The Roles of the Federal Government in Performing Science and Technology: The Canadian Context and Major Forces

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THE IMPACT GROUP

Contents

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1.0 Introduction

This report was commissioned by the Council of Science and Technology Advisors (CSTA) in December 1998. CSTA was established in May 1998 to provide the Cabinet Committee on Economic Union with external expert advice on internal federal government science and technology (S&T) issues that require strategic direction. CSTA is composed of representatives of external advisory boards which report to Ministers of federal science-based departments and agencies (SBDAs).

CSTA asked The Impact Group to do two things:

1. Undertake a review of past research and studies on the issue of the roles and operations of federal S&T establishments ... take stock of past work on the issue ... and determine the nature and extent of the response of federal S&T establishments to the studies;

2. Review and examine the major forces that affect and will affect the roles and operations of federal S&T establishments.

> **S&T Activities of the Federal Government**
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> In 1997 SBDAs performed or funded over $2.8 billion of R&D. SBDAs performed approximately $1.5 billion worth of R&D themselves and financed an additional $1.3 billion of R&D at organizations and institutions outside of government. Thus federal SBDAs funded or performed about 11.4% of all R&D undertaken in Canada in 1997. In addition, SBDAs performed or funded nearly $2.3 billion of related scientific activities (RSA), such as scientific data collection, astronomical observations, maintenance of meteorological records, and wildlife and fisheries surveys.
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> In recent years, federal science spending has consumed a fairly consistent portion of all federal program spending. Federal spending on R&D has ranged between 2.8% and 3.2% of all federal program spending since 1987. Spending on S&T - which includes both R&D and RSA - has ranged between 4.7% and 5.4% of federal program spending.

We undertook this study in three ways. First, we conducted a review of the major Canadian studies and reports that have been issued in the past 35 years or so to see what issues, findings, conclusions and recommendations had been made, and what common themes had emerged. We also reviewed commentary in the (science) policy literature and popular press.

Secondly, we consulted with senior officials in a number of SBDAs and with a number of knowledgeable individuals outside of government to gain a perspective on current issues and operations. Finally, we drew on recent work we have conducted for different SBDAs on these and related topics.

2.0 Findings

In this section we present the key findings of our literature review, with special emphasis on the role and operations of federal S&T[1]. We began writing this report with an intention to group the findings into two categories - roles and operations. First, what the best-known past studies had to say about the roles of federal S&T. And secondly, what they said about the operations of the federal S&T establishment.

After reviewing the available science policy resource materials, it became apparent that much more has been written about the operations of federal science than about its roles. In other words, much more emphasis has been placed on how the federal government should conduct S&T - and particularly R&D - than on what S&T it should undertake and why.

However, as we explored the issues it began apparent that the question of roles and operations were often too closely linked to be neatly separated. And so it was decided to blend the discussion under the key issues or themes that have been explored in the studies. Appendix 1 contains a detailed review of past research and studies that have dealt with the role and operations of federal S&T. Following is a synopsis of the key issues raised in the review.

Issue #1 - A Policy for Science

Starting with the Glassco Commission report in 1963, many studies have commented in one way or another on the fact that there is no high-level resource-allocation mechanism for federal S&T (or for that matter other federal spending).

> *"... there is no universally accepted pattern for arriving at these vital (S&T spending) decisions"* (Glassco)

Glassco had in mind issues such as the amount of resources devoted to R&D, the distribution of funds, the areas to investigate, and coordination of international scientific linkages. In many respects the search for a resource allocation guiding policy remains the holy grail of science and industry policy; one which we are no closer to today than ever. Presumably, a policy for science would deal in a comprehensive way with the role of federal S&T, so that appropriate spending decisions could be made.

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[1]The studies reported on in Appendix 1 summarize all report contents, not only those dealing with the role and operation of federal S&T.

The Commission also recommended the creation of a National Scientific Advisory Council to harness views on science policy inside and outside government, to provide independent advice to the government, review all government scientific programs, and occasionally address important specific problems of issues. Over the years this recommendation led to the establishment of a variety of organizations, ranging from the Science Council of Canada, to the Prime Minister's National Advisory Board on Science and Technology (NABST), Advisory Council on Science and Technology (ACST) and Council of Science and Technology Advisors (CSTA).

The central machinery of government science was also of concern to the Lamontagne Commission, as was national science policy. However, for Lamontagne the role of national science policy was to provide a basic framework for specific policies, not to replace them.

Issue #2 - Allocating Resources

Subsequently, many reports have returned to the topic of a policy for science. In 1984 NABST (*Spending Smarter*) found that S&T was a clear priority for government, but it was not managed as a strategic asset. There was no apparent rationale for the distribution of S&T expenditures amongst departments and agencies, and no explanation or information on why or how expenditure levels were established. There was no horizontal method to select S&T priorities in government.

A 1995 report prepared for NRCan found that Program Review had been conducted essentially as a top-down horse-trading exercise, with little effort to (re)balance expenditures among government priorities or among departments.

Although governments lack a coherent mechanism for allocating resources among different purposes of expenditure, there is an exception that bears noting. In 1998 NSERC was able to undertake a thorough re-balancing exercise in which it re-allocated spending among different branches of science and engineering according to where the scientific fields were headed and how much benefit the research promised for Canada. This exercise led to significant reductions in some fields and significant gains in others. However, NSERC was fortunate - it "dodged a bullet" - when it received additional funds in the 1998-99 budget so that it could boost the threshold of funding for all disciplines and avoid any losses in real spending power.

Allocating resources took on another meaning for the Science Council (*The Role and Function of Government Laboratories and the Transfer of Technology to the Manufacturing Sector.* 1976) The questioned why federal labs were concentrated in the National Capital Region, and concluded there was no apparent underlying logic to locating labs in the regions. There was value in concentrating labs to create a critical mass of expertise. Labs also needed to be close to the seat of power in order to protect their interests.

Issue #3 - Managing Resources

Management of federal laboratories was another theme of the reports reviewed. Pierre Lortie (*Revitalizing Science and Technology in the Government of Canada.* 1990) found that outdated and "seriously deficient" operating and administrative policies were making it difficult for federal labs to meet expected quality and productivity standards. Even then, Lortie found that lab morale was low. Part of the problem, according to Lortie was that the mandates of science organizations needed to become more focussed, and management needed to be less costly and bureaucratic. Lortie noted that previous attempts at management reform often led to micro-management.

Interestingly, Lortie commented on the need for S&T establishments to develop their own identity, in order for them to pursue quality work. However, because they were integrated into larger departmental structures and planning and budgeting systems, making it difficult for them to maintain a unique work culture. Like other commentators (e.g. Wright, Auditor General), Lortie notes that evaluation systems needed to be improved, as few of the systems in place directly addressed issues of quality.

Lortie advanced a form of the Rothschild customer-contractor principle. He proposed that each department transfer its labs into a single departmental S&T institute with a CEO and board of directors (cf. Wright). Institutes would contract with their client departments for S&T services. This would help ensure that the services provided met the department's objectives. Lortie wanted the institutes to be depending on clients for their operating funds. The proposed new management structure would give institutes greater authority to manage their relations with their departments, and greater control over such matters as fees and intellectual property commercialization.

Alongside these changes Lortie proposed development of a new evaluation system, including peer review. Federal scientist and engineers would vote for the top 100 of their peers based on the excellence of their work. Those selected would form the pool from which peer review panels would be drawn. There would also be a National Panel for Quality Evaluation to ensure that institute evaluations met recognized international norms.

Issue #4 - The International Race

Lamontagne introduced the metaphor of "the international scientific and technological race" in the 1970s. No doubt an offshoot of the Cold War "arms race" and "space race" ethos, the idea was that Canada lagged in the production and use of science and technology. MOSST picked up on this theme in a 1985 working paper *Science, Technology and Economic Development.* This paper found that the Canadian economy was often 8-10 years behind other countries in the "race" to adopt new technologies. MOSST argued in 1987 (*Innovaction: The Canadian Strategy for Science and Technology*) that "Canada cannot afford to fall behind" its competitors in matters of S&T.

Technology-adoption gap studies have become another enduring feature of science policy in Canada, and a recurring theme of discussions of the role of federal labs. That is, if there is a technology adoption gap in industry, then one role of federal labs is to help industry close that gap.

Thus, one rationale for a strong (federal) research capability was to keep up with our competitors.

Issue #5 - A Policy "Czar"

A second theme made popular by Glassco, and pursued on and off by reviewers ever since, is the idea that there should be a single minister responsible for science in Cabinet, with sufficient analytical resources to monitor inputs, activities, outputs and impacts across government. Such a minister should also have sufficient clout to bring important government-wide issues to the Cabinet table.

Glassco's conclusion led to the formation of the Science Secretariat in the Privy Council Office, which later evolved into the Ministry of State for Science and Technology, which was in turn absorbed into Industry Canada. It also led to the creation of a junior Cabinet position - the Minister of State for Science and Technology (now Science, Research and Development).

As with the science policy, one presumed outcome of having a cabinet minister responsible for science affairs across government, would be the development of a comprehensive statement on the role and operations of federal S&T.

As we now know, the idea of a science czar has constantly foundered on the rock of ministerial and departmental responsibility. Individual ministers are legislatively responsible for their own (science and technology) affairs and neither ministers nor officials take kindly to central direction of their S&T operations, even though they are usually willing team players when dealing with cross-departmental and national issues[2]. However, the jury is still out on the extent to which SBDAs have evolved the necessary structures, financing management arrangements to make horizontal S&T truly workable.

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[2]For example, departments are more than willing to cooperate on issues such as the government's rural communities agenda, climate change, and biotechnology.

Issue #6 - Basic versus Applied Research and Development

In the late 1960s and early 1970s Lamontagne began to ask questions about the balance of basic research, applied research, engineering and development in federal laboratories. At that time the labs were emerging from an era in which they acted as de facto substitutes for the nation's under-developed university S&T infrastructure. For instance, Canada's premier national lab, NRC, was then organized along university disciplinary lines (chemistry, physics, etc.) and operated with many of the features of a university culture. Industrial research had a negative connotation and basic research had higher prestige.

Lamontagne noted that Canada still trailed most other OECD countries in its levels of R&D spending - especially in industry - and shifted the focus of federal research in an industrial direction. This has been a recurring theme of lab policies ever since. The argument went that because Canada's industrial structure - small unsophisticated firms and a high degree of foreign ownership - we needed strong federal labs to do what in other countries would be done by the private sector.

Lamontagne was supported by the Science Council of Canada, which issued its landmark report *Towards a National Science Policy for Canada* in 1968. Like Lamontagne, the Science Council decried the over-emphasis of Canadian science on basic research. The Council added the observation that too much applied research was being performed at a distance removed from the "point of innovation" - that is, industry. It also concluded that more R&D should be performed outside of government labs by universities and the private sector.

The Science Council agreed with Lamontagne and recommended that federal labs should contract out more research. It added that the federal government should use its procurement policy to upgrade the technological capacity of industry.

The 1984 Wright Committee report returned to this theme:

> *"We believe, however, that these traditions of excellence are being undermined by a growing atmosphere of irrelevance and an excessively bureaucratic management style. Some (federal) laboratories, which once played central roles in national development, now find themselves struggling to find appropriate challenges. Others whose missions were once so clearly defined that they almost "ran themselves", are now subject to a nit-picking supervisory style ... the lack of clearly defined missions, plus an excess of administration, were the criticisms we heard most frequently"*

In one guise or other the basic-versus-applied debate is an ongoing feature of science policy reviews. As recently as December 1998 (*Report of the Auditor General*), the debate was still in full swing. The Auditor General's report said that the government needed to pay greater attention to mission-driven, results-based research with an S&T plan and performance. The nomenclature had evolved from "applied" research to "mission-driven" research, but the message was the same.

Issue #7 - Relevance and Excellence

The basic-versus-applied debate is closely linked to the research relevance debate. Lamontagne and Wright each questioned different aspects of the relevance of federal research. For Lamontagne it was a question of whether the labs were over-emphasizing basic research at the expense of applied work. For Wright, the question was one of the quality of work produced by the federal laboratories. As Wright said:

> *"It is sometimes argued that the quality of work produced by the federal laboratories would improve if their budgets were increased. We disagree. The problem isn't a lack of money ... The problem, in the case of some labs, has been a lack of constructive criticism from other scientists ... In our view this "peer review" process should be strengthened ... to monitor the overall relevance and effectiveness of specific laboratory missions. Quality must be pursued in the context of a clearly defined purpose."*

According to Wright:

> *"Nearly all federal laboratory research bases its claims to relevance on one of two premises: either it supports the needs of some government agency or it supports the goals of private industry ... If a federal laboratory exists to support industry, its research and development efforts can be justified if, in addition to being in the national interest:*
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> *! the risks or expenditures involved are too high, or the potential payoff too small or too far down the road, to attract private industry;*
>
> *! the industry is too fragmented to undertake the necessary R&D."*

Wright went on to decry the lack of effective consultative mechanisms; calling many existing mechanisms "window-dressing".

However, Wright pointed out that there are many federal labs whose client is government and not industry. These labs: test or monitor, establish codes, standards and regulations, maintain data bases, operate national facilities, address national or regional problems, and carry out federal security or treaty obligations. He argued that federal lab managers should be held accountable to their clientele, and recommended establishing Boards of Directors - <u>not</u> Advisory Boards - for each lab.

Perhaps because the decade of the 1980s marked a low-point in the outside world's perception of federal labs' relevance, or because it marked the high point of bureaucratic hubris ("federal labs know best"), Wright called for a fundamental review of every lab:

"We therefore recommend that a review of all federal laboratories be carried out, with each laboratory being required to demonstrate to a designated central agency its relevance and usefulness."

The Auditor General returned to this theme in December 1998. In discussing scientific excellence in federal labs, he pointed out that labs were seeking expert advice with respect to their research planning, but not for the quality of their research. Implicit in his statement was a reference to the role of peer review in government science.

The tension between public and private science was a theme of the Science Council's report as well. The Council pointed out "two solitudes" of government and industrial research. It said there was a need to eliminate the "tough dialogue" between the two, especially industry's criticism of NRC. The Council went on to say that "the major weakness of the technology transfer process may lie in the poverty of industrial attitudes to the government research institutions: the failure to fully appreciate the missions of the laboratories; the absence of persistent association with the government research community; and in general, the low level of demand pull by industry on government research."

The Science Council had independently studies the question of relevance, and in particular the role of federal labs. Their study highlighted the roles of government R&D and why and when it should be performed:

- when issues of security are involved;
- when the mission of the R&D is inappropriate to industry;
- when it is necessary for the regulatory functions of government;
- for the setting of standards and norms;
- to be able to maintain a sufficient in-house competence to fulfill departmental missions; and,
- when R&D facilities are costly, and too much for one firm.

Issue #8 - In-House Research versus Contracting Out

Once Lamontagne drew a distinction between basic research and applied research, the debate inevitably began to turn to the question of "who should do what"? A logical conclusion was that universities should do basic research and industry should do developmental research and engineering. But how would these get funded?

This question became identified with the issue of in-house versus contracted research. In order to build the capabilities of university and industry labs, it began to be argued that money allocated to federal labs should be spent in universities and industry. Lamontagne and Wright recommended that reviews of intramural government R&D should be performed to see which aspects could be contracted out.

In part, the contracting-out movement was a response to what was seen as bloated bureaucracy and a lack of accountability in federal labs, and in part a desire to strengthen the research capacity of the other sectors in order to produce more benefit to Canada in the form of jobs, ownership of domestic industry, and so forth. Thus began what could be termed the contracting-out era of federal science policy, which dominated the debate in the late 1970s and 1980s.

