Science *and* Technology Excellence in the Public Service

S T E P S

A Report of the Council of Science and Technology Advisors

Canada

Science *and* Technology Excellence

in the Public Service

A Framework for Excellence in Federally Performed Science and Technology

Excellence defines the value
of federally performed
science and technology

August 2001

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Introduction

Science and technology (S&T) is fundamental to the advancement and application of knowledge across the national system of innovation. S&T underpins virtually every aspect of our lives — the economy, health care, safety, and our leisure activities. Across industry, academe, and government, S&T is central to the ability of organizations and individuals to fulfil their goals and responsibilities.

The public expects government to employ S&T to provide a high quality of life, a competitive and fair trading economic environment, and an opportunity-filled working life. In addition, there is increasing public dependence on government to conduct and use science and technology to verify the safety and efficacy of new products and services, and to ensure the health and safety of Canada, its environment, and its citizens. In several countries, recent controversies over tainted blood, “mad-cow” disease, water contamination, and fish stock assessments — together with the legal challenges that have followed — have shaken public confidence in the ability of governments to conduct and use sound science. To perform its many roles well, and to maintain credibility with stakeholders and the public, it is critical that government ensure, and be able to demonstrate, that the S&T it conducts is excellent. The government’s demand for excellent S&T has never been greater.

In recognition of the importance of S&T excellence, the Cabinet Committee on the Economic Union (CCEU) has asked the Council of Science and Technology Advisors (CSTA) to conduct an examination of excellence in federally performed science and technology. Specifically, we have been asked to identify the characteristics of excellence and to provide guidance on appropriate mechanisms for measuring excellence in the conduct and management of federal S&T. Our report provides a framework for S&T excellence in government and a series of recommendations to foster excellence in federally performed S&T.

Recent federal budgets have placed considerable emphasis on S&T. The January 2001 Speech from the Throne and the Prime Minister’s response indicate that we can expect S&T to remain a priority for government. Increasing demands for S&T on complex, emerging issues such as climate change and biotechnology have intensified competition for limited government resources. We welcome the government’s commitment to at least double the current federal investment in research and development (R&D) and to ensure that Canada’s R&D effort as a share of gross domestic product (GDP) is among the top five countries in the Organisation for Economic Co-operation and Development (OECD) by the year 2010. But the government has recognized that money alone is not enough. We applaud the government’s commitment to continue to pursue research excellence in government labs and encourage the government to consider our framework and recommendations in fulfilling this commitment.

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The Present Study

Background

The 1996 federal S&T strategy, *Science and Technology for the New Century*, recognized the importance of "scientific excellence" in ensuring the effectiveness of federally performed S&T. The strategy concluded that the scientific merits of a particular activity are best confirmed through external review, including an independent assessment of the potential, design, performance, and impact of the proposed effort. The strategy called on each federal research facility and program to "establish and follow a rigorous schedule for submitting its proposed research activities to an expert review by clients, stakeholders and peers in order to ensure the scientific, economic, and environmental excellence of its research." The strategy also called on each science-based department and agency (SBDA) to "set clear S&T targets and objectives, establish performance measurement indicators based on outputs, develop evaluation frameworks, and maintain mechanisms for external advice and review" (Government of Canada 1996).

The Auditor General also focussed on the management of federal S&T in his November 1999 report, in the chapter entitled "Attributes of Well-Managed Research Organizations." The chapter describes how well-managed research organizations focus on "doing the right research project and doing the research project right." This means ensuring that the research project is properly aligned with the organization's mandate and "ensuring that the project produces, and is based on, excellent science and technology and that it stands up to the scrutiny of world-class experts" (Auditor General of Canada 1999).

The CSTA, in its initial reports, emphasized the importance of S&T excellence. In *Science Advice for Government Effectiveness (SAGE),* the CSTA stressed the importance of "sound science" as a key input to science advice that supports government decision making. The SAGE report called for science advisory processes that include "due diligence procedures for assuring quality and reliability, including scientific peer review" (CSTA 1999a).

