that there is a clear, commonly understood identification of each player's roles and responsibilities in the collaborative S&T initiative. Collaborators must complement one another (i.e. "fit") in terms of their interests, knowledge, experience and skills so that the collection of assigned roles/responsibilities fits seamlessly together to form an integrated whole.
- Adopt a management structure for the initiative that is sustainable, but that also has a built-in mechanism to dissolve the collaboration or to allow one partner to withdraw as desired. The management structure should also include an agreed dispute resolution mechanism.

- Assign predictable, dedicated financial and human resources to the collaborative initiative, whether new or existing resources. These resources must be committed to the initiative and managed in a way that serves the priorities of the initiative. Different models of funding can be employed, depending on the specific circumstances. The aim is to enable funding to go to the individuals and organizations best able to do the necessary work. For example, some options include the following.
  - Create a central pool of money dedicated to an issue/initiative (e.g. in the fiscal framework) that all partners can access, according to agreed priorities and program outcomes collectively identified.
  - Dedicate A-base resources by participating departments. Although some SBDAs allow their contributions to be used only by their own departmental personnel, greater benefit might be derived by partners allowing their resources to be allocated to any worthy science activity within the collaborative initiative that aligns with their objectives.
- Apply dedicated resources to the ongoing administration of the collaborative S&T initiative, to support the day-to-day management of the program/project.

Relationship Building

Regardless of the institutional and management structures in place, the success or failure of collaborative S&T initiatives often comes down to the human factor. Fostering personal relationships and information and knowledge sharing among partners is fundamental to success. It helps to build trust and "buy-in" among participants and to foster a shared culture and common lexicon. Specific guidelines include the following.

- Invest time and resources in facilitating personal acquaintance and familiarity among participants in a collaborative S&T initiative. This fosters a team spirit and allows participants to learn collaborative skills from the experience of collaborating (a history of working together typically facilitates collaboration).
- Identify opportunities for face-to-face communication in cases where participants are geographically dispersed. This is especially important in the early days of a collaborative initiative when the partners are getting to know one another.
- Investigate opportunities for the co-location of partners, or creation of a central project office where partners can meet. There are serendipitous benefits from the informal interaction that this can foster.

Communications in the Texas Air Quality Study

One of the keys to the effectiveness of the Texas Air Quality Study was the extensive and intensive communication among project participants. Key elements included a "base camp" headquarters for the initiative. According to one participant, this physical proximity was important: "With all the [researchers] in the same area, you can just go down the hall and talk to somebody and find out what's going on." In addition, partners in the study made use of frequent newsletters and teleconferences, and employed a "playbook" as a means of ensuring effective communication about research procedures.

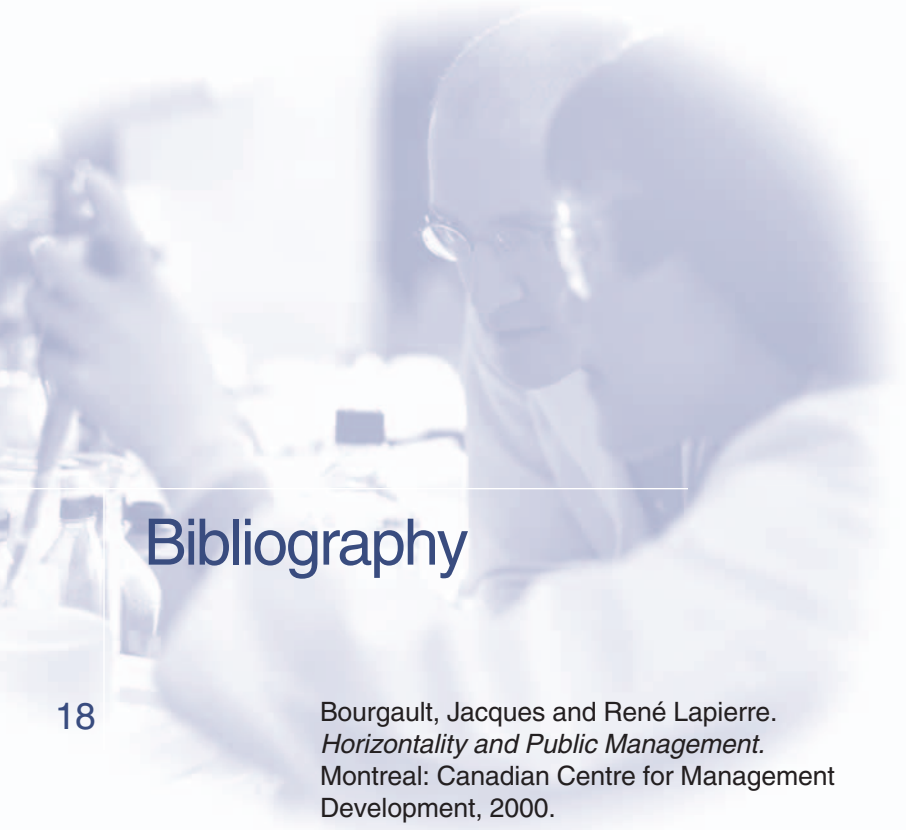
- Take greater advantage of modern information and communications technologies, recognizing that they are more useful at the "keeping in touch" stages of a collaborative initiative than at the early stages when partners are getting to know one another.

Recommendations to Promote Federal S&T Linkages

Canada's social and economic well-being depend increasingly on the government's ability to use S&T linkages to draw on the most appropriate expertise, experience and resources wherever they reside, in order to more effectively identify, address and resolve national issues. To respond effectively to modern challenges, opportunities and priorities, Canada needs a mature science and innovation system characterized by S&T linkages.

To this end, the Government of Canada should undertake the following.

- **Embrace a vision of a linked S&T system**, championing S&T collaboration as a core way of doing business.
- **Promote an environment in which innovation can thrive**, facilitating the health of all three sectors (government, industry and academia), so that each is well positioned to contribute to a linked national S&T system.
- **Demonstrate the political will to share knowledge and information** and foster ongoing individual and institutional relationships across departments, sectors and disciplines.
- **Implement a new model of federal S&T to address barriers to internal and external linkages**, including creating and adopting a new system of accountability and resource management that recognizes and integrates vertical and horizontal responsibilities.
- **Identify a senior individual in each SBDA who is responsible for the organization's S&T** and who can serve to facilitate linkages across departments, disciplines and sectors.
- **Promote the adoption in SBDAs of the good practices identified herein** that foster effective collaborative S&T initiatives at the program/project level.



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2. All studies commissioned by the CSTA are available on the CSTA web site: **www.csta-cest.ca**