Wright was clear - and adamant - about the division of in-house and contracted research:

> *"In our view, R&D should only be done in-house when there is a need for secrecy or neutrality, or when contracting out is not cost-effective in the long run. In-house R&D can also be justified by the need to develop scientific competence in particular areas, or by the need to maintain contacts with the international scientific community. In all other cases, we believe, the government should attempt gradually to shift the bulk of its research requirements to outside contractors."*

However, the contracting-out debate did not question that there was a good reason for undertaking the funded research in the first place, and was more a debate over "how" rather than "what" or "why" . It was in large part a debate over control of resources, and to which party the benefits would flow, rather than an examination whether the research needed to be undertaken at all.

Another development in the in-house versus contracting-out debate was growing interest in the "Go-Co" (government-owned, contractor-operated) model of federal research in the 1980s. Wright said explicitly:

> *"We believe this model for managing federal laboratories (government-owned, contractor-operated) should be used more widely in Canada, on a deliberately experimental basis.*[3]

More recently, Michael Porter (*Canada at the Crossroads: The Reality of a New Competitive Environment.* 1991) also recommended that "government should increasingly shift its internal spending on R&D in its labs to industry".

By the early 1990s momentum in R&D had begun to shift to the private sector. The enormous growth of the information and telecommunication industries - admittedly with a major impetus from early government research and funding (cf. Arpanet) - encouraged Porter to call for the private sector to lead the development of the information highway in Canada. This, of course, was taking place in any event, but it was symbolic in that it perhaps marked an explicit recognition that the era of government labs paving the way to a bold new future had ended. Henceforth, government labs would be important <u>partners</u> (with industry and universities) in

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[3]That is exactly what happened in the early 1990s when Stuart Smith, former Chair of the Science Council, raised private funds to establish the Wastewater Technology Centre at the National Water Research Institute in Burlington.

the development of the new industries - infotech, biotech, robotics, remote sensing, advanced materials - but would no longer be the driving force they had been in earlier times

Issue #9 - Bridging Roles of Federal Labs

If, as Lamontagne declared in the 1970s, basic research was properly the role of universities and applied research the role of industry, what then, was the role of federal labs? Naturally enough, given that resources that formerly went to the labs would now be directed to universities and industry, labs could rightly claim that one of their roles was to support research in universities and industry. After all, they were responsible to their ministers for the money was spent, and someone had to specify what work universities and labs would undertake with (lab) money, and monitor the performance and output of external contracts.

Another result of the contracting-out era is that some labs began to position their role as a "bridging function". They argued that industry did not have the knowledge, expertise, facilities or equipment to properly integrate the results of esoteric university basic research into their own activities. University research was usually far removed from a practical application, and therefore the role of the federal lab was to help industry translate basic research into new products or processes.

Not that government labs would actually create those products or processes, but that they would work at a "pre-competitive" stage, where the research was sufficiently generic to apply to the needs of an industry sector, and not just an individual company. Many industrially-oriented labs (e.g. IMI[4]) began to organize multi-client research programs - sometimes termed Special Interest Groups[5]. These often focussed on SMEs. In the case of IMI the strategy was to begin with presentations about where best industry practice was headed. This led to the identification of shared R&D problems and a cooperative R&D program. Participating companies often began their own R&D programs in response to the opportunities they were introduced to by the federal lab.

Issue #10 - Industrial Sovereignty

The mid-1970s marked an era of concern over excessive foreign ownership of Canadian industry. Industrial and technological sovereignty became dominant themes of public policy, culminating in the National Energy Program, which was designed to wrest control of Canada's energy resources from foreign hands. The Science Council of Canada (*Forging the Links: A Science Policy for Canada*) recommended that industrial strategy should be based on technological sovereignty - the development of the technological capacity of Canadian firms. The Council proposed four goals:

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[4]NRC's Industrial Materials Institute

[5]IMI was a pioneer in this field.

! increase demand for Canadian technology (for example, through procurement and trade policy)
! increase industry's ability to develop technology (for example, through the promotion of networks and consortia)
! increase industry's ability to absorb new technologies (this was a particular concern for small and medium-sized firms, who faced personnel and financial obstacles)
! increase industry's ability to import technologies in a way favourable to Canada (this was seen as a problem of high foreign ownership and the nature of branch plants)

Thus, for a time, helping firms become technologically-sovereign became an underlying rationale of federal labs.

Issue #11 - Highly Qualified Personnel

Through its system of postdoctoral fellowships, NRC had become the country's premier research training organization. For two or more generations NRC had been the training ground for almost every scientist and engineer of note in the country. The emergence of a strong university research infrastructure in the 1960s and 1970s shifted the training emphasis away from NRC. However, NRC postdocs are still coveted positions and NRC has a strong training role through its system of guest workers and through external research partnerships. Perhaps because of its university culture NRC was able to exercise a stronger role in training that other federal agencies. Part of the reason is that while it could offer young researchers an internal career path, many used NRC as a stepping stone to employment in industry and universities. For industry and universities, an NRC accreditation was an assurance of quality.

In the 1970s Lamontagne had called for creation of a "Canadian Research Board" with operations in the physical science, life sciences, and social sciences and humanities, to increase the nation's capacity for research in these areas. At that time (late 1960s and early 1970s) NRC had been responsible for national S&T training matters. In 1978 the government created 3 Granting Councils (NSERC, MRC and SSHRC), and a large part of NRC's training mandate was shifted to the Councils. This event marked a new era, in which government funding of university research was separated from the funding of federal laboratories, putting the two institutions on different development paths.

Issue #12 - A Policy Framework for S&T

Following decades of debate over resources for federal S&T, in-house versus contract research, and the like, in 1994 the Auditor General issued a report that pointed out the emperor had no clothes (*Report of the Auditor General of Canada to the House of Commons*) - that there was no effective system of science priority setting or management. He said bluntly, among other things, that:

! Establishing S&T priorities is essential

- Government requires a framework and indicators to monitor its performance in S&T and to evaluate the success of its efforts to support S&T

- Parliamentarians have no basis for assessing government expenditures on S&T and if they reflect Canadian needs and opportunities

- Despite an ongoing series of reviews, government cannot clearly state what it seeks to achieve through its activities, nor is it able to manage its efforts in such a way as to produce a maximum return on its investments

- Most departments need to improve their ability to identify the potential uses and users of the results of their activities

- Most departments overemphasize projects on the basis of revenue generation

- The commitment to evaluate S&T activities varies across organizations

In 1995, the AG's report led NABST (*Health, Wealthy and Wise: A Framework for an Integrated S&T Strategy*) to explore ways to improve the integrated management of federal assets and investments in S&T. While acknowledging that some cuts to ineffective science programs might have been merited, it declared there was no evidence that less S&T spending was good, as national spending was already low.

NABST recommended development of an S&T governance structure which would link economic and social goals, and establish S&T priorities. It declared that government's role is increasingly to facilitate and promote innovation, information sharing, partnerships and the leveraging of private funds, rather than engaging directly in innovation activities. It also said federal lab activities should be evaluated and justified against strategic needs.

In 1996 the federal government undertook a nation-wide S&T consultation that culminated in a new S&T Strategy *Science and Technology for the New Century*. It found that as program review had resulted in a drop in federal S&T expenditures, the government needed to focus on core activities: funding and performing scientific research in departments and agencies; university and hospital research and the NCE program; and, supporting private sector R&D. The S&T Strategy proposed seven operating principles:

1. Increasing the effectiveness of federally-supported research by stressing principles of excellence, relevance and technology transfer.
2. Capturing the benefits of partnership, such as promoting the development of consortia, and having an open door policy in the federal research infrastructure.

3. Emphasizing sustainable development and preventive approaches (such as improved health).

4. Placing Canada in the emerging regulatory regime.

5. Building information networks.

6. Promoting international S&T linkages.

7. Promoting a stronger science culture[6].

A 1996 follow-up report by the Auditor General was generally favourable to the S&T Strategy and called for a forum to share best practices in the management of S&T. It also said the true challenge for the strategy would be implementation, accountability and the need to promote parliamentary oversight. By 1997, the House of Commons Standing Committee on Industry (*Review of Science and Technology and the Innovation Gap in Canada*) was able to report that:

- Government research had become less basic, with more focus on commercializing research results and working with partners in universities and industry.

- Linkages and networks such as the NCEs and IRAP are important in the national system of innovation.

- It was sceptical about the new S&T policy framework and strategy, given the failure of such strategies in the past.

- Parliament needed to keep a closer and better eye on S&T.

Returning to the S&T strategy four years after its major review, in 1998 the Auditor General (*Report of the Auditor General*) criticised the government for being slow to implement improved S&T management measures. It called the government to task for ignoring some of the commitments it had made in the Strategy and reported uneven departmental response to the strategy's seven operating principles. The AG said there was a need to move from coordination of S&T to collective action, including joint goal-setting, research planning, and a common management framework. S&T priorities were as yet incomplete. The government's annual S&T report should focus more on results and horizontal S&T issues.

[6] In 1998 Industry Canada terminated its science culture programs.

Issue #13 - Science for Defence and Security

One theme which is striking for its absence from discussions of the role of federal S&T is S&T for national defence and domestic security. Possibly because of the need for secrecy, or possibly due to Canadians' reluctance to see themselves as a military power, the mainstream science policy literature has paid little attention to role of R& for the Canadian Forces, RCMP, CSIS and other defence or security organizations. This is in contrast to the U.S., where defence and security R&D debates have high visibility.

3.0 Response of the Science Establishment

Federal SBDAs have been under a microscope for nearly 35 years, since Glassco. In that time we can discern three sets of change drivers. First, is what might be termed role drivers. These are periodic changes in paradigms, models and expectations, often resulting from external reviews such as the Wright, Lortie, Porter, Auditor General, or OECD reports. Reports of this kind tend to drive organizations' perception of their roles and operations from a top-down theoretical perspective.

A second set of change drivers is policy drivers. These are the meat-and-potatoes of the day to day work of governments. BSE, genetically modified plants, climate change, sustainable forestry, allowable catches, blood safety, building standards, environmental standards, natural hazards, energy efficiency, value-added strategies, productivity, brain drain, Y2K ... the list is nearly inexhaustible of public policy issues which boil to the surface every day, week and month. Through this all, federal labs are on the front line in providing science advice to their ministers, who are in turn accountable to parliament and the public.

The third set of change drivers is budgetary drivers. Against a seemingly un-ending list of government's science needs is the annual reality check of budgets. For much of the post-war period, lab budgets expanded in line with the overall growth of government spending, in some years doing somewhat better, and in some years somewhat worse. Starting in the 1980s and accelerating in the 1990s, budget stability crashed up against the rock of fiscal restraint. Suddenly, incremental budget increases or decreases gave way to deep cuts.

In reality all three forces are continually at work influencing the role and operation of the federal science establishment. Sometimes one set predominates and at other times another. Sometimes the forces reinforce one another - e.g., brain drain and funding for the Canada Foundation for Innovation - and sometimes they conflict - e.g. environmental standards and environmental inspector job cuts.

What makes it difficult for science managers to judge success or failure or progress is the absence of universal performance indicators. Unlike their colleagues in industry, they have no standard measures to gauge their progress - no quarterly profit, new product launches, capital gains or sales.

How has the science establishment responded to 35 years of scrutiny? Some of the response has been positive and some raises concern.

3.1 Improved Business Practices

Labs are adopting business practices that would have been unheard of only five years ago. Project management systems, key performance indicators, business development offices, advisory committees, vision and mission statements, client satisfaction surveys, revenue generation targets, impact studies and other related business practices are being rapidly integrated into lab operations. By most any measure the modern federal lab is being run in a far more business-like way than ever before.

3.2 Expanded Partnerships

Partly driven by declining finances, but also motivated by a new appreciation of their role in national systems of innovation, labs are building partnerships with the business, university and non-profit sectors. Increasingly, labs are the focal point for collaborative industry research, participation in Networks of Centres of Excellence, cross-department project teams, Special Interest Groups, and other forms of research partnership.

In some instances expanded partnerships have been extremely successful. One department has leveraged $35 million of internal money into many times more research by industry. This has reduced the department's perceived need to try to do all things for all its clients.

3.3 Selectivity

The government's 1995 program review forced some federal science organizations to abandon "cheese paring" - across-the-board budget cuts - and eliminate whole programs that were seen to no longer fit with their mandates. In some instances those programs had long been known to be non-essential, but sometimes, as in the case of regional facilities, were preserved purely for political reasons. Large scale budget reductions created the impetus for ministers and deputy ministers to make hard choices. Some organizations realized that further cross-the-board cuts would reduce critical mass in many or all programs, and chose instead to maintain a stronger capability in the surviving programs. Most SBDAs will acknowledge that program review did at least help them cut out some dead wood, even though it had other effects which were not so positive.

3.4 Contracting Out

In at least some departments one impact of program review was that cuts were apportioned more to external research activities than internal research. In those agencies there was a large reduction in grant, contract and contribution funds, in order to preserve a viable internal S&T capability.

3.5 Depth of Capabilities

Many departments and agencies now feel they are "thin on the ground". That is, they no longer have the depth of resources they need - facilities, equipment and expertise - to fulfil their mandates. Some have triaged their capacity according to whether they need to lead, follow, or watch science developments in a particular area.

3.6 Capital Infrastructure

Many labs point out they have had to cope with budget reductions by postponing capital re-investment, both in facilities and equipment. In 1998-99, for example, total federal government capital expenditures were projected at $206 million, out of a total S&T budget of $5,481 million, or 3.76% of S&T spending. R&D capital expenditures were projected at $105 million of a total R&D budget of $3,322 million, or 3.2% of R&D spending. Capital spending for R&D in 1998-99 ($105 million) was around half what it had been in 1994-95 ($205 million). With spending running at such low levels the federal science establishment will continue to consume its capital base with no hope of revitalizing its infrastructure.

In some instances facilities no longer meet modern health and safety requirements and could be threatened with closure. In other instances, equipment is no longer state of the art. This has several impacts. First, it reduces the value that labs can add to industry and university research projects. Secondly, labs lose an edge in the expertise that goes along with the use of modern equipment. Thirdly, they have difficulty recruiting new personnel, who would prefer not to work in aging facilities if they have a choice.

3.7 Human Infrastructure

The baby boom generation phenomenon is catching up with all federal science establishments. This is no secret and has been known for some time. The difficulty is that labs have few options to plan for a transition period. They have few resources to bring new people into their organizations for a period of training and adaptation. And, government-wide HR policies constrain their ability to recruit from outside.

Another issue is retraining of existing staff to learn new techniques and methods. Leaving aside the matter of training budgets, if there is no new equipment for them to utilize after their training, then the training itself is somewhat redundant.

Finally, four years after program review morale is still low in many research organizations.

3.8 Time Horizons

Another way in which SBDAs have adapted to recent circumstances is by shortening the horizon for their research activities. More and more, resources are devoted to near-term issues, and the capacity to look into the future and anticipate (public policy) S&T requirements is eroding. All hands are bailing the ship and the lookouts have been pressed into service. Unlike the 1970s when future studies were the rage and all departments had internal "think tanks" looking at emerging trends and issues, today departments operate in a more reactive and less proactive way than before.

4.0 Major Forces at Work

What then are the major forces that are likely to impact on the federal science establishment in the future? Foretelling the future is difficult at the best of times, but in the spirit of provoking discussion, we offer the following ideas for consideration.