The CSTA's second report, *Building Excellence in Science and Technology (BEST),* identified excellence as critical to public and stakeholder confidence in the credibility of government S&T. According to the BEST report, government S&T must be of the highest quality, demonstrate that it meets or exceeds international standards for S&T excellence, and deliver social or industrial relevance. At the same time, however, the report acknowledges that criteria for excellence in government S&T may need to differ from those for university or industry research, and may require a range of different measures and processes. The report specifically identified the importance of expert review (CSTA 1999b).

While excellence is the focus of our current study, it is important to recognize that it is but one of three fundamental principles — alignment, linkages, and excellence — that we believe must be applied to the conduct of all federally performed S&T. The adoption of all three principles is essential to ensuring that the government remains a credible contributor to the national innovation system and fulfils its responsibilities to Canadians. In the BEST report, we called for federally performed S&T to be aligned with departmental mandates and the overall priorities of government. We also called for improved linkages within government, with other sectors in the national system of innovation, and with international performers of S&T.

Approach

To conduct the present study, the CSTA commissioned several international examinations of current practices employed by foreign governments (Australia, France, Germany, New Zealand, Sweden, the UK, and the US). The objective of these studies was to explore how these countries measure and ensure excellence in the S&T performed by their research organizations, and to identify practices and mechanisms that could be usefully applied within Canadian federal S&T facilities. An additional study examined existing practices within Canadian federal SBDAs and provincial research organizations. A number of governmental S&T organizations have implemented a variety of effective mechanisms and processes to measure and demonstrate S&T excellence. Appendix I includes examples drawn from Canadian SBDAs and foreign governments.

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Characteristics of Government S&T

As part of its examination of excellence, the CCEU asked the CSTA to identify the characteristics of federally performed S&T. We believe there are a number of fundamental differences with respect to S&T in government, academe, and industry. Understanding these differences, as outlined below, is critical to developing a framework that will stimulate excellence in federally performed S&T.

The Roles of Government in S&T

The range of federal S&T activities and functions is diverse and complex, and includes international responsibilities. As we indicated in the BEST report, we believe there is a clear need for the federal government to conduct excellent S&T in support of the following roles:

- *Support for decision making, policy development, and regulations* — e.g. new means to measure compliance with pulp and paper effluent regulations.
- *Development and management of standards* — e.g. contribution to the resolution of trade issues such as the dispute with the European Union on pinewood nematode in Canadian softwood lumber shipments.
- *Support for public health, safety, environmental, and/or defence needs* — e.g. federal capacity for independent research into food safety assists the government in ensuring the safety of Canadians.
- *Enabling economic and social development* — e.g. research into health service delivery or sustainable farming practices (CSTA 1999b).

Purpose

Because government S&T supports a diversity of roles, assessments of excellence should first identify the purpose and objectives of the activity and then specify the characteristics to be used as evaluation criteria. The relevant characteristics of excellence and how they can best be measured may vary depending on which role the S&T is targeted to support. For example, *originality* is of great importance in an academic setting where the objective of basic research is the creation of new knowledge. While originality is a necessary attribute of leading-edge federal S&T, federally performed S&T conducted for other purposes often involves *independence* in the context of the government's mandate to provide third-party assessments, and *consistency* in the provision of ongoing data collection.

Client

The notion of conducting S&T for clients distinguishes federally performed S&T from that performed in other sectors. Traditionally, academic researchers have not identified with the concept of client: university researchers whose work advances

the state of scientific knowledge probably view the scientific community as the primary beneficiary of their S&T. The concept of client is more common within industry where S&T excellence is measured against the contribution to customer satisfaction and shareholder value. Government S&T must meet the needs of a variety of clients, internal and external. The specific clients will vary depending on the role supported by the S&T but will typically include government decision makers, internal and external stakeholders, and Canadians. In addition, government is making greater use of partnerships and other collaborative S&T arrangements. Criteria and measures of excellence must be appropriate for, and acceptable to, all partners.