4.1 Growing Cost of Research

An obvious factor affecting all future research is cost. Equipment, literature, supply and facility costs do not respect the consumer inflation rate or government budgets. As with passenger cars, lab equipment is far more capable today, but that capability often comes at a higher price. Moreover, the pace of change in equipment is such that in many cases users cannot derive full benefit before the equipment becomes obsolete. However, federal R&D spending is falling:

Federal Budgetary Expenditures on S&T and R&D											
	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997*
(Constant 1986 $ millions)											
S&T	4303	4394	4406	4618	4751	4669	4759	4576	4417	4399	3904
S&T	2564	2652	2686	2762	2835	2882	2924	2894	2708	2637	2348
Share of federal program spending (%))											
S&T	4.7	4.8	4.9	5.0	5.0	4.7	4.9	4.9	5.0	5.4	4.8
R&D	2.8	2.9	3.0	3.0	3.0	2.9	3.0	3.1	3.1	3.2	2.9
* Industry Canada estimate											

4.2 Expanding Science and Technology

Science and technology are not static fields. The doubling-time-of-science phenomenon pointed out by Derek de Solla Price in the 1950s, means that research organizations need to work harder and harder to maintain their positions in world science. Or, they have to periodically re-define their objectives. The expansion of S&T seems inexorable, and so does its impact on public policy. Who, fifteen years ago, would have predicted that ozone depletion would have become a major public policy issue in every country? Or AIDS? Or sustainable fisheries? Or a host of other issues that now occupy government researchers?

How do departments add new capacities to deal with emerging science and technology - genomics, biotechnology, robotics, photonics, etc. - and at the same time maintain a capacity in existing fields?

4.3 Networking

Government has recently elected to make a significant re-investment in university research infrastructure through the Canada Foundation for Innovation. Meanwhile, investment in the federal science establishment is at an all-time low[7]. Some would say there is no credible scenario in which SBDAs will receive sufficient financial resources to meet all their anticipated human and physical capital requirements. This highlights the need for SBDAs to tap into external research networks to gain access to a significant portion of the equipment and talent they will require in the future.

Improved networking is important for other reasons as well. One is early talent identification; identifying promising researchers and policy analysts while they are still in university, and orienting their studies and research in a direction that will benefit federal science organizations. Another is that networking can help SBDAs to maintain a watching brief on new and emerging areas of science that may impact their fields in the medium to long term.

4.4 Aging Workforce and Flexible Hiring

SBDAs have already done a considerable amount of work to identify the impact of the aging federal workforce on their research capacity. However, for the most part the analytical work has yet to be translated into viable action plans. At work here are federal employment practices, which tend not to differentiate the unique needs of SBDAs from other federal employers. Greater flexibility in hiring is required if SBDAs are going to manage the 5-10 year transition period. Compounding the challenge is that labs will need to anticipate future skill requirements and not simply replace past ones.

4.5 Compensation and Competition for Talent

In some fields of S&T federal salaries are not competitive with those being offered in the private sector. This will make it difficult for SBDAs to compete for talent in high demand fields. Their competitive disadvantage may be compounded by the diminished status of employment in government. However, this point is still debatable, as the federal government still receives more job applications than it has positions to fill.

4.6 Cross-Portfolio Science Management

Science policy issues of the day do not respect government's somewhat arbitrary departmental structures. Climate change, fisheries habitat, AIDS, and a long list of other issues demand cross-portfolio solutions. Science organizations find it difficult enough to "matrix-manage" issues within individual companies or organizations. The difficulty is compounded when

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[7]Although as a proportion of federal program expenditure it is within a normal range.

different organizations are involved. There is a need to evolve new management structures in which temporary teaming arrangements can be easily formed, disbanded, properly resourced from multiple budget sources, and managed to conclusion. Many expect these cross-portfolio issues to exert a greater influence in the future.

4.7 Science Assessment: Linking of Research to Policy

Attention in government has only recently turned to the linkage between government research and the policy making process. Emerging thinking is that perceived recent failures of government science (cf. fish, blood) have really been failures to properly assess available research, rather than bad government research per se. Developing more transparent and robust science assessment mechanisms will be increasingly important for government, but the need for confidentiality in policy advice makes this a delicate challenge.

4.8 Declining Credibility of Government

Federal S&T organizations operate in the worldwide climate of a declining credibility of government. The public still expresses a high level of confidence in government scientists (as opposed to politicians or journalists), but the ship is slowly sinking and even the upper deck passengers are getting their feet wet. If public mistrust of government science were to continue to grow, it would have severe consequences for the ability of governments to develop and implement science-based policies. At some point the public will need to deal with issues such as nuclear waste disposal, airport siting, and carbon taxes. A credible science establishment is a prerequisite for success.

4.9 Precautionary Thinking

There is a risk that falling resources, negative publicity, and public perception of failure will cause the federal science establishment to become more conservative in its outlook and go too far in the direction of avoiding risk. This will manifest itself in a decline in leadership and a certain reluctance to try new things. Government is inherently risk-averse, and the federal science establishment needs to maintain a delicate balance between sticking to tried and true solutions and experimenting with new approaches.

4.10 Emerging Diseases and Unforseen Threats

SBDAs need to have a capacity to deal with what the military calls "asymmetrical threats". These threats can range from emerging diseases such as new strains of TB, viruses, and drug-resistant bacteria , to urban bio-terrorism, information warfare, earthquakes, floods, severe weather, asteroid collisions, and other natural disasters. The dilemma for the public sector is that events such as these tend to have a low probability of occurring, but major consequences if they do. And yet society expects the federal science establishment to be in the forefront in protecting it from these possibilities.

4.11 Aging Capital Infrastructure

The federal science establishment's physical infrastructure requirements are a product of the role that society expects them to play, and their strategies for undertaking that role. Therefore, there may be no absolute way of determining "how much is enough?". Nevertheless, there is evidence that budget cutbacks have had a negative impact on capital infrastructure in many SBDAs, and that a round of re-investment may be required. To date, the government has been reluctant to investigate this question. At some point decisions will have to be made about whether and how to rejuvenate infrastructure.

However, while improving physical infrastructure may be a necessary condition for creating a healthy lab system, it is by no means sufficient. Infrastructure merely provides a capacity to do useful work, but does not ensure the work will get done. Simultaneously, labs will need to deal with the matter of staffing of new facilities and equipment, and their overall skill requirements, especially as it relates to assessment and policy.

4.12 National Facilities

A 1991 study conducted by the Canadian Research Management Association[8] demonstrated that companies surveyed used federal laboratories primarily to gain access to leading-edge facilities which they cannot afford on their own, and to the expertise that goes along with the use of those facilities. Thus, the ability of federal labs to help companies is directly linked to the state of their (national) facilities, equipment, and expertise. With research and manufacturing becoming increasingly global, it is becoming easier for firms to source their R&D requirements outside of Canada. Therefore, federal labs need not only to be the best available resources in Canada, but often the best available anywhere. This is especially true for labs' dealings with large firms, which are in a better position to access the best S&T, wherever it exists. If large firms are not working with federal labs, and in many instances providing their base load of research collaboration, then labs may not survive to work with smaller firms.

4.13 Assessment and Policy Capacity

Making improvements to SBDAs' research capacity does little by itself to improve policy-making. Policy making builds on a sound research base, but requires a different set of processes and skills. In particular, the capacity to assess the results of in-house and external science, and to translate the results of the assessment into policy. Simply increasing internal research

[8] CRMA. Effectiveness Of University And Government Research Funded by Industrial Corporations. 1991.

capacity is no guarantee that improved (science) policy will result. Improvements in science assessment and in policy making must go hand in hand with improved research capacity.

4.14 COTS

Increasing use of commercial off-the-shelf (COTS) technologies and industry-standard software is becoming the watchword of military procurement. This procurement philosophy will also impact non-military government procurement. Where previously government labs would custom-make equipment or software to suit their needs, in the future they will need to rely more on commercial hardware and software to meet their needs.

4.15 Faster, Better, Cheaper

"Faster, better, cheaper" is the phrase made popular by Dan Goldin at NASA. Goldin's challenge to NASA was to make space exploration more affordable and more reliable while simultaneously reducing cost. Streamlined management practices and the use of new technology were the tools envisaged to make this possible. This challenge of government science management is now finding its way into other fields of government science, and will be the challenge to all science managers for the foreseeable future.

4.16 Relevance to External Stakeholders

Even though the federal science establishment often sees government (policy) as its main client and raîson d'ètre, it is often its perceived relevance to external stakeholders - industry in particular - that determines its future. Because of their political influence, industry stakeholders are often in a stronger position to influence the future of federal labs, even if they are not the labs' main clients. Loss of external support can lead to fewer resources for a lab and directly influence its policy mission. And yet, an excessive orientation to external stakeholders can also detract from a lab's public policy mandate. However, external stakeholders don't have to walk the walk, meaning they may not appreciate the full range of a lab's mission. Clearly this issue requires a balanced approach. Managing external stakeholder expectations is an ongoing issue for federal labs.

4.17 Lack of Champions

Who speaks for federal labs? Universities and industry can lobby government directly to address their interests. Yet protocol, custom, and the absence of a strong external champion such as Glassco or Wright, restrict the ability of federal labs to make their case within government. Often they find themselves competing for resources with other parts of their departments and agencies. Who then will ask the question "Does our science establishment have the resources to do what we demand of it?" Perhaps CSTA will.

5.0 Conclusions - Lessons Learned

What conclusions can we draw about roles and capacities from our survey of 35 years of reports, discussions with science leaders, and review of major trends affecting our federal labs?

5.1 Roles of Federal Labs

Even though federal labs have been the subject of decades of study and analysis, no definitive statement or model of the role of federal labs has emerged from domestic reports. Most reviews have focussed on the "how" of federal S&T, rather than "what" and "why" (role) questions.

The fact there is no government-wide role framework for labs' activities can be partly explained because labs' role derives in the first instance from their individual departmental mandates, and not from a government-wide S&T or R&D mandate. As there is no "science budget" nor any formal mechanism for top-down science direction or resource allocation in government, there has been no impetus nor mechanism for developing a comprehensive role statement that would apply to all labs. Instead, from time to time government has advanced general policy frameworks (such as Wealth Creation, Quality of Life, Advancement of Knowledge) under which labs are encouraged to elaborate their roles.

On occasion, government has set out guidelines for helping departments select (or de-select) programs. For example, during the 1994-95 Program Review exercise that led to large budget reductions at many labs, the following 6 "tests" were proposed for continuation of programs or activities. Departments and agencies were encouraged to assess whether programs were in accord with:

1. Public Interest (essential public service)
2. Role of Government (appropriate role for government)
3. Federalism (appropriate role for federal government)
4. Partnership (delivery with partners)
5. Efficiency (scope for enhanced efficiency in delivery)
6. Affordability (in light of available financial resources)

While departments used this framework extensively to help them choose which programs to discontinue or continue, it is not apparent that the tests were applied to entire organizations, such as labs.

Labs' roles reflect both the legislation that establishes them, and the policy priorities of the government of the day. Some labs, such as NRCan's Explosives Lab, have clear mandates and roles that derive directly from their legislation (cf. Explosives Act. R.S., c. E-15, s. 1.) Other labs operate under more general provisions of their enabling legislation. Thus, NRC's legislation does not mandate the creation of institutes dealing with Microstructural Sciences or Biotechnology, but rather,

> 5. (1) Without limiting the general powers conferred on or vested in the Council by this Act, the Council may ... (c) undertake, assist or promote scientific and industrial research, including ... (i) the utilization of the natural resources of Canada ... (ii) researches with the object of improving the technical processes and methods used in the industries of Canada, and of discovering processes and methods that may promote the expansion of existing or the development of new industries ... (iii) researches with the view of utilizing the waste products of those industries ... etc. (R.S., c. N-14, s. 7; 1976-77, c. 24, s. 55.)

The permissive nature of the legislation under which many labs operate gives them the flexibility to adapt their mandates to meet important national objectives (e.g. climate change, toxics in the environment), by designing specific solutions as new objectives emerge.

In some respects understanding the role that federal labs play is only possible if one understands the diverse roles that the federal government itself plays, and how those roles evolve over time. Understanding the many roles which labs play - in promoting quality of life, creating wealth, or advancing knowledge - is further complicated by the fact that an initiative originally launched to address one objective can end up fulfilling another. Research toward improved drug testing might have wealth creation impacts as well. For instance, if a new toxicity test developed in a federal lab were to be licensed to a Canadian company and sold internationally.

Because it is hard to completely spell out the role of federal labs, some studies have tried to delimit their roles by adopting what amounts to a "default" approach. According to these studies, the role of federal labs is to do what industry, university, or non-profit labs will not, cannot, or by consensus should not do. Taken to an extreme, this approach is ultimately unsatisfactory. Few people would suggest that large businesses[9] should contract their core or strategic R&D requirements - those that give the company its competitive advantage - to external organizations. Similarly, we suggest, no country can afford to contract-out every aspect of the public good role that labs play.

[9]In some respects the federal government is the country's largest "business" - or more accurately, family of businesses.

Table 1. Total Federal Government R&D Expenditures, 1989-90 to 1998-99 ($ million)

R&D Activity or Performer	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99*
Current $										
Current expenditures	2,723	2,938	3,068	3,164	3,249	3,228	3,091	3,043	2,926	3,061
Administration of extramural programs	112	120	142	145	150	152	150	147	139	156
Capital expenditures	198	169	194	201	195	205	163	141	129	105
Total R&D expenditures	3,033	3,227	3,404	3,510	3,594	3,585	3,404	3,331	3,194	3,322
Constant $ (GDP Price Index Base)										
GDP Implicit Price Index	93.3	96.1	99.4	100.1	101.5	102.6	105.1	106.7	107.4	107.0
Current expenditures	2,919	3,057	3,087	3,161	3,201	3,146	2,941	2,852	2,724	2,861
Administration of extramural programs	120	125	143	145	148	148	143	138	129	146
Capital expenditures	212	176	195	201	192	200	155	132	120	98
Total R&D expenditures	3,251	3,358	3,425	3,506	3,541	3,494	3,239	3,122	2,974	3,105
Percent of expenditure (Constant $)										
Current expenditures	89.8	91.0	90.1	90.1	90.4	90.0	90.8	91.4	91.6	92.1
Administration of extramural programs	3.7	3.7	4.2	4.1	4.2	4.2	4.4	4.4	4.4	4.7
Capital expenditures	6.5	5.2	5.7	5.7	5.4	5.7	4.8	4.2	4.0	3.2
Total R&D expenditures	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Capital Expenditure as a Percent of Current Expenditure (Current $)										
Capital/Current Expenditure	7.3	5.8	6.3	6.4	6.0	6.4	5.3	4.6	4.4	3.4

Table 2. Total Federal Government R&D Expenditures, 1989-90 to 1998-99 ($ million)

R&D Activity or Performer	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99*
Federal Government R&D Expenditures in the Natural Sciences & Engineering, by Performer										
Current $										
Intramural	1,533	1,654	1,671	1,703	1,744	1,741	1,715	1,774	1,619	1,593
Canadian business enterprises	607	573	750	767	772	755	665	572	623	738
Higher education	660	766	778	817	810	832	795	758	724	802
Canadian non-profit institutions	44	34	34	51	66	73	58	72	67	47
Provincial and municipal governments	41	32	18	12	34	33	38	27	30	25
Other Canadian	48	59	59	52	54	28	27	23	21	19
Foreign	100	109	94	108	114	123	106	105	110	98
Total	3,033	3,227	3,404	3,510	3,594	3,585	3,404	3,331	3,194	3,322
R&D Contracting to Industry as a %of Intramural R&D Expenditures										
Intramural Expenditure (Int)	1,533	1,654	1,671	1,703	1,744	1,741	1,715	1,774	1,619	1,593
Canadian business enterprises (BE)	607	573	750	767	772	755	665	572	623	738
BE/Int	39.6	34.6	44.9	45.0	44.3	43.4	38.8	32.2	38.5	46.3

That is not to say that aspects of core research cannot be contracted-out. Overall figures indicate that labs currently contract around 22% ($738 million) of their total R&D spending to industry (Table 2). This is equivalent to 46% of labs' intramural R&D spending ($1,593 million) in 1998-99. Thus labs already contract out a substantial amount of their R&D requirements to industry, and one wonders if increased contracting-out would yield additional benefits.

To pursue the private sector metaphor, few large company executives expect their R&D divisions to contract their services to unrelated firms in order to earn revenue for the corporation. And in fact, the number of R&D divisions of private companies that provide such R&D services on contract is very small[10]. Yet many federal government labs now rely on outside contracts to provide up to 30% of their budgets.

Society does not expect private sector labs to behave like their public sector counterparts. Nor should it expect public sector labs to behave like private sector organizations. We know that even private sector labs often have substantial difficulty demonstrating their value to company executives, and that many find this a never-ending challenge. Thus, measuring the impact and value of corporate labs is a recurrent theme at the annual conferences of organizations such as the Canadian Research Management Association. And yet in comparison with private labs, public sector labs are called on to fulfill even more diverse roles. Whereas private labs operate in a relatively straightforward profit and loss business context, public sector labs need to fulfill much broader roles, many of which do not lend themselves to standard business accounting techniques.

Moreover, federal labs often play a developmental role that evolves over time. The role that an agricultural research lab played in developing a new crop species in the 1940s, when there was little private agricultural research capacity, might have been legitimate and important for the nation. By the late 1990s, similar work might simply duplicate an industrial capability. A more appropriate role for the lab of the 1990s might be to develop new platform technologies - for instance one that would facilitate gene insertion in a wide range of plants deemed important to the national economy.

Hopes of producing a definitive study of labs' roles are bound to fail for another reason; because many of the roles they play are informal. For example, nearly every federal lab plays an important role in supporting Canadian scientific societies (e.g. chemists, geophysicists, etc.) that serve a wider professional community, in industry and universities, and which promote national as well as international scientific objectives. There are few professional societies in Canada that could survive without the active and passive support of federal labs. This is only one of the informal roles that labs play. Other examples include; role of federal S&T in international relations, foresight role of federal S&T, role of federal labs in HQP training.

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[10]Of course, there are companies whose business is precisely to provide such contract R&D services.

Largely absent from the reports reviewed here, is a discussion of the role of federal S&T in policy development. In our opinion, this is an important topic worthy of a separate study. An important role of a majority of federal labs is to provide policy advice to government. Most labs would say that the government or their minister is their chief client. "Are European attempts to restrain the export of Canadian metals based on sound science?" "Is there global warming, and if so what should we do about it?" "What is the carrying capacity of our oceans?" "Should we allow a new pesticide into the country?" "Is it feasible to reduce nuclear weapon stockpiles by burning plutonium in CANDU reactors?" "Should Canada create a genomics industry, and if so, how?". "What level of arsenic is acceptable in groundwater?". "What will be the environmental impact of a diamond mine in the North?" "What HDTV or digital cell phone standard should Canada adopt?"

The list of science-based policy decisions that citizens demand of their governments is nearly endless. The consequences of wrong decisions can affect the health, safety, and economic prospects of thousands and millions of individuals. In many instances government finds itself directly liable for wrong decisions. The financial and human cost to the public of bad decisions can be enormous[11].

That said, there is no direct link between more and better science, and improved policy making. An adequate science capacity and infrastructure may be necessary conditions for good policy making, but not a sufficient ones: additional capacities, such as improved science assessment, are also needed to translate the findings of scientific research into actionable policy advice. Likewise, given that the vast majority of relevant research in a particular field will inevitably be conducted outside of federal government labs, in Canada and abroad, there is a need to create stronger linkages between intramural lab research and extramural sources of expertise.

As in the world of industrial or university research, the importance of individual and team vision and foresight also plays an important part in shaping the role of federal labs. Practically every federal lab can proudly point to its "stars" who made a significant impact on the public good - be it a Nobel prize winner such as Gerhard Herzberg, or a world specialist in the use of fly ash in high performance concrete, such as Mohan Malhotra at NRCan, or Larry Morley, whose work at CCRS (Canada Centre for Remote Sensing) created a viable remote sensing industry in Canada. Often these people laboured patiently for years on high-risk projects that did not fit neatly into a formal definition of their labs' roles. In many instances, Canada is the beneficiary of their efforts.

[11]cf. Thalidomide, Hepatitis C, and the Cod fishery.

5.2 Capacity Measurement

The second major question that is of interest to CSTA concerns the capacity of federal labs to fulfil their various roles. None of the studies we have reviewed has explicitly addressed this question. Unlike operational reviews, which have taken place at regular intervals and tend to focus on how government science is undertaken, there has been no government-wide review of capacity per se.

It is informative to contrast how university faculties tackle the issue of capacity. University graduate programs undergo comprehensive external reviews on a pre-determined schedule, as a condition of retaining their accreditation. Such reviews examine all aspects of a program - facilities, equipment, teaching quality, course offerings, etc. While there is no comparable system of accreditation review for federal labs, many individual labs have voluntarily adopted external review procedures.

The fact that until now there has not been sufficient concern to prompt formal capacity studies, could in itself be a sign to the government (and CSTA) that underlying capacity problems are building. Table 1 provides one indicator. On a constant dollar basis funding of R&D capital across government has fallen to unprecedented low levels (from $212 million in 1987-88 to $98 million in 1998-99). However, much work remains to be done to specify the nature and extent of the problem, if indeed there is one.

One impediment to this kind of determination is the absence of a general framework (and specific tools) for capacity measurement. It is not too difficult to specify the main elements of science capacity - people, ideas, capital infrastructure, financial resources, partnerships, networks, alliances, etc. But there is no uniform accounting-style method for assessing capacity needs or resources against these elements. Nor is there a mechanism for undertaking such reviews either within individual labs, or across SBDAs, such as a Treasury Board or Office of the Comptroller General-mandated 5 year review. Because there is a policy vacuum with respect to the management of science in government, the Auditor General's office has emerged as the only independent agency reviewing the sector. Unfortunately, no study or report has provided a universal science capacity measurement system.

One example of the problem can be seen in the difficulty of measuring the capacity of facilities and equipment. While businesses maintain separate capital accounts on their books, and depreciate their capital acquisitions on a schedule specified by Revenue Canada (which presumably accounts fairly for the useful life of plant and equipment), there is no comparable accounting system in the federal government. Federal capital expenditures are fully expensed in the year in which they are made, so there is no incentive or system for depreciating facilities or equipment. Therefore, government labs have no way of evaluating the useful life of their infrastructure, nor of comparing their own infrastructure capacity with that of other organizations, such as industrial labs. To do so would require federal labs to establish separate bookkeeping systems and undertake a substantial amount of work to capture information on the existing capital base.

As another example, in the domain of human resources, labs have made considerable progress in establishing their top-level requirements resulting from demographic changes. However, there are few tools available for measuring HR capacity against skill requirements, or for examining government-wide HR capacity shortfalls.

Despite the difficulties, individually and cooperatively, labs do conduct reviews - in many cases external reviews - of their science capacity, in order to determine the nature and size of their capacity shortfalls. However, as stated earlier there is no standard methodology for assessing capacity proposed in any of the past studies. This suggests that one useful role for CSTA would be to develop a uniform capacity measurement framework that all labs could periodically utilize.

5.3 The Way Ahead

Despite many domestic reports on federal S&T, no uniform framework or model has emerged for describing federal lab roles[12] or for assessing science capacity. What useful contribution can CSTA make in the present climate? In our opinion, CSTA could choose three different directions for its work. The first approach would be thematic - to review lab roles and capacities in respect of specific issues such as:

- Core function(s) of federal labs
- HR and skill needs in federal labs
- Networks, alliances and partnerships
- Capital infrastructure and national facilities
- Emerging science challenges to government
- Improving business practices
- Impact of the precautionary principle on government science
- Science assessment - translating research into policy
- Etc.

However, reporting on each of these themes or issues - and they are only a sample of those that could usefully be addressed - would warrant in-depth analysis and could consume a great deal of time and money. Thus, in our opinion it would be most valuable for CSTA to focus its efforts on the first issue - the core function of federal labs - and to develop a framework or "decision tree" that would help labs to determine their roles and assess their research activities against those roles.

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[12]However, work is ongoing to define roles. Please see *Government Science and the Public Interest.* John de la Mothe. NRCan 1998.

A second approach, equally valuable in our opinion, is for CSTA to develop a process and framework that labs can use to assess their capacity requirements to fulfil their mandates, with due regard to future challenges. At present, there is no common metric for labs to assess their individual capacity shortfalls (or surpluses), nor for departments to assess their overall capacity situation. Development of such a metric - ideally in cooperation with the labs - would be a useful contribution for CSTA to make.

Such a framework would do much to help SBDAs individually assess their labs' capacities, and would be valuable in and of itself. However, there is a separate but related question that individual lab assessments will not answer: "What are the Government of Canada's science capacity requirements?". This is a somewhat different question than the capacities of individual labs.

A third approach is to undertake a top-down federal science capacity analysis. This could be done in two ways. First, is to aggregate the results of individual departmental and lab capacity assessments, and looking for areas of duplication, shortfall, etc. However, this approach presupposes that individual assessments are available for analysis, and this is unrealistic in the short term. A second approach is to conduct a top-level statistical analysis, utilizing existing information from Statistics Canada and other sources, of the type presented here in Tables 1 and 2. Such an analysis would reveal long term trends of:

- Capital investment;
- Human resource and skill requirements;
- Intramural vs. extramural funding;
- Purpose of research by socioeconomic objective;
- Comparisons between government, industry, and university capacities;
- Prevalence and trends in networks, linkages, partnerships;
- Impacts/return on investment of federal S&T; and,
- Other capacity issues.

In our opinion, CSTA could make a valuable contribution by undertaking work in each of theese three directions.

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Appendix 1

Literature Review

The Roles of the Federal Government in Performing Science and Technology: The Canadian Context and Major Forces

Part 1 - S&T Reports

***Final Report,* Royal Commission on Government Organization (the Glassco Commission). (established 1960, reported in 1963)**

Context:
The task force was charged with reporting on the organization and methods of operation of the Canadian government, and was to recommend changes to promote efficiency, economy and improved service to the public. The commission considered science policy to be a "special area of consideration," as it saw R&D as being very important for the well-being of the country and its citizens. Thus it undertook the first ever comprehensive overview of Canadian science policy.

Major findings:
- within the context of attempting to organize more coherently government services and programs, the report documented a need to reorganize federal science activities
- in particular, the commission noted the lack of supervision, planning and direction, often in the fear of stifling scientific curiosity and creativity
- while expenditures on science and technology were increasing, they were increasing on an ad hoc basis, without clear policy guidelines: "there is no universally accepted pattern for arriving at these vital decisions" on national science policy, the amount of resources devoted to R&D, the distribution of funds, or the areas to investigate
- the federal government, including the NRC, did not effectively stimulate private industry's research efforts, even though industry benefited from government funds and research findings. In part this was due to the academic orientation of the NRC; the lack of overall scrutiny for agencies and departments involved in science and research; the lack of an effective advisor to cabinet in such matters; the Privy Council committee on science policy met infrequently, which meant that decisions involving science and technology were often decided by the political power of ministers and bureaucrats involved
- Canadian science policy was ineffective in part due to the lack of a single minister responsible for science in cabinet, and the lack of a secretariat to perform data gathering and analysis; still the commission believed that responsibility ultimately lies with the Prime Minister and Cabinet, even though they only have a lay knowledge of scientific issues
- while it may be desirable to have the Prime Minister responsible for science policy, given its importance, or that a Department of Science be created to coordinate R&D activities, these were rejected: the former for its impracticality, and the latter because of the pervasiveness of technology and research across the public service

- there was a growth in international scientific linkages, but no formal method for the government to coordinate its activities

Major recommendations:
- that the recommended position of President of the Treasury Board also be responsible for federal science and R&D policy, that the position have access to science policy specialists, and that a Central Scientific Bureau serve as a science secretariat to cabinet (this ultimately led to the creation of the Science Secretariat in PCO)
- creation of a National Scientific Advisory Council to harness views on science policy inside and outside government, to provide independent advice to the government, to review on an annual basis all government scientific programmes, and to occasionally address important specific problems or issues (this ultimately led to the creation of the Science Council of Canada)
- that the proposed Central Scientific Bureau assume responsibility for international science activities, with the assistance of the Department of External Affairs and the NRC

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***A Science Policy for Canada,* 4 vols. Senate Special Committee on Science Policy (the Lamontagne Committee)**

Context:
The Canadian Senate established the Special Committee on Science Policy in 1967. Its mandate was to examine federal science policy in order assess its effectiveness and efficiency, and its priorities and budgets, in a comparative manner. Of note was the requirement to report on the principles, long-term financial requirements, and the organization of a "dynamic and efficient" Canadian science policy. Science policy gained more attention because of the growing importance of science and technology, particularly at the international level, in achieving social and economic goals. The use of the metaphor "the international scientific and technological race" reflects the concern that if Canada did not possess the structural conditions and political and economic will to promote technological development and innovation, it would be left behind by its competitors. As we will see throughout this report, this is a common theme in Canadian science policy.

The significance of the undertaking, and indeed its urgency, is reflected in the fact that the special committee released four volumes of its findings and recommendations during the 1970s. The first set of public hearings were held in 1968 and 1969, which led to the release of the first three volumes. However, in 1975 the committee found that there remained serious problems in federal science policy. In particular, it found that many of its recommendations were not implemented, or wondered if perhaps its diagnosis of federal policy was inaccurate (again, a common theme). Thus it sought to further explore federal science policy through public hearings from 1975 to 1977, which led to the release of the final volume of its report in 1977.

Volume 1 provided a historical overview of Canadian science policy, and a comparative analysis of Canadian science policy with respect to the performance of other countries. Volume 2 looked at targets and strategies for Canadian science, technology and innovation. Volume 3 looked at the organization of government necessary for implementing a coherent science policy. Volume 4 examined changes in federal science policy since the work of the committee began, and again urged the federal government to undertake action.

Major findings:

- in the late 1960s, there was practically no federal government organization dealing with science policy, and there lacked quality data on the national science effort
- the central machinery of the federal government needed to be strengthened if a coherent science policy was to be developed and implemented
- it was important to include the social sciences in deliberations about, and the development of, science policy
- Canadian science policy focussed on research, especially basic research, and ignored key issues such as development, innovation and engineering; industrial research was seen in a less than positive light, and was equated with commercial life, while basic research was associated with "timeless values"
- while the pace of the Canadian R&D effort increased exponentially in the post- WW II era, Canada still trailed most of its competitors in terms of GERD/GDP
- Canada devoted a far greater proportion of its R&D expenditures to fundamental research than did most of its competitors, and far less to development; this reflected the growing increase in the importance of university research and the "persistent" Canadian emphasis on basic and applied research, to the detriment of development and innovation
- similarly, the state of industrial R&D was poor: business performed only 38% of national R&D, and government funded relatively little of the cost of industrial R&D, when compared to the USA, Great Britain and France
- national science policy should act in a similar fashion to broad macroeconomic policy, that is, to provide a basic framework for specific policies, not to replace them. Thus it should address issues such as linking the provision of HQP to national needs, provide a scientific and technological information network, provide balance in sectors of performance and areas of emphasis, and maintain an overall picture of inputs and outputs of the national science effort

Major recommendations:

- as much as possible, government's R&D needs should be met by universities and the private sector
- reviews of intramural government R&D should be performed to see if it can be contracted out
- creation of a National Research Academy, to perform most of the government's basic research, and with three foundations in the life sciences, the physical sciences, and the social sciences, to fill gaps in basic research. This research would be done for government and industry on a contract basis, when it could not be performed by the universities

- creation of a more meaningful role for the Ministry of State for Science and Technology, in that it should become the focus of the government's policy machinery in science and technology, and thus build on its policy role. It should have responsibility for reviewing the government's annual and five year plans included in the science budget, and its minister should become an ex-officio member of the Treasury Board and the cabinet's P&P committee
- creation of an innovation bank to provide risk capital (the Canadian Innovation Bank)
- GERD target of 2.5% by 1980 (later revised to 1.5% by 1982)
- increase industrial R&D to 60% of the national effort by 1980
- creation of a Canadian Research Board, with three foundations in the physical sciences, the life sciences, and the social sciences and humanities, to increase the capacity for research in these areas, and to support the full cost of direct and indirect research

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Arthur Cordell and James Gilmour, *The Role and Function of Government Laboratories and the Transfer of Technology to the Manufacturing Sector.* (Ottawa: Science Council of Canada, 1976)

Context:
The study was situated within the ongoing key debate in Canadian innovation: "the inadequate linkage between the market place and much of the research conducted in this country." Specifically, the study looked at one element of this debate, namely issues associated with technology transfer from federal laboratories to industry, a necessarily key consideration given that federal labs perform a high degree of Canadian R&D and the industrial sector is seen as being a weak performer. The study provided an overview of the role of government labs and their historical importance; issues in technology transfer between the two partners; and used survey findings and interviews to support their key findings. Explicit recommendations were not provided.