Type of S&T Activity

The nature of government S&T ranges from routine testing and monitoring to leading-edge, fundamental research. In contrast, S&T performed by universities and firms tends to involve a much smaller range of activities. The selection of measures to ensure excellence should reflect the nature of the activity being performed, e.g., basic research, applied research, strategic research, technological development, and related scientific activity (RSA).[1] RSA includes many activities not normally performed by university or private sector researchers such as disease surveillance, monitoring, testing, S&T information services, archiving, and museum and media services.

The government also needs to maintain ongoing efforts to identify emerging S&T issues and to prepare for the challenges and opportunities they will bring. The CSTA believes that performing a full range of S&T activities is critical to anticipating and responding to these emerging science-based challenges and opportunities, and to assessing the implications of advances in S&T.

Time Frame

Unlike academic science, which tends to have longer time horizons, and industrial R&D, which tends to be oriented to providing results in the short term, government S&T responds to a range of time frames. For example, government S&T must be able to respond quickly to crises or transient events but also must provide long-term monitoring and research on issues of strategic importance to Canada. Measures of excellence must accommodate these various time frames.

1. *Research and Development (R&D)* — Creative work undertaken on a systematic basis to increase the stock of knowledge, including the knowledge of humans, their culture and society, and the use of this stock of knowledge to devise new applications of science and/or technology.

   Related Scientific Activity (RSA) — Those activities that complement and extend R&D by contributing to the generation, dissemination, and application of scientific and technical knowledge. Examples include data collection, testing, scientific and technical information services, and museum services. RSA includes many activities not normally performed by university or private sector researchers such as monitoring or disease surveillance.

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The S&T Continuum

For the purposes of this report, we have identified a common continuum of S&T activity shared by all three sectors in the innovation system — industry, academe, and government. However, because of the specific roles, purposes, clientele, and ranges of S&T activity characteristic of government S&T, as described above, there are important factors that distinguish S&T performed in government from that performed in academe and industry. This report will consider excellence in federally performed S&T throughout the following six stages of the S&T continuum.

1. Definition of scientific priorities and programs

In academe, research directions are determined largely by the scientists' curiosity. In industry, R&D programs are defined by considerations of a firm's competitiveness. The definition of government S&T programs involves the translation of government policies, priorities and departmental mandates into S&T programs and research agendas that should reflect the needs of a diverse base of clients and stakeholders.

2. Proposal and project selection

In industry, research projects are selected based on their anticipated contribution to new products, processes, and services. Universities and Canada's granting councils use peer review to make competitive project-selection decisions based on scientific merit. In addition to scientific merit, government projects should demonstrate independence, alignment with government and departmental mandates and stakeholder needs, transparency, openness, and ethics.

3. Scientific inquiry

Given the universality of the scientific method, the characteristics of excellence pertaining to the conduct of scientific inquiry are generally the same regardless of where the research is performed or its purpose. For example, all three sectors recognize the traditional characteristics of scientific excellence such as *originality, objectivity, rigorous methodology, repeatability, research integrity,* and *ethical behaviour.* Differences between the sectors may arise in the conduct of RSA, an area of S&T dominated by government and one where traditional characteristics and measures of excellence may not be sufficient.

4. and 5. Immediate results (outputs) and Ultimate impacts (outcomes)

Demonstrating S&T excellence requires an assessment of the direct results of S&T activities and their broader impacts on the economy and society. In academe, for example, outputs include new contributions to knowledge as captured in publications, while a broader outcome is the training of new generations of well-qualified scientists and engineers, as indicated by numbers of S&T graduates and their employability. Similarly, in industry, direct results of R&D are new ideas as captured in patents, products and services, while broader impacts might include contributions of these direct outputs to increased shareholder value.

Outputs such as publications, patents, and new or improved products, processes and services are indicators of excellence in academe and industry and have often been the basis of assessment for government S&T excellence. However, government is facing pressure to demonstrate that the S&T it performs results in solutions to problems, contributes to sound policy and regulatory decisions, and meets public expectations of ethical conduct. As a result, there is an increasing focus on outputs such as weather forecasts, scientific advice and new regulations, as well as outcomes such as improved crop production, lower incidence of extreme weather-related deaths, and improved public confidence in the safety of products and services.