Major findings:
- a key function of public labs is the provision of public goods which, defined broadly, includes the state of the national economy
- federal labs were concentrated in the National Capital Region (Ottawa-Hull) to ensure a "critical mass" of expertise; another factor was political: survival of such labs depended on continued government funding, so proximity to decision-makers at the Treasury Board was not unimportant. Thus, in 1973-74, 42% of S&T employees and 41% of S&T spending was in the NCR
- outside of the NCR, "regional disparities" existed in terms of employees and expenditures, but there was no apparent underlying logic to the location of labs and the role they might play in the regions
- the study highlighted the roles of government R&D and why and when it should be performed: when issues of security are involved; when the mission of the R&D is

inappropriate to industry; when it is necessary for the regulatory functions of government; for the setting of standards and norms; to be able to maintain a sufficient in-house competence to fulfill departmental missions; and when R&D facilities are costly, and too much for one firm

- there are "two solitudes" of government and industrial research: there is a need to eliminate the "tough dialogue" between the two (especially firms critical of the NRC) and instead people should be making greater efforts to increase interaction and exploit the rich resources of the federal lab system
- industry often criticizes the federal labs as being unaware of the market pressures in innovation and the needs of industry
- however, "the major weakness of the technology transfer process may lie in the poverty of industrial attitudes to the government research institutions: the failure to fully appreciate the missions of the laboratories; the absence of persistent association with the government research community; and in general, the low level of demand pull by industry on government research." This was partly a product of the branch plant structure of Canadian industry
- that industry is generally not well-informed about the role and nature of government labs is a reflection of a general lack of interaction between the two: even though the work in the labs is generally seen as high quality, lab professionals do not visit industry enough
- "the problem of technology transfer from government establishments inevitably leads to the question of what the establishments are doing, how much they are doing, and whether they are doing the 'right' things."

Science Council of Canada, *Towards a National Science Policy for Canada* (1968)

Context:
This report was geared towards helping the government formulate a comprehensive *national* (not just the federal government) science policy.

Major findings:

- need to set goals for science policy within the framework of broader social goals, including national prosperity; improved quality of life; improved education; personal freedom; and personal development; and the quest for world peace
- the past failing of Canadian science is rooted in too much emphasis on basic research, which was also too removed from the training of new researchers, as well as the fact that too much applied research was being performed far from the point of innovation
- there is an important role for mission-oriented programs in the growth and development of Canadian science
- more emphasis must be placed on development and innovation, and there is a need for more R&D to take place closer to the point where innovation is initiated. More R&D should be performed outside of government labs, performed instead by universities and the private sector
- it believed that the short-term goal of a GERD/GDP ratio of 2% was cautious and that it would be quickly surpassed

Major recommendations:

- comprehensive, mission-oriented programs should be created to address major national problems in a coordinated and multidisciplinary fashion
- any new R&D initiative should be carefully reviewed in order to identify the appropriate performer, which may be the university or industry, and not government
- federal labs should contract out more research
- the federal government should use its procurement policy to upgrade the technological capacity of industry

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Science Council of Canada, *Forging the Links: A Technology Policy for Canada* (1979)

Context:
In the mid-1970s, the Science Council was concerned with Canada's declining technological capability, and the impact this had on Canadian firms. This was a period of stagflation, high trade imbalances, and a declining Canadian share of world exports, including in traded manufactured goods. Moreover, the impact of new technologies on production was now being detected, as was the presence of new low labour cost competitors. Thus the Council sought ways to maintain a high wage, high employment society in light of these conditions, and the role of government in achieving this goal. It therefore looked at the impact of government policy on the innovation capacity of firms and the implications for firm and national technological competitiveness.

Major findings: The report concluded that the federal government did not provide proper support for industrial policy for the following reasons:

- *institutional problems:* many departments dealt with industrial policy issues, which produced diverse and at times inconsistent policy; the Industry Department was not really able to act as a strong champion of industrial policy due to its trade mandate
- *policy priorities:* the government simply did not place a high priority on industrial policy, restructuring, and attacking the root causes of industrial decline
- *lack of commitment:* the government lacked the political will to have a comprehensive industrial policy that featured not only federal-provincial cooperation but a federal-provincial review of industrial policy; hence the appearance of ad hoc policies, plus the "ideological aversion" of the federal government to policies which required cooperation with industry

Major recommendations: industrial strategy should be based on *technological sovereignty:* the development of the technological capacity of Canadian firms; it can be promoted through the following four goals:

- *increase demand for Canadian technology* (for example, through procurement and trade policy)

- *increase industry's ability to develop technology* (for example, through the promotion of networks and consortia)
- *increase industry's ability to absorb new technologies* (this was a particular concern for small and medium-sized firms, who faced personnel and financial obstacles)
- *increase industry's ability to import technologies in a way favourable to Canada* (this was seen as a problem of high foreign ownership and the nature of branch plants)

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Ministry of State for Science and Technology, *A Technology Policy for Canada* (1983)

Context:
MOSST was created to integrate S&T considerations into broader government policy, and to increase national R&D investments, particularly by the private sector. However, its efforts were undermined by, among other factors, a rapid turnover of ministers and its status as a ministry of state.

Major policy thrust:
The policy sought to use technology development as a means to promote economic growth; increase awareness of the benefits and threats associated with technological change; ensure the equitable distribution of the benefits of technological development; and promote an appropriate culture for technological development.

Major initiatives:
- creation of a cabinet subcommittee for integrating technology concerns into all policy fields
- attempt to improve the coordination of incentives for research, science and technology efforts
- increased funding of key agencies and programs such as the granting councils, and the IRAP program of the NRC
- increased R&D incentives

Canada. The *Canada Tomorrow Conference: Proceedings* (November 7-9, 1983)
Context:
At a time of rapid technological change and very poor domestic economic conditions, the government held this conference to discuss opportunities and challenges associated with restoring economic well-being. While recommendations for action were not specifically offered, the major subjects for discussion reveal the government's thinking on these matters:
- the importance of technology in economic development
- the development and diffusion of new technologies
- concerns about managing the impact of technological change, particularly the impacts on workers, the challenges for education, and issues of health and safety
- concerns as to whether or not national safety nets are good enough to deal with the consequences of this change

Canada. Task Force on Federal Policies and Programs for Technology Development (the Wright Report). (July 1984)
Context: The task force, chaired by Doug Wright, President of the University of Waterloo, was mandated by the Minister of State for Science, Technology, Regional and Economic Development to examine the state of federal promotion of technological development. The task force examined key issues such as the effectiveness of government programs; the role of federal spending in promoting the private sector's development of its R&D capacity; the university-industry relationship; and the performance of federal laboratories, including their functions, goals, outputs and relations with industry.

Major findings:
- the long tradition of excellence in federal labs is being undermined by a "growing atmosphere of irrelevance and an excessively bureaucratic management style."
- the key is not to increase the budgets of these labs, as these levels are adequate. Rather, it is a matter of poorly-defined missions and an "excess of administration" that are the major problems, not lack of funds.
- the peer review process must be strengthened to ensure the relevance and effectiveness of laboratory missions. Quality is dependent on clear missions.
- the relevance of federal labs, upon which they should be evaluated, should be determined by a variety of criteria, including: supporting industry (if the industry is too fragmented, or if private R&D cannot be generated because of high costs or high risks in the short-term); supporting important government services (testing or monitoring; establishing norms and codes; maintaining data bases; operating national facilities; addressing regional or national problems; carrying out international obligations; national security; or ensuring national strength in key scientific sectors)
- a more formal evaluation structure of federal labs is needed
- managers of federal labs should be accountable to their clientele
- the government's contracting out policy for S&T has been a somewhat positive exercise, generating technological development, economic spin-offs, and preventing bureaucratic burdens from developing; however, the application of the policy has been spotty, particularly when established research programs were involved
- the use of the GOCO model (government-owned, contractor-operated) of federal labs should be used more often
- new labs should be established only after extensive consultations to demonstrate that a real need exists
- management practices should be more flexible to allow for labs to be more responsive to market forces

Major recommendations:
- a review of all federal labs should be undertaken, to demonstrate its relevance and usefulness
- an incentive system should be developed to allow government scientists to bring their ideas to the market

- more links with industry should be made, and those researchers and managers who support such efforts should be recognized for their efforts
- each lab should have a board of directors, with representation from its clientele including the private sector, and the board should review the institution's missions and priorities, and ensure the link between goals and budgetary allocations

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MOSST, *Science, Technology and Economic Development: A Working Paper* (1985)

Context:
This paper was written shortly after the election of a government committed to a rationalization of public expenditures, some evidence of support for technology development, and a concern for national unity. Its view was that the private sector was the key engine of economic recovery, and that innovation is one of the keys to that engine. The paper was prepared for the February 1985 meeting of federal and provincial ministers responsible for S&T, the first such meeting since June 1978. It had been agreed in advance that the ministers would work towards the development of a national S&T policy (achieved in 1987). This paper provided the foundation for such discussions.

Major findings:
- that the Canadian economy was often 8-10 years behind other countries in the "race" to adopt new technologies
- governments need to work together to get the private sector to increase its expenditures on research, development and innovation
- a "paradox" was at play: while the private sector as a whole agreed that investments in R&D were too low, individual firms believed that their own levels of investment were satisfactory

Major policy thrust:
- a need to increase private investments in S&T
- a need to increase rates of technological diffusion
- a need to reexamine the role of government in R&D
- the need to recognize the importance of university R&D

Major recommendations: there was federal-provincial consensus that there were two priority issues that required attention:
- an accelerated application of technological advancements to Canadian products
- the need to find an "expeditious solution to the current university financial crisis"

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The National Science and Technology Policy (March 12th, 1987)

Context:
At the 1985 meeting of federal and provincial ministers responsible for science and technology, it was agreed that it was necessary to create a comprehensive and coordinated science policy

Major policy thrusts: 6 major policy goals were included:
- improving innovation and diffusion
- an emphasis on the development and diffusion of strategic technologies
- promoting the training of highly qualified personnel
- supporting basic and applied R&D
- managing the impact of technological change
- promoting a science culture

Major initiatives / outcomes:
- creation of the Council of Science and Technology Ministers
- action plans for each area identified in the S&T policy
- led to the federal InnovAction strategy

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InnovAction: The Canadian Strategy for Science and Technology (1987)

Context:
This was the federal government's response to the March 1987 national S&T strategy, and was released shortly after the national S&T policy was announced. The government argued that "Canada cannot afford to fall behind" its competitors in matters of S&T. It argued that S&T had not been a national priority; that the S&T infrastructure could be stronger; that the public was unaware of the importance of S&T in these new economic times; and that industry was slow to adapt to the new technologies.

Major policy thrusts: InnovAction had five major policy thrusts:
- promotion of industrial innovation, technology diffusion, and cooperation between various actors in the S&T system
- identification of strategic technologies
- promotion of the effective management of federal S&T resources
- promotion of the development of HQP and the retraining of workers, in light of technological change
- promotion of the public awareness of science and technology

Major initiatives / outcomes:

- $1.5 billion for a national microelectronics strategy
- new technology diffusion strategy, including a federal laboratory policy and external technology centres
- Networks of Centres of Excellence
- Canada Scholarship Program for undergraduates
- government procurement strategy
- increased funding for IRAP
- increased funding for university matching grants program

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Canada. *National Conference on Technology and Innovation: Proceedings* (January 13-15, 1988)

Context:
Globalization, new technologies, and the emergence of new low-cost producing countries provided new challenges for the Canadian economy. Prosperity, it was argued, depends increasingly on a solid science and technology foundation. Moreover, leadership was seen as a key in promoting innovation. Thus the conference was marked not only by the presence of key political, economic and academic leaders and researchers, but also by the keynote address by the Prime Minister.

Key themes: The concerns and priorities of the government were reflected in the subjects of the major workshops:

- *revitalizing established industries:* this depended on creating an S&T culture (the importance of education and awareness; teacher upgrading; promotion of S&T; and exchanges) and on corporate leadership in transformation efforts
- *developing higher value-added products and services for the markets of the future:* again, corporate leadership, education and the training of HQP were seen as critical; other important issues were the participation of labour in restructuring efforts, capital financing, and a clarification of the role of government
- *building new technology-intensive firms:* the key factors were the need of a favourable climate for innovation; an emphasis on education and HQP; the promotion of entrepreneurship; and the creation of a new culture of innovation

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Science Council of Canada. *Winning in a World Economy: University-Industry Interaction and Economic Renewal in Canada.* (1988)

Context:
In an era of globalization and the rise of the knowledge economy, the need to link S&T to economic renewal is greater than ever. Universities therefore have a critical role to play in the knowledge economy, given the ongoing weak nature of industrial R&D and the ongoing importance of the university sector in the performance of Canadian R&D. Interaction between universities and industry is slowly growing, a not unimportant consideration given the growing financial crisis of the university sector.

Major findings:
- a need to define the roles of the major players in the R&D system, as there is too much confusion
- the need to increase collaboration between universities and industry
- the need for a coherent U-I strategy that is long-term and can survive political change
- the need to focus on wealth creation in order to "afford the social values that distinguish Canada as a caring society

Major recommendations:
- universities must refine their traditional mission statements (teaching, research and service) to recognize their particular strengths, as part of the reorientation of teaching and research emphasizing the transfer of knowledge and technology to industry: this transfer function must be legitimized, and indeed must become a university priority
- there is a need to ensure that the social sciences and humanities are included in this process, for they perform more than "essentially cultural and critical functions": in a knowledge economy many SSH fields have a great and growing commercial value, such as the management of technology
- universities must develop a new image: they are not just "ivory towers." They must become more "in touch" with society and develop the services to do so
- there is a need to fund more university-industry programs
- universities must recognize and reward such U-I programs and initiatives, both in terms of the programs and in terms of the academic reward system for professors

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Science Council of Canada. *Emerging Technologies: Springboard for a Competitive Future* (1989)

Context:
It was argued that three major groups of technologies were transforming industry: information and communication technologies, biotechnology, and advanced industrial materials. They open

up all sorts of new opportunities in all economic sectors, but they also pose a threat to smaller industrialized countries like Canada, due to their high costs, their mastery by the industrial superpowers, and the low cost competition of some countries.