6. Communications

There is a particular challenge in demonstrating the contributions of federally performed S&T. While academe and industry typically communicate their S&T results to a well-defined audience, the federal government has a more diverse stakeholder base that includes a public that is not necessarily interested or literate in S&T. The government's credibility rests on its ability to demonstrate that the S&T it performs meets international standards of excellence and has been applied in a manner that meets public expectations.

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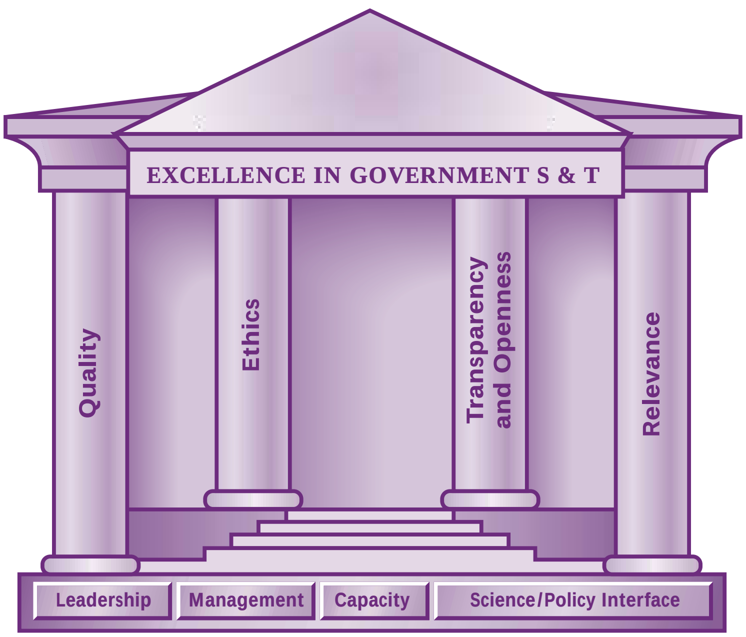
Framework for Excellence in Government S&T

Science and technology is increasingly central to all facets of life. Excellent federal S&T provides an essential contribution to the knowledge and innovation needed for a progressive and supportive society, and a competitive economy. We have developed the framework for excellence in government S&T outlined here to foster excellence. The framework is built on a *foundation* of essential conditions for excellence and *four pillars* that define the elements of federal S&T excellence. The framework reflects the factors that distinguish government S&T from that performed in other sectors. Excellence in government S&T requires that all activities along the S&T continuum be conducted in a manner consistent with this framework.



Foundation of Excellence

The foundation on which S&T is conducted directly affects the excellence of the activity. The following conditions contribute to an environment where S&T excellence can thrive. They are important building blocks for excellent government S&T. While they are not sufficient to ensure excellence, excellent S&T is rarely evident when these conditions are absent.

Leadership

Excellence in government S&T requires leadership from individuals with a vision of excellence and an ability to achieve and maintain it. Leaders with a passion for excellence can motivate and influence others to achieve it. Leadership is not only expected and encouraged in managers, but should be demonstrated and fostered at all levels within federal departments. In addition to being leaders themselves, ministers have an important role as catalysts and enablers of leadership.

Management

Excellence in government S&T requires highly developed management skills to:

- encourage innovation and creativity at all levels within departments;
- translate government priorities, strategies, and departmental mandates into clearly defined research objectives and programs;
- engage staff, clients, and stakeholders in the strategic planning process to anticipate emerging issues, to ensure that scientific questions and requirements are appropriately defined and to ensure the integrity of S&T processes;

- provide a supportive work environment that emphasizes human resource development and provides opportunities for S&T personnel to work collaboratively with colleagues in other organizations within Canada and internationally; and
- ensure that the results of government S&T are effectively communicated to decision makers and the public.