Findings:

- Canada lacks clear strategies that link to clearly-identified goals in these three sectors
- Canadian firms are largely slower to adopt enabling technologies: they either do not know of their benefits, or lack the knowledge to manage them strategically

Major recommendations:

- Canada needs medium to long-term strategies for the enabling technologies, with Industry, Science and Technology Canada in the lead
- regions, cities and provinces need to develop a "technological identity," so that they can use the new technologies to promote regional development
- there is a need to promote industry self-help to get industry to learn about or manage access to the new technologies
- Canada must establish national projects in the enabling technologies to increase demand for R&D in these sectors
- pre-competitive R&D must be funded, and help must be provided to allow small technology firms to access capital
- university research in these technologies must be supported in order to build a knowledge base and produce graduates for industry: thus funding for the Strategic Grants program of NSERC must be increased

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Canada. *Public Service 2000.* (1989)

Context:

The government saw renewal of the federal public service as essential, given a more active citizenry, the economic pressures of globalization, and the need for increased consultation with a variety of publics. Emphasis must be placed on high quality service provision and citizen satisfaction. Public servants must be valued for skill, loyalty and dedication.

Major findings:

- The report of the Task Force on Training and Development noted that the training and development of scientists and professionals in the public service must improve

Major recommendations:

- within the context of a variety of broad measures to reorient the public service along the goals noted above, it was recommended that the expansion of training opportunities take place

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NABST. *Revitalizing Science and Technology in the Government of Canada.* (November 1990)

Context:
This was the report of the Committee on Federal Science and Technology Expenditures, chaired by Pierre Lortie. The committee's mandate was to examine the manner in which science and technology activities were managed and performed in government departments and agencies, and to assess the overall effectiveness of the federal science structure, and to make recommendations on ways in which to improve this management and performance, in terms of issues such as the quality of the work, facilities and personnel, the competitiveness of various scientific sectors, and government objectives.

The four key criteria for the committee in its evaluation were: the clarity of an organization's mission statement, against which practices and goals can be measured; the organizational structure, against which can be evaluated the quality and relevance of the work as well as the relationships built with other actors; personnel; and the management structures.

Major findings:

- federal science is a major component (14%) of Canada's R&D effort
- outdated and "seriously deficient" operating and administrative policies make it very difficult for federal S&T activities to meet expected quality and productivity standards
- morale in the federal science system is low, and many people question the value of government-performed S&T
- total federal S&T expenditures were $4.5 billion in 1988-89. When deducting expenditures for agencies such as the granting councils and the NRC, they totalled $2.3 billion. When deducting funds for contracted-out S&T services, the value of intramural federal S&T was $1.6 billion. This places Canada in the middle of the pack in terms of international comparisons
- the ongoing environment of fiscal constraint necessarily raises the issue of the quality if the S&T performed, the maximization of returns on investments, and the choices made as to what is or is not performed
- mandates of organizations must become more focussed
- overhead must become less bureaucratic and costly
- management practices must be improved, as they contributed to poor morale, constraint on the resources available, and imposed "stifling" controls on S&T performance; "reforms" have often simply led to further micromanagement (which increases the need for a radical change in the administration of federal S&T)
- S&T establishments must develop their own identity to pursue quality work, yet federal S&T establishments are thoroughly integrated into departmental planning and budget systems: this forces the establishments to use considerable energies to retain their unique culture to perform their work
- evaluation systems must be improved, as few of those systems in place directly addressed the issue of quality

Major recommendations:
The major recommendation is the implementation of a new integrated management framework with five constituent elements:

- each department should transfer its science institutions into one department science and technology institute, with a CEO and a board of directors, although establishments within any institute could maintain a separate identity
- relations between the institute and the department would be based on contractual relations, to increase the link between departmental objectives and S&T services (both to ensure that services provided meet the objectives, and to ensure that they are of high quality)
- the institute is to be revenue dependent for its operating funds: parliament appropriates funds for departmental activities, which in turn allocates funds to institutes on a contractual basis in return for services
- a new management structure giving institutes greater authority to mange relations with the department, including revenues, intellectual property to set fees, and so forth
- a new and rigorous evaluation system should be developed: this includes the development of a new peer review system, in which federal scientists and engineers could vote for the top 100 of their peers on the basis of their excellent work; those selected would form the pool form peer review panels of S&T institutes and their establishments; and the creation of a National Panel for Quality Evaluation, to ensure tat institute evaluations meet recognized international norms

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Canada. House of Commons. Second Report of the Standing Committee on Industry, Science and Technology, Regional and Northern Development. *Canada Must Compete* (December 1990)

Context:
In an environment of increased governmental and private concern about innovation, science and technology, the committee examined the state of Canadian S&T, as well as specific issues such as the space station, in order to understand issues confronting the science community and the role of S&T in economic development.

Major findings:

- given the centrality of S&T in the new globalizing economy, there is a strong need to support science, technology and education
- Canada needs "dramatic efforts" to change attitudes towards S&T in order to overcome Canada's decline in S&T relative to its competitors

Major recommendations:

- set GERD/GDP ratio of 1.9% for the year 2000 and 2.5% for the year 2005
- given the centrality of S&T, double the budgets of the three federal granting councils over a period of three years
- review Canadian support of "big science" projects: the committee argued that Canada might be better off supporting a broad spectrum of small programs
- establish a 5 year science expenditure plan, published annually, to provide stability in the R&D sector
- expand the Networks of Centres of Excellence program
- the government must respond more publicly, visibly, and rapidly, to reports by groups such as the Science Council and NABST, as an effective S&T policy requires the federal government to consider such reports in a more meaningful way
- promote science literacy, especially in elementary and secondary schools
- the federal government should adopt measures so that its procurement policy supports industrial S&T, innovation and new business formation
- coordinate federal science policy in PCO (earlier removed, with creation of Science Council)
- the federal government should promote national technology transfer and improve access to venture capital, especially for small high technology firms
- development of scientific and technical skills
- strengthen IRAP, particularly in the north

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Michael E. Porter. *Canada at the Crossroads: The Reality of a New Competitive Environment* (1991)

Context: The study, sponsored by the Government of Canada and the Business Council on National Issues, applied Porter's concept of national competitive advantage to the Canadian economy. This study reflected a continued concern with Canada's poor productivity performance despite its relative wealth. It also reflected the continued changing philosophy underlying public policy, from a concern with broader social and economic goals, to a more straightforward competitiveness discourse, with a concern for economic restructuring, international competition, and the challenges associated with new technologies.

Major findings:

- despite significant real economic growth in the 1980s, there were "worrisome performance trends" which could affect future economic performance
- these were associated with traditional "paternalistic" government policies which, when combined with other factors, produced an insulated economic environment in Canada: this clearly was a problem in the new globalizing economic context
- the gravest problems were low productivity growth rates, considerably lower than other nations; high and rising unit labour costs; high unemployment rates; lagging investments in

upgrading skills and technology (notably in poor private investments in training and R&D); and high public deficits and debt

- Canada has a high dependence on the export of *unprocessed* natural resources, which reflects the inability or unwillingness of Canadian industry to upgrade its technological base, or exploit new markets or opportunities. Few Canadian resource-based industries upgraded their source of international advantage
- in many Canadian industries, the lack of intense domestic rivalries has inhibited pressures for upgrading, again reflecting the insulated nature of the Canadian economy
- government policies and actions have often had a negative effect on Canadian competitiveness through, for example, high tariffs, subsidies and government ownership; government procurement, which can be a good tool for stimulating innovation, has generally not succeeded. While in some cases government has helped upgrade competitive advantage (such as product safety), in others it has not (environmental industries)

Major recommendations:

- firms must focus on areas of true competitive advantage rather than simply offering a wide product range
- firms must increase their investments in specialized human resource development
- firms must link more closely with educational institutions and engage in more co-op programs; as well, they should deal more with community colleges
- firms should become more pro-active in the commercialization of university research
- labour unions should become more involved in the effort to raise productivity levels, and should be more active in promoting the upgrading of the skill levels of their members
- governments must become more involved in promoting training for the unemployed and in encouraging private sector training
- government should promote science skills and interest in science, particularly in elementary and secondary schools
- governments must examine funding arrangements for universities to ensure that fields which relate to the competitiveness agenda (such as S&T related courses) are adequately supported
- governments must improve the coordination and delivery of R&D programs, as their fragmentation often undermines their effectiveness
- there is a need to create stronger ties between universities, government labs, provincial research organizations and the private sector, as S&T policy tended to favour the advancement of science and the training of HQP
- government should increasingly shift its internal spending on R&D in its labs to industry
- there is a need to encourage greater specialization between universities
- government procurement policies should emphasize competitive and innovative suppliers

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Canada. The Prosperity Initiative, *Inventing our Future* (1992)

Context:
NABST had released a statement on competitiveness, which stated issues Canada had to address to improve the competitive performance of the economy. The federal government's prosperity initiative, a national consultation round on economic and social issues, was launched in cooperation with the private sector. This reflected the government's concern with the greater renewal of Canada, as seen in its proposals not only on restructuring but also on national unity. Indeed, its proposals on federalism were partly geared towards strengthening the economic union. The report therefore identifies the factors and challenges facing Canadians.

Major findings:
- Canada has been slow to adjust to changing economic conditions, and therefore must take steps quickly to position the Canadian economy in the changing international economic order
- lifelong learning is central to future prosperity. There is a need to ensure that all people have basic skills, and we must encourage people to gain new advanced or specialized skills (hence the release of the discussion paper, *Learning Well...Living Well*)
- other key elements for future prosperity include science and technology; financing of investment; trade; and a competitive domestic market
- in the are of S&T, it was noted that private sector R&D was very low; there was a low rate of use of new technologies; and there was a mismatch between the supply of and demand for skilled labour

Major recommendations:
The initial report did not contain recommendations *per se*, but rather identified some barriers in key areas. Thus, for example, in the area of investment, it was simply stated that there was an urgent need to increase the availability of investment capital.

However, the group's final report, *Inventing our Future: An Action Plan for Canada's Prosperity* (1992) did include a series pf recommendations:
- the creation of a National Quality Institute, to raise the standards of Canadian products
- a thorough government policy and program review, and the elimination of interprovincial barriers
- a variety of measures to increase the use of new technologies and to increase and improve access to federal and provincial technology support programs
- the private sector should lead the development of the information highway
- development of a learning culture: the introduction of competence-based learning systems top promote excellence and quality in learning; a greater use of information technologies in learning, training and education; a greater link between work and school; and increased employer-led training
- creation of a Competitiveness Council, to provide leadership

- creation of as Technology Change Centre, to assess international S&T linkages, emerging technologies and the impacts of new technologies

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NABST. *Spending Smarter.* (1994)

Context:
As part of its activities, NABST undertook a review of S&T programming in 19 federal organizations accounting for 89% of federal S&T expenditures. It applied four principles to their review: the development of a knowledge-thirsty society; market-driven technological development; competitiveness; and sustainable development.

Major findings:
- S&T was a clear priority of the government, but it was not managed as a strategic asset
- there was no apparent explicit rationale for the distribution of S&T expenditures amongst departments and agencies, and no explanation or information on why or how expenditure levels were established
- there lacked a horizontal method to select S&T priorities in government

Major recommendations:
- government should attempt to manage S&T as a distinct strategic asset
- the main objectives of federal S&T programming should be the development of a knowledge-thirsty society and market-driven technological development
- the government should develop a system for S&T priority-setting within and among federal organizations

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Vince Wright, "S&T Priority Setting: Trends, Experiences and Lessons," *Resource Book for Science and Technology Consultations,* vol. 2 (August 1994)

Context: As part of the federal S&T review, the Resource Book, vol. 2 sought to provide background on specific issues. This article summarizes an international brainstorming workshop held in Ottawa in May 1994, at which participants discussed issues and strategies related to the management of S&T, priority setting, and raising the profile of S&T. The article discusses major trends and observations in S&T across countries.

Major findings:
- in recent decades, GERD/GDP levels in most countries have remained rather constant
- there is an increasing emphasis away from the "S" in "S&T" to "T": technological innovation and diffusion are a key part of the new industrial competitiveness agenda, at least in *political rhetoric*
- S&T priority setting is important, given that S&T budgets are often not mandated through statutory requirements and are thus vulnerable to budget cuts in an era of financial restraint
- there are no "magic formulas" in S&T management: S&T decisions are often subject to the lobbying process, and are not usually part of a rational policy framework. This increases the need for a structure for coordinating S&T governance
- national foresight exercises can be very useful, as they can stimulate more focussed exercises, or strengthen alliances and networks developed during the process
- output indicators are "elusive" yet remain important, as they can reflect the state of confidence in the national S&T system
- the role of universities is even more important in an era of increased emphasis on knowledge-based policies, such as providing more skilled workers; therefore universities and the university research community need to be more connected to the economic decision making process
- many governments want more short-term gains from their investments in the university research community
- S&T and related issues often lack public attention (and thus a higher profile) due to "science illiteracy" in the general population

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Canada. Task Group on Sustainable Wealth and Job Creation. *Towards an Innovation Strategy.* (November 1994)

Context:
This was one of three interdepartmental task groups working under the aegis of the federal S&T review. This group sought to provide an S&T policy review, within the context of wealth creation and sustainable development, and not actually evaluate S&T resource allocation. As such, it offered a framework for federal decision making and priority setting. Its emphasis on innovation policy reflects the view that innovation is the process through which S&T (and other inputs) gets turned into wealth and jobs. Federal S&T investments must thus promote innovation, including the further development of the national system of innovation, building and strengthening linkages between partners in the wealth and knowledge enterprise.

Major findings:
- the nature of the new technologies is such that new industries are emerging, based increasingly on cross-sectoral linkages and the producers and users of the new enabling technologies. Therefore, the role of government policy is not to lead the innovation

process (which it cannot do) but to support it through the promotion of collaborative relationships and the furthering of cross-sectoral R&D.
- the imperatives of sustainable development require that the economic and environmental agendas converge, and that energies shift from theory to the implementation of sustainable development.
- in an era of globalization, Canadian trade and investment strategies must pay much more attention to S&T; similarly, a federal S&T policy must be sensitive to the imperatives of regional economic development.
- federal S&T policy should promote the idea of labour market flexibility and employability to allow the work force to adapt to change produced by innovation.
- the wide range of major instruments of innovation support must be deployed on a more cost-effective basis, and become more flexible in order to support links between actors in the national system of innovation, knowledge transfer, and be responsive to the needs of partners

Major recommendations:
- the federal government must place higher priority on international S&T, and improve its management and coordination of its international S&T activities; this includes developing a greater capability fort gathering international S&T intelligence, knowledge and data.
- the management and development of new federal S&T institutions ne more attuned to the nature of industrial clustering and regional development
- the federal government should develop a comprehensive strategy for promoting human resource development, including addressing issues such as skill enhancement, labour mobility, education, and the impacts of new technologies.
- federal labs should be made more accessible to non-government users, and they should have more flexible management systems based on a mission of increased relevance, partnerships and cost-recovery
- the federal government should improve the access to government innovation support services, and promote the transfer of knowledge from federal labs to the private sector

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Canada. *Report of the Auditor General of Canada to the House of Commons.* (1994)

Context:
In light of the recently announced S&T review, geared towards developing "a true strategy, one with real priorities, real direction and a real review of results," the Auditor general's office conducted a review of federal S&T.