Capacity to address current and emerging needs

Human Resources — Changes in the global economy and society are creating new and constantly evolving demands on federal S&T personnel. To respond to emerging S&T-based issues such as climate change and biotechnology, the government requires a dynamic and highly skilled human resource capacity capable of operating in multi-disciplinary environments. Given the increased competition for highly skilled scientists and technicians from other sectors, the government's ability to conduct excellent S&T depends on its ability to provide a dynamic, flexible and nurturing work environment, and innovative human resources strategies to recruit, rejuvenate, and retain its work force.

Infrastructure and Equipment — Proper facilities, platforms, and equipment are required to support excellent S&T. Advances in S&T, as well as changing priorities for S&T, often make existing infrastructure and equipment obsolete, and usher in requirements for new infrastructure and capabilities. Maintaining an S&T infrastructure capable of supporting excellent S&T requires ongoing investments.

Financial resources — Predictable, ongoing, and adequate financial resources are required to conduct S&T in support of the roles of government, and to address emerging science-based issues. Resources must be allocated in a manner that is aligned with the priorities of the government and supports the performance of excellent S&T.

Science/policy interface

Excellence in government S&T requires clearly defined and well-structured processes to communicate both the policy requirements for S&T and S&T results. As we emphasized in our SAGE report, scientists and technologists need to have the means to communicate their findings and results in a form useful to decision makers, ministers, senior officials, policy analysts, and the public. In turn, these parties require an appreciation for what S&T can and cannot say about the issues under consideration.

Pillars of Excellence in Government S&T

Although the term "scientific excellence" is broadly understood within the scientific community, the concept is not readily defined in the government context. As discussed above, there are factors that distinguish government S&T from that performed in other sectors. Within government, we believe that S&T excellence rests on four pillars working together to support the roles of government and to engender public confidence in the results of federal S&T. Federal S&T should be of high *quality* in terms appropriate to the nature of the S&T conducted; *relevant* to the roles and priorities of government; conducted with the degree of *transparency and openness* called for in a democratic nation; and pursued in accordance with the *ethics* of society.

Quality

Government must ensure that its S&T is of high quality at all stages of the continuum. Quality should be defined in terms that are appropriate to the nature of the S&T conducted. The quality of both the S&T and the process employed to achieve it should be readily demonstrable to all stakeholders, including the scientific community and lay public. While there is a plethora of quantitative indicators of quality, there is no single measure that can be broadly applied to S&T to ascertain quality. Rather, quality of S&T is usually based on the collective view of experts with respect to the veracity and merit of the methodology and results.

Relevance

To ensure the relevance of the S&T performed by government, it must be aligned with departmental and government mandates, missions, and priorities. As we indicated in the BEST report, "departments and agencies should only be performing the S&T that is needed to support their mandate and that cannot be obtained more effectively from other sources" (CSTA 1999b). By working closely with other sectors, the government can ensure that it applies its limited resources to the tasks it is uniquely equipped to deliver. Government should ensure that its S&T is useful to and useable by its clients.

Transparency and openness

As we indicated in the SAGE report,

> Transparency implies an articulation in plain language of how decisions are reached, the presentation of policies in open fora, and public access to the findings and advice of scientists as early as possible. Openness implies early and ongoing consultation with stakeholder groups, as well as public discourse (CSTA 1999b).

The government should involve stakeholders throughout the S&T continuum, from planning to the assessment of results. This openness will contribute to the relevance of government S&T and its utility. The government should also ensure that its S&T findings and analyses are communicated to the scientific community, to those involved in delivering the government's many roles, to stakeholders, and to the public. To maintain credibility as a performer of S&T, the government needs to communicate the mechanisms and processes it has employed to ensure the excellence of its S&T. In instances of multi-disciplinary S&T, or where there are multiple lines of accountability, the benefits of transparency and openness are even greater.

Ethics

Government should articulate how it is taking account of ethical considerations and should demonstrate that its performance of S&T reflects stakeholder and public expectations of ethical behaviour. Ethics are based on community and stakeholder values, and are key to public trust.