Major findings:
- most earlier S&T reviews failed to produce results and thus failed
- establishing S&T priorities is essential

- there is a need for partnerships involving all actors involved in the S&T system
- government requires a framework and indicators to monitor its performance in S&T and to evaluate the success of its efforts to support S&T
- Parliamentarians have no basis for assessing government expenditures on S&T and if they reflect Canadian needs and opportunities
- despite an ongoing series of reviews, government cannot clearly state what it seeks to achieve through tis activities, nor is it able to manage its efforts in such a way as to produce a maximum return on its investments
- most departments need to improve their ability to identify the potential uses and users of the results of their activities
- most departments overemphasize projects on the basis of revenue generation
- the commitment to evaluate S&T activities varies across organizations

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NABST. *Healthy, Wealthy and Wise: A Framework for an Integrated S&T Strategy.* (1995)

Context:
In light of the federal S&T review and the 1994 Auditor General's report stating that there was nothing new in thirty years of S&T reviews, NABST explored ways to improve the integrated management of federal assets and investments in S&T.

Major findings:
- the report noted the significant budget cuts in the 1995 budget. While some cuts to ineffective programs may be merited, the report suggested that there was no evidence that less S&T spending was good, especially when it is known already that Canada invests less in S&T than many of its international competitors

Major recommendations:
- the key to improving the management of federal S&T assets is to make the explicit recognition that economic and social goals are closely related
- thus, there is the need to develop an S&T governance structure which can reflect this principle and allow for the establishment of S&T priorities; government's role is increasingly to facilitate and promote innovation, information sharing, partnerships and the leveraging of private funds rather than engaging directly in innovation activities. This includes an important role in setting standards and regulations to encourage innovative private sector performance
- federal laboratory activities should be evaluated and justified against strategic needs

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Canada. *Federal Science and Technology Review.* (1996)

Context:
Building a Federal Science and technology Strategy, the discussion paper for the review, set out the parameters of the review, stressing that innovation, based on a strong S&T base, can help Canadians achieve their economic and social goals. In an environment of fiscal restraint, there is an urgent need to examine choices and priorities to promote wealth and job creation; an improved quality of life; and the advancement of knowledge. This is particularly important given the perception that Canada might be lagging behind its competitors.

Major findings: The review resulted in a new S&T strategy, *Science and Technology for the New Century: A Federal Strategy* (1996):

- given that program review resulted in a drop in federal S&T expenditures, the government needs to focus on core activities: the funding and performance of scientific research in departments and agencies; university and hospital research and the NCE program; and supporting private sector R&D
- the social sciences and humanities are important in the new economic environment, particularly applied research in these fields

Major recommendations:

- to improve advice given to government, an Advisory Council on Science and Technology (ACST) should replace NABST
- in the realm of decision-making, there is a need to strike a balance between central coordination and a decentralized system which separates S&T from the core roles of departments
- to ensure this need for coherence and flexibility, the Economic Development Policy Committee of Cabinet is to review S&T performance and make recommendations to Cabinet; as well, ACST should offer advice to Cabinet
- an annual report to Cabinet on S&T should be made
- to improve the management of S&T, emphasis should be placed on improving coordination and collaboration, and avoid overlaps and duplication
- the federal government will adopt a common framework of seven operating principles: departmental S&T action plans were also developed to promote these principles:
    i) increasing the effectiveness of federally-supported research, by stressing principles of excellence, relevance and technology transfer
    ii) capturing the benefits of partnership, such as promoting the development of consortia, and having an open door policy in the federal research infrastructure
    iii) emphasizing sustainable development and preventive approaches (such as improved health)
    iv) placing Canada in the emerging regulatory regime (modernizing the regulatory framework, such as in trade policy or intellectual property)
    v) building information networks (sharing data and building the information highway)

vi) promoting international S&T linkages, which allows Canada to access international knowledge necessary to transform the economy since it is not possible to develop such knowledge independently
vii) promoting a stronger science culture: here the information highway can be a valuable new tool

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Canada. *Report of the Auditor General of Canada to the House of Commons.* (1996)
Context:
Following the federal S&T review, the Auditor General's office conducted a follow-up to its major 1994 review of federal S&T.

Major findings:
- the Auditor General was favourable to the 1996 federal S&T strategy. It was seen as a step in the right direction, as it offered a framework of operating principles which could guide government and departmental activities
- science-based departments and agencies were making progress in focussing their S&T activities and setting priorities; while this was not enunciated at a government-wide level, there now existed a mechanism for making S&T recommendations to Cabinet
- the strategy recognizes the importance of coordination and cooperation
- the strategy lacked a forum to share best practices in the management of S&T
- the true challenge for the strategy was implementation: there is a need to ensure accountability, and to promote parliamentary oversight leadership from all levels of government

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Canada. House of Commons. Fourth Report (Interim) of the Standing Committee on Industry. *Review of Science and Technology and the Innovation Gap in Canada.* (February 1997)

Context:
The committee examined the technologies and industries important to the evolving Canadian economy; the role of government in promoting emerging technologies; impediments to their adoption; how to develop and promote a climate supportive of both science and entrepreneurship; the impact of foreign ownership on the innovation gap; and the ability of institutions to ensure that they help in the economic transformation of Canada (as in the provision of HQP).

The committee cited the OECD, which argued that high technology appeared to be less important in Canada than abroad; that the big deficit in high technology products reflects a concern that Canadian business is not as innovative or as flexible as abroad; and the fact that Canadian business does not perform as much R&D as business abroad suggests that Canada may have an "innovation gap." It should be noted that there were dissenting reports from the reform party and the Bloc Québécois.

Major findings:

- S&T is a key to Canada's economic future
- government research has become less basic: more focus has been placed on commercializing research results and working with partners in universities and industry
- universities are very important vis-a-vis international competitiveness in the national research effort, though there is a need for increased efforts to commercialize the results of university research
- small firms are a key in high technology sectors, but they often lack the skills and resources necessary for expansion; for example, R&D tax credits do not improve their cash flow (often a problem for small firms)
- linkages and networks are important in the national system of innovation: the NCE and IRAP are great examples of programs which support economic transformation
- foresight exercises are important, as seen in foreign experiences; however, Canada lacks a long-term vision and plan for the knowledge-based economy of the 21st century
- the committee expressed scepticism about the new S&T policy framework and strategy, given the failure of such strategies in the past
- Parliament needs to keep a closer and better eye on science and technology

Major recommendations:

- the government should support phase III of the NCE program
- the government should earmark part of its new infrastructure program to the renewal of the university research infrastructure
- the Finance Minister, in the budget speech, should stress the importance of S&T, in order to raise its public and political profile
- the committee supported the S&T measures and recommendations of the 1997 Finance Committee report, including making increased funding to the granting councils a priority; support for Phase III of the NCE program; a new infrastructure program which should in part provide for a renewal of the research infrastructure in universities, colleges, hospitals and other research institutions; and the continued support of programs which promote a science culture

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Canada. ***Minding Our Future: A Report on Federal S&T.*** **(1997)**

Context:
This is the first annual report following the 1996 federal S&T strategy. It highlights federal actions on implementing the S&T strategy, as well as other S&T activities. Thus, the government claims that it is achieving one of the goals of its strategy and using its new framework. It also notes the increase in private sector R&D.

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Canada. ***Report of the Auditor General of Canada to the House of Commons.*** **(December 1998)**

Context:

Two years following the federal S&T strategy and four years after its major review of the S&T portfolio, the Auditor General assessed progress in the implementation of measures aimed at improving the management of federal S&T.

Major findings:
- the Auditor General criticized the government for being slow to implement measures for improving S&T management
- the government ignored some of the commitments it made min the strategy, and there has been a varied response across departments to the seven operating principles outlined in the strategy
- there is a need to go beyond simple coordination of S&T to collective action: joint goal-setting, research planning and a common management framework
- the establishment of S&T priorities was incomplete: some priorities may be implied, however, such as increased funding for non-departmental agencies like CANARIE Inc.
- the government's annual report, *Minding our Future*, was a good initiative, but it should focus more on results rather than highlights, and it provided scant information on horizontal S&T issues

Major recommendations: the Auditor General suggested that three issues require special attention:
- mission-driven, results-based research, with an S&T plan and performance measures
- scientific excellence: while expert advice has been sought on research planning, it was less common in the review of scientific quality
- the promotion of partnerships: the experience with this varies considerably across federal organizations

COMMON THREADS EMERGING FROM THE S&T REPORTS:

Despite changing economic conditions, the emergence of new technologies, changing governments and so forth, it is possible to discern certain themes and tendencies across time:

7. *As Dufour and de la Mothe have noted, and as noted in the Auditor General's report, the key question is Canadian science policy is "science policy for what?"* There has been no clear answer to his question in the past several decades: is it for prosperity? Regional development? International prestige? Instead, what we get is a constant re-thinking and restructuring of government policies and programs.

2. *There is an ongoing concern with promoting the development of a science or innovation culture, which includes increasing the scientific literacy of elected officials and the executive.* Clearly, scientific illiteracy and a sense that Canada lacks a sufficiently innovative and entrepreneurial climate and culture are seen as key contributors to Canada's lagging investments in S&T, the relatively poor performance of Canadian firms in matters of innovation, and the lack of people entering the physical sciences, medicine and engineering.

   On a related note, the relative paucity of academic research and writing on S&T policy can be linked to the lack of specialized Canadian outlets on such matters following the demise of *Science Forum* and *Scientia Canadensis.* For the most part, people writing on such matters must either publish in international S&T journals or in mainstream journals (such as *Canadian Public Administration*), where such issues are not necessarily taken as serious and must compete with publications in other fields. In the former case, we assume that foreign writings on S&T can apply to the Canadian case, or Canadian academics and policy makers necessarily do not become engaged in a sustained debate. In the latter case, S&T debates simply become marginalised. In either case, such phenomena contribute to the stifling of the development of a more scientific or innovation-based culture

3. *A concern with promoting more innovation and development, and de-emphasizing basic research.* The strength of Canadian university research and the strength of federal labs in the 1960s were noted, as was the weak performance of industrial R&D and innovation. A constant theme is the argument that Canada needs to move away from performing research in public labs, and that universities need to link more closely with industry.

4. *One of the key incentives cited for investing in S&T, in improving S&T management, or in raising its importance on the policy agenda is the fear of "falling behind" international competitors if Canada does not act rapidly.* The metaphor of the "race" is used frequently in federal reviews. The implication is that the standards of living enjoyed by Canadians will drop if we "lose" the race. However, this metaphor does not address two issues: first, if Canada is always lagging in the "race," how did it get to enjoy such great material benefits?, and secondly, if the race is so important, why doesn't it enjoy a higher position on the policy agenda?

5. *An ongoing concern with the management of science and technology.* This is most clearly linked to issues in points 1 and 3 above. There is a sense that while S&T is a federal priority, there lacks an effective governance system to manage these resources and to achieve the goals (whatever they may be) of these investments. The ongoing debate about S&T management, and the two models most commonly cited (increased centralization and coordination versus decentralization), and the myriad factors involved in instigating and implementing institutional reform, raises the question of whether or not it is realistic and indeed feasible to develop a satisfactory S&T governance system.

6. *The focus of many reports has been on how to "do" science and technology, rather than focussing on what should be done and why. This is particularly true of federal laboratories.* Concern about management, the roles of federal R&D, government policy and other issues, while important, ignore an important question: what should be the goals and focus of R&D, and in particular government research.

7. *Despite the public recognition of the importance of S&T and innovation, it is generally revealed that governments have not taken these issues seriously.* This can be seen in the need for constant reviews of performance, recommendations to raise the profile of S&T, the lack of meaningful institutional change, and the subjecting of investments in S&T and innovation to the lobbying process and the vagaries of budgetary politics. Thus, despite the public rhetoric surrounding the importance of innovation and S&T, investments, policy and programming have been quite inconsistent.

8. *Procurement policy is a useful method for increasing the innovative performance of the private sector.* However, it is incumbent on government to develop high standards which increase the innovative capacity of firms. Moreover, a contradiction may be at play. On the one hand, the value of government in stimulating demand and initiating technological development is recognized. On the other hand, the role and functions of federal research may be misunderstood. The focus has often been on simply transferring activities or research results from federal labs to the private sector without recognizing either a difference in missions between the two sectors, or in recognizing the interaction that does indeed take place between the two.

9. *There is a link between economic and social policy objectives, and science, technology and innovation are key means to achieve these goals and act as the link.* However, the context for such a link has changed. In the more "heady" environment of the 1960s, the positive modernistic potential of science and technology was recognized. In an environment of economic turmoil in the late 1970s and early 1980s, emphasis was placed almost entirely on competitiveness and restructuring. In the 1990s, the link has been established, but within the context of fiscal restraint and a smaller role for government.

10. *Universities have a critical role to play in the S&T system.* Their role has changed with the emergence of a knowledge-based economy, so we must encourage the transformation

somewhat of their missions, but they remain fundamentally important in their research and training functions.

11. *There is an important role for the social sciences and humanities in the development of national science policy and in the transformation to a knowledge-based economy.* Their important role is often overlooked, either because they are not seen as "true" or "pure" sciences and thus do not relate to science policy, or because it is often assumed that they do not require much financial support.

Part 2 - Academic Scan

N.H. Lithwick, *Canada's Science Policy and the Economy* (Toronto: Methuen, 1969)

Synopsis: Lithwick examines the issues pertaining to the impact of R&D in the economy, and situates his analysis of Canadian science in this context.

Key points:

- Canadians have invested "substantially less" in university research than Americans
- the gap between the low level of Canadian industrial R&D and the levels of international competitors is "real," but the gap is not due to the Canadian industry mix or policy emphasis: rather, it is partly due to the cheap access to American supplies of R&D, a lower use of R&D professionals in industry, and a lack of available financing
- "there is no evidence that foreign ownership deters R&D. If anything, the evidence tends to support the alternative hypothesis." (82-83)
- government R&D is highly internalized: there is little sponsorship outside of research agencies and little sponsorship of industrial research outside of defence
- thus, government research focusses less on social need than on those areas where it has a role to play, and pays little attention to development issues
- there is a need to focus the debate on the role of university research; there is a need to decide on social priorities to develop a science policy and consequently allocate funds and resources: then it will be possible to meet objectives
- there is no real science policy in Canada, except for the belief that science is good

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G. Bruce Doern, *Science and Politics in Canada* (Montreal: McGill-Queen's University Press, 1972)

Synopsis: Doern looks at the state of relations between science and politics/policy in Canada, and the forces affecting the debates on and evolution of Canadian science policy.

Key points:

- the criticisms suffered by the NRC reflect the fact that the NRC experienced "goal displacement": it focussed too much on its function of supporting research, to the detriment of its other functions, namely supporting and promoting industrial research, and coordinating federal science activities
- efforts to implement a new science policy machinery (the Science Secretariat in PCO and the Science Council) demonstrate the difficulty in creating institutional change, as these mew bodies were seen with a combination of "suspicion and uncertainty"
- debates about "big science" projects, notably the ING Affair, reflected a change in the balance of power in the relationship between the government and academic sectors of the

scientific community. Scientists became involved in group politics, and government scientists needed academic researchers "on board" to get their projects realized, whereas in the old system individuals were essentially reliant and dependent on government to provide individual grants
- thus, in the era of big science, we see more organized challenges to government and to scientific bodies
- the debate and fight in Canadian science policy is not about the goals of science policy; rather, they are about where "science should be located." Therefore, the fight takes place across sectors of the scientific community, not scientific disciplines.

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F. Ronald Hayes, *The Chaining of Prometheus: Evolution of a Power Structure for Canadian Science* (Toronto: University of Toronto Press, 1973)

Synopsis: Examines the prosects for the development of a coherent Canadian science policy in light of the evolution of the Canadian science system.

Key points:
- because of the "good times" for Canadian science in the post-WW II era, Canadian scientists did not develop the political instincts necessary to promote their interests
- as a result, they basically were reduced to pleading for more money; they could not and did not provide decision-makers with a "usable framework" to help them allocate funds for science; but of course, "the planners will plan anyway..."
- how can you reconcile the "objectivity and independence of science with the responsibility of government?" The result is deadlock: control versus "no control:"
- federal labs should phase out their basic research activities, as the university research community has become more developed and sophisticated
- trial and error is still the best system for science. It is not realistic to expect the development and implementation of a perfect science system: "the nation will need, from time to time, a review of the whole system." (200)

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***Science and Public Policy* vol. 15, no. 1 (February 1988) Special issue on Science and Technology in Canada**

Synopsis: The journal ran a special issue on Canadian S&T, for as it was noted, S&T policy has almost never been higher on the policy agenda than it was at that time. The articles deal largely with an overview of the S&T system and the associated politics: scant attention is paid to government's role in the system. Still, Yvonne van Ruskenveld notes that government in Canada historically played an important role, and that it can still have a positive influence: however, this has been undermined by historic low investments in R&D and ongoing fiscal restraint. This produces a need for growing cooperation between the major players in the S&T system.

Gingras and Rivard, in their overview of energy R&D, provide a good example of the impact of organizational issues (including management issues and associated weaknesses in management systems) on R&D performance and policy implementation. They note that government R&D in this field was reorganized due to a shift in national gaols following the oil crisis of the 1970s: new goals emerged, such as energy self-sufficiency. Thus government adopted a more coordinated approach to energy R&D, and provided more funds, though its focus still tended to be on attaining short-term goals

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Andrew H. Wilson, "The Gendron Report: Another View of Canadian Science Policy," *Science and Public Policy* vol. 16, no. 5 (October 1989): 269-281

Synopsis: Wilson provides a comparison of the Gendron Report, a 1971 report on science policy that had remained classified until 1987, and the 1983 Wright report, suggesting that issues which emerged in the Wright report had clearly been identified a decade earlier. Dr. Gendron had been requested by Prime Minister Trudeau to provide advice on the establishment of a central government science policy agency. He was to examine the organization of federal science and recommend changes.

Key points:

- Gendron supported the concept of MOSST, rather than a full Ministry of Science. A Minister responsible for science should be able to provide solid advice and analysis to cabinet, but not administer funds, nor be directly responsible for the management of the federal laboratory system
- government should promote the "optimum use" of science by Canadians in order to reach national goals
- basic research is an activity of the universities: if government has a role, it is to support such research through grants
- government should target areas for support that are important for Canadians but are not prioritized abroad
- government labs should be more applied, with little basic research performed (except as a small incentive for some researchers)
- where possible, government funding of R&D for use by the private sector should be performed by industry
- procurement policy can help industrial R&D
- industry was very disconnected from the work of NRC labs; thus there was a need for a new method of administration of work performed for industry in the public labs
- there should be more contracting out of science services

- the Wright report parallels the Gendron report, Wilson argues, by stating the case for a new management of public labs, the need for clearly defined mandates for government departments (as the early success of such labs was tied to them having unclear mandates and roles), stressing the importance of procurement, noting the current quagmire of public labs is rooted in them having their long tradition of excellence undermined by a growing irrelevance and bureaucratic (mis) management, and noting that these labs often served government, not industrial needs.

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Frances Anderson and Robert Dalpé, "The Evaluation of Public Applied Research Laboratories," *Canadian Journal of Program Evaluation* vol. 6, no. 2 (October/November 1991): 107-125

Synopsis: The article provides an overview of the political context of public labs in Canada and Quebec, noting the changes in their major functions. The authors argue that in light of the growing criticism of public labs, there is a need for new evaluation methods of such labs.

Key points:
- despite the long and important history of Canadian public labs, it was only with the work of the Lamontagne Committee that we witnessed an effort to orient the activities of public labs
- a new policy issue in federal public labs has been the decentralization of their activities outside of the National Capital Region (Ottawa-Hull)
- helping industry develop expertise and providing technical support to industry through the diffusion of knowledge has become the key function of public labs, overshadowing their other functions of contributing to the development of science and providing governments with the knowledge they need to fulfil their functions
- the growing criticism of public labs, as seen for example in the Wright report of 1984, has produced a need to develop and use new evaluation methods: the common methods include evaluation by users of labs, scientific peer review, and the use of scientometrics and bibliometrics. The authors tend to lean towards the use of the latter, despite recognized problems associated with such methods (such as the choice of indicators and access to the relevant information)

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Robert Dalpé, Chris DeBresson and Hu Xiaoping, "The Public Sector as First User of Innovations," *Research Policy* vol. 21, no. 3 (June 1992): 251-263

Synopsis: The article attempts to gauge the role government can play in the promotion of technology development and innovation, using Canadian data from the late 1970s.

Key points:
- the Canadian public sector has a significant role in the development of new technologies, particularly in terms of "world firsts", and especially in R&D-intensive industries
- its greatest impact is its role as a first user of innovations: from 1945 to 1978, the Canadian public sector was the first user of 25% of Canadian innovations
- its second most important role is as a potential user of patented Canadian inventions (13%)
- the Canadian public sector has a less important role as a consumer of manufactured goods (only 8%)
- the public sector's role is important, whether it has an explicit procurement policy or not

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Richard Isnor, "Federal Biotechnology Policy in Canada: Relative Success or Ineffectiveness?" *Science and Public Policy* vol. 20, no. 1 (February 1993): 17-25

Synopsis: The article attempts to gauge the effectiveness of the federal biotechnology strategy in light of federal budget restraint and low private investment in biotechnology R&D.

Key points:
- given low private investments and federal budget cuts, it has been difficult to capture "significant" returns in the biotechnology sector
- still, government policy is key for the rapid development and growth of the sector
- despite the relatively low amount of federal spending on biotechnology R&D, the Canadian industry is still somewhat competitive due to the strategic emphasis by government of the sector (InnovAction), the IRAP program, and NSERC's training support programs in the sector

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Philippe Faucher and Kevin Fitzgibbons, "Public Demand and the Management of Technological Risk in Large-scale Projects," *Science and Public Policy* vol. 20, no. 3 (June 1993): 173-185

Synopsis: The authors seek to assess the role of the public sector in the development of new technologies and the promotion of technological change, through a study of 79 large-scale projects from the 1950s to the 1990s in the energy, communications, transportation and defence sectors.

Key points:

- Public demand can generate the promotion of technological development and technological change, particularly through procurement
- the public sector was involved in 78.5% of these large-scale projects, the most common form of participation being the Crown corporation
- the public sector played a key role as a supplier of technology in 5 of the 10 most innovative projects, and as a public market in 7 of the 10 projects

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Donald G. McFetridge, "The Canadian System of Industrial Innovation," in *National Systems of Innovation: A Comparative Analysis,* ed. Richard R. Nelson (New York: Oxford University Press, 1993), pp. 299-323)

Synopsis:

The chapter provides an overview of the Canadian innovation system, arguing that it is defined by characteristics specific to Canada: the small size of the domestic market, its natural resources, and the vast size of the landscape. These factors have been accentuated by the proximity to the United States. Opportunities and constraints are thus present: access to American technology, for example, has in some cases contributed to the advancement of the innovation system and created new innovative linkages between actors (such as the resource and machinery sectors).; however, the impact of high levels of foreign ownership on national R&D has at the least raised concerns as to its negative impact on innovation rates.

Key points:

- despite the fact that many small countries share similar characteristics with respect to innovation, Canadian governments perform a greater proportion of national R&D (just under 20%) than governments in other smaller countries
- this is linked to the fact that government R&D has been focussed on resources (agriculture, mining and energy) and NOT defence
- however, government's share of R&D performance dropped by 47% over twenty years
- the key factor in the debate about the future of government labs is the apparent lack of communication between the labs and their (potential) clients.
- while there are many individual examples of cooperative research projects (such as IRAP), there are "few examples of institutionalized industry-wide R&D activity." This may be linked to the fact that the NRC and provincial research organizations perform research that otherwise might be performed by industry associations; there are many cost-efficient engineering services firms; and there is a scale effect associated with being a small country, as broadly-based technologies are more easily adopted from abroad, with industrial R&D focussing on more local issues.

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John de la Mothe and Gilles Paquet, "Circumstantial Evidence: A Note on Science Policy in Canada," *Science and Public Policy* vol. 20, no. 4 (August 1994): 261-268

Synopsis: In light of an impending science policy review, the article examines the history of Canadian science policy, the pressures which have shaped its evolution, and offers ideas for elements of an appropriate strategy.

Key points:

- Canadian science policy has been highlighted by pressures for both increased coordination (maximizing returns) and increased autonomy (the views of the "Republic of Science"): the result has been "decades of national equivocation, marked by a series of unsuccessful attempts to find effective compromises between the need for relevance in matters where public funds are involved and the iron of excellence which is served best, academics assert, by curiosity-oriented 'peer-reviewed' research." (262)
- the challenge, therefore, for the S&T review is to find the appropriate balance between the two.
- while in the 1950s the government played a major role in setting science priorities and in the funding and performance of R&D (through the funding of NRC labs or in big science projects, for example), the federal government's management of the portfolio was viewed as inefficient by the Glassco Commission
- by the 1970s, we see a tension emerging: the financial crisis of the state and the system, versus the "moral authority" of the Republic of Science: the latter's views were impeded by the implementation of many recommendations coming out of the Lamontagne Committee
- the NRC historically was in a conflict of interest position, given its role as an operator of labs versus its role as a science policy coordinator
- given that Canada is a middle power country, it must make choices in the research it funds and performs, as it cannot excel in all fields
- it is important to ask the right questions in order to develop a meaningful policy framework: it is necessary to identify scientific niches, adapt them to Canadian circumstances, including the needs of the Canadian socio-economy, and engage in social learning to further the science system

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Robert Dalpé and Frances Anderson, *Contracting Out of Science and Technology Services*, CIRST paper 95-03 (Montreal 1995)

Synopsis: The article evaluates Canadian federal policy for contracting out S&T services for civilian technology since 1973, within the context of a broader international trend towards the contracting out of government services. A case study of energy research is offered.

Key points:

- the issues surrounding the contracting out of government services include flexibility of services offered; savings and efficiency; the social effects of contracting out; and the role of the state
- it is difficult to evaluate the contacting out of S&T services, since such services are not necessarily tangible: for example, bids in such cases are hard to compare
- the 1972 cabinet decision to contract research to industry rather than doing it in-house whenever possible was ultimately related to S&T objectives, and not-cost-saving motivations, as it was geared towards increasing private R&D, and increasing the links between government, universities and industry
- successful bidders gain expertise and thus have a subsequent advantage over other bidders in future competitions
- a bidder to assume control over research services may indeed have more knowledge of a research service than the agency or department contracting out the service
- the contracting out of research services in energy led to an increased use of other non-profit or public agencies, and not exclusively the private sector;
- contracting out makes it easier to cut budgets and reorient activities, but it also produces a lack of continuity in departments due to changing policy priorities
- while competition between bidders may be a desired goal, a concentration of expertise can occur
- it is easier to obtain government support for contracts than it is for the building of new equipment or the hiring of researchers

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John de la Mothe, "Government Science and the Public Interest." In *Government, Science and Global Change*, ed. G. Bruce Doern (Toronto: University of Toronto Press, 1999 forthcoming)

Synopsis:
The author examines the role of the government in conducting S&T within the context of the emergence of a knowledge-based economy, ongoing government restructuring, the decline of government-performed S&T across the industrialized world, and the growing importance and complexity of science and science-based issues. Central to these issues is the very meaning of public goods in this environment. The article thus examines the history of government science in this context and explores future directions it may take.

Key points:

- the importance of RSA (non-scientific activities), in which government has played an important role in closing the innovation gap, has been somewhat lost in the current environment

- while it is important (and indeed currently popular) to question the organization of federal science, doing so simply in terms of a limited amount of resources suggests that there is a magical "right balance", which furthers the trend towards micromanagement, instead of focussing on the reasons for governments to conduct science.
- the complexity of science and public policy (for example, the spread of infectious diseases through tourism or the trans-border flow of organic pollutants) ensures an ongoing important role for science-based departments and agencies (SBDAs)
- adopting an innovation systems approach to public policy (as has been done in Canada) can allow for the role and importance of government SBDAs to be clarified and strengthened
- government science in such an environment should be strategic, not reactive: it should be focussed on the medium and long-term, and not just focus on the short-term. In this sense, government science should not be caught between the imperatives of a market logic and the traditional university approach to basic research, but should always match science to the public interest.
- given the importance of government science for protecting and promoting the public interest, we must be wary about focussing on partnerships and the idea that government science can be performed more efficiently elsewhere.

Part 3- Media Scan

A media scan of print reports on federal science and technology policy over the past decade was conducted. Using common search terms in a variety of search engines, it is possible to gain insight into how issues related to Canadian science and technology, and in particular the federal role in science and technology, are reported in the print media (all the while acknowledging that a more exhaustive search might reveal additional insights).

From this scan, a few themes emerge:

1. Apart from one or two writers, notably David Crane and to a lesser extent Peter Calami, there is very little coverage of matters relating to Canadian science, technology and innovation.

2. Most print stories would be considered "newsworthy:" that is, they are stories about events: budget or program announcements, for example, or stories on the release of studies or data. Apart from David Crane's regular column in the *Toronto Star,* there are few editorials on the state of science, technology and innovation, and even less so on the federal role or the scientific infrastructure. Of course, there are isolated stories in newspapers across Canada on, for example, issues pertaining to a federal lab, but these are quite the exception.

3. Issues which received considerable coverage in the print media were, among others:

- the politics of the federal science and technology review, notably the launch of the review, some of the public consultations, and the final report;
- the need to increase Canadian investments in R&D, particularly in light of lagging investments vis-a-vis international competitors
- the need for increased private sector R&D
- issues related to the development of the information highway, particularly during the time the Information Highway Advisory Council was active

4. Examples of some of David Crane's writing:

5. There are not really any media outlets for a popular discussion of science, technology and innovation issues. Indeed, it is doubtful that there has been such an outlet since the mid-1970s and *Science Forum.* The mandate of *Science Forum* was to provide, in lay language, a forum for debate on science and technology issues, and link them to broader social and economic issues. Of note, funding supporting the magazine was provided by the Donner Foundation and various federal and provincial government departments and agencies.

Science Forum provided a good forum for a public discussion of contending viewpoints on science and technology. One common theme of contributions over the years was that of the "Republic of Science" and the argument for greater government support of science and research, and less government control over its direction. For example, Martin Johns ("The Growing Crisis in Canadian Science - and How to Avert It," vol. 1, no. 6, Dec. 1968) argued that government actions in S&T were shortsighted, as they were geared towards saving money, and displayed no conception of the role of science in economic growth. Only this can explain such actions as the cancellation of the Queen Elizabeth II telescope and the Intense Neutron Generator project, and cutbacks in the budgets of government laboratories.

On the other hand, many contributors discussed the need to forge linkages between the various partners in the Canadian science system. For example, John Martin ("Public Support of all Industrial R&D: Big Benefits, Little More Cost," vol. 8, no. 3, June 1975) discussed solutions to the ongoing problem of poor industrial performance of R&D. Martin argued that most government R&D supported research in federal laboratories and the universities, and that little of this research met industrial needs. The solution, for Martin, was to increase industrial access to federal laboratories and the professionals who work in them.

Finally, *Science Forum* provided an outlet for discussions on science policy. For example, W.G. Schneider, ("The Role of Government as a Patron and User of Science and technology," vol. 6, no. 1, February 1973) a former president of the NRC, discussed the nature of science policy. He argued that a comprehensive science policy has two dimensions: *a policy for science,* which includes the development of research capability, infrastructure, and the support of research, and *policies for the application and use of science,* which are related to national missions and objectives. It should be noted that such a view made an effort to bridge the competing views noted above, and demonstrate foresight in terms of contemporary science policy debates.

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