Evidence-based ethics call for decisions that have been informed by an understanding of these values.

Government should ensure that its S&T is guided by ethical considerations that reflect a sensitivity to the following:

- scientific community values (e.g. objectivity, rigour, integrity),
- public service values (e.g. accountability, due diligence, avoidance of conflict of interest, loyalty, public scrutiny), and
- community values (e.g. respect for the autonomy of the individual and basic human dignity, fairness, the avoidance of harm, and the production of good).

In addition, government S&T should adhere to specific guidelines with respect to the treatment of human and animal subjects, and scientists must conform to acceptable standards of research integrity. It may be worthwhile to consider the experience of Canada's granting councils in this regard. The government also needs to ensure that it employs mechanisms to identify and respond to the ethical dimensions of emerging S&T issues. The Review section in Appendix I outlines a series of questions useful in gauging the ethics of S&T.

Mechanisms

In developing this report, we identified a common continuum of S&T activity shared by all three sectors in the innovation system — industry, academe, and government. As discussed above, the characteristics of excellent government S&T are influenced by a number of distinguishing factors. In selecting appropriate measures of excellence, consideration should be given to the unique characteristics of government S&T at each stage of the continuum. Consideration should also be given to the level of the evaluation (e.g. individual researcher or research project; research groups, laboratories or institutions; government programs; or the entire national research base or system of innovation).

A number of traditional and recently developed mechanisms are available to measure and foster excellence in federally performed S&T. The variety of options provides the federal government with several highly effective means to assess its S&T. Four categories of the more commonly used measures are summarized below. A more detailed examination of mechanisms and examples drawn from Canadian and foreign government departments and agencies can be found in Appendix I.

Review

The most widely accepted process to measure excellence, both at the project selection and project assessment stages, is peer review. There are many variations on peer review such as expert review, modified peer review, and colleague review, but all are based on the premise that the *quality* of scientific work is best judged by experts in the field. The integrity of the review process requires the selection of qualified reviewers who possess the appropriate expertise and credentials, as well as independence from the S&T being assessed. Other types of review include in-house assessment, stakeholder input, and international review. These types of reviews value the inclusion of clients and stakeholders to assess the *relevance, transparency and openness*, and *ethics* of government S&T.

Quantitative metrics and indicators

To complement the subjective nature of review, quantitative metrics can provide measures of productivity, relevance, and impact, as well as provide data on the functional health of an organization. Bibliometric analysis provides a relatively easy and independently verifiable indicator of scientific productivity using quantitative measures of published research outputs such as journal articles, books, citations, and articles appearing in high-profile, peer-reviewed journals.

Indicators such as numbers of patents, royalties from licences, sales of new products and services, and technology transfers may be more appropriate means of assessing excellence in technology development. Indicators of the accuracy of monitoring and testing procedures may provide better data for related scientific activity such as water testing.

Another important indicator of S&T excellence is the recognition of one's scientific peers. Quantitative metrics in this area include the number of prestigious prizes awarded to researchers within an organization, memberships in learned societies, participation on expert panels, journal editorships, and invitations to make presentations.

The quality and relevance of federally performed S&T can also be measured in terms of its ability to modify or influence government policies, regulations, and processes.

Benchmarking

Benchmarking involves comparing organizations, products or processes against world standards of excellence in similar work settings. It allows an organization to apply any best practices or lessons learned to improve its operations or output. Benchmarking can be applied to all types of S&T functions, but is particularly useful in assessing related scientific activity that may be less amenable to mechanisms such as peer review or bibliometrics.

Satisfaction and impact analyses

Indicators of client or customer satisfaction with the outputs and relevance of government S&T can provide useful information to government managers regarding the perceived excellence of their departments' S&T activities. Examples of satisfaction analyses include the following:

- surveys of the satisfaction of clients, users, and stakeholders,
- public opinion polling,
- return clients and partners, and
- willingness to share costs.

Government must also be able to demonstrate that the S&T it performs has a positive impact in economic, social, or environmental terms. Economic rates of return have traditionally been used to measure the impact of research, although

social-benefit measures are developing. Retrospective analyses such as tracer studies outline the history and impacts of S&T in areas such as economic development and new commercial products, technological processes, or industries. Case studies and success stories can also be used to discern the effects of various institutional, organizational, and technical factors on the conduct of S&T.

The Need for a Balanced Approach

While the determination of excellence has traditionally relied on qualitative indicators such as peer review, quantitative metrics are receiving increased recognition and emphasis. However, no single indicator or measure is sufficient. Too much emphasis on any single measure (especially quantitative measures) may lead to a skewing of behaviour towards the production of immediate outputs (e.g. publications) at the expense of the desired longer-term policy outcomes. Rather, a combination of qualitative and quantitative measures is valuable in establishing a solid understanding of the entity under evaluation, allowing comparability across evaluations, and improving the management of government S&T.

Assessment mechanisms should be chosen selectively to avoid creating an unnecessary evaluation burden. Selecting “a vital few” qualitative and quantitative measures contributes to a balanced approach to measuring excellence in federally performed S&T. The choice and use of measures should reflect a response that is proportionate to the scale of the program or project, the level of complexity, and the degree of uncertainty involved in the science or issue facing the government. The greater the complexity or potential controversy of a particular issue, the greater the need for government to invest more effort in encouraging and demonstrating S&T excellence.

Communications

While it is critical that the government employ diverse mechanisms to measure and stimulate excellence, government must not stop there. Open channels of communication between government, industry, academe, and the public are necessary if we are to translate scientific and technological advances into a strong national system of innovation and improved quality of life for Canadians. Effective communications are also required to demonstrate the credibility and results of federally performed S&T. The tools government employs to communicate should take into consideration the audience the government is trying to reach (i.e. scientists, citizens, stakeholder groups) and should provide relevant information in a succinct manner, using the most appropriate medium (i.e. the Internet, scientific journals, town hall fora). A review of select communications tools used by Canadian and foreign government departments can be found in Appendix II.

Challenges

The national innovation system cannot realize its full potential without the government's fulfilling its role as a catalyst, facilitator and performer of S&T. As noted in BEST, "where the government is unable to mobilize its S&T resources in support of its mandated regulatory, economic and social development roles, there can be a significant adverse impact on university and private sector activities in knowledge creation and economic and social development" (CSTA 1999b).

The government faces a number of capacity challenges in fulfilling its role in the national innovation system. As indicated in our BEST report, we believe that the biggest challenge facing government S&T relates to the government's ability to provide the environment and conditions in which excellent S&T can thrive. While some progress has been made in some areas, we remain particularly concerned with the many serious human resource challenges facing government. These include:

- outdated staffing rules that hinder flexibility and responsiveness,
- poorly defined career advancement opportunities for scientists and technicians,
- outdated, inflexible promotion criteria and uncompetitive wages, and
- an ageing work force, coupled with inadequate recruitment of new workers.

The competition for highly skilled scientific personnel has increased rapidly over the past few years and will most certainly escalate in the future. Higher salaries, job security, opportunities for promotion, and rewards and incentives are being offered to new graduates and experienced government personnel as a means to entice them to other sectors. Compounding this issue is the fact that a large segment of the government's scientific personnel is nearing retirement.

Re-establishing the government as the "employer of choice" among these highly skilled scientific professionals will require providing employees with excellent opportunities for personal and professional growth. Government must provide a stimulating work environment that offers challenging assignments and appropriate rewards. Ongoing education and training, mentoring and career mobility, as well as rewards and incentives that are designed to attract and retain talented personnel, are critical to establishing the S&T capacity required to address the opportunities and challenges facing government.

We are also concerned that deteriorating facilities, platforms, and equipment compromise the government's capacity to perform S&T and to attract and retain excellent, motivated S&T personnel. As noted in BEST, the government needs "to identify what capacity is needed to allow [it] to meet current and future needs, and to enhance its ability to meet these future challenges" (CSTA 1999b). Predictable, ongoing and adequate financial support to government departments, programs, and laboratories is essential in this regard.

We believe that new investments in S&T are required to support the ongoing roles of government, to establish the new capacities required to respond to emerging science-based opportunities and challenges, and to fulfil the government's role in the national innovation system. In addition, the government must take immediate steps to eliminate those capacities that have become redundant or are no longer required. Given competing demands for the government's finite resources, the government and the public need to be confident that existing and new investments will foster excellent government S&T. We believe our framework provides useful guidance on how excellence can be achieved and judged.

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Recommendations

This is the third CSTA report, and it builds extensively on both the SAGE and BEST reports. In the SAGE report, we called upon the government to employ measures to ensure the quality, integrity, and objectivity of its S&T. In the BEST report, we recommended that the government integrate the principles of *alignment, linkages* and *excellence* into its priority setting and decision-making processes, and that it commit the resources necessary to ensure that it has the S&T capacity required to fulfil its roles. This report provides the means to implement a number of our previous recommendations.

In addition, this report identifies the unique characteristics of federally performed S&T and provides a framework that defines S&T excellence within a federal context. The framework provides guidance on how to foster excellence in federally performed S&T and identifies mechanisms to measure excellence in the conduct and management of federal S&T. Based on our examination, we recommend the following to the Government of Canada:

Implementation of the Framework

- Adopt the *Framework for Excellence in Federally Performed Science and Technology* across government, and require those federal departments and agencies engaged in S&T to manage and conduct it in a manner consistent with the framework.

Quality

- Employ external, expert review processes throughout the S&T continuum to support project-selection decisions and to assess the results of S&T. Reaffirm the commitment made in the 1996 federal S&T strategy, which called on each federal research facility and program to "establish and follow a rigorous schedule for submitting its proposed research activities to an expert review by clients, stakeholders and peers in order to ensure the scientific, economic, and environmental excellence of its research" (Government of Canada 1996).

Relevance

- In the context of existing program evaluation mechanisms, require that departments involve external science advisory bodies in assessing the relevance of S&T programs. Science advisory bodies should call on departments to demonstrate the requirement for the S&T, the need for the S&T to be conducted in-house, and their ability to perform it to standards of excellence.

Transparency and Openness

- Include communications and publication strategies in program and project planning documents, and require that departments publish or otherwise make available information on all funded S&T projects. Information such as abstracts, progress reports, summaries,

and program evaluations should be accessible to the lay public. Departments should also be explicit and transparent with respect to the mechanisms they use to assess their S&T.

Ethics

- Develop, publish, and implement government-wide guidelines to ensure the ethical conduct of federally performed S&T.

Appendix I: Mechanisms for Measuring S&T Excellence

Interest in research evaluation has grown substantially in the last decade and “the current state of the art . . . is based on specific methods and procedures that have been considerably enriched and refined in recent years” (OECD 1997). This section will briefly describe a wide range of mechanisms and measures that are available to assess S&T excellence in a government context. Examples in this appendix have been drawn from the studies commissioned by the CSTA.

Review

Included in this category are measures such as traditional peer review, in-house assessment, stakeholder input, and international review. These can be achieved through processes such as ad hoc technical panels, expert committees, standing advisory bodies, formal third-party evaluations, and public hearings. Review processes should be designed to measure and ensure the integrity of each of the four pillars of excellence.

The most widely accepted measure of scientific quality is peer review. There are many variations of peer review but all are based on the premise that the *quality* of scientific work is best judged by other experts in the field. Peer review provides a qualitative indicator that can be used to certify the appropriateness of methodologies and the plausibility of results. Peer review should be employed to support project selection, funding, and publication decisions. Peer review can also be employed at other levels of focus, whether in support of individual personnel decisions (e.g. promotion, tenure) or to compare the relative performance of national innovation systems.

United States — Environmental Protection Agency

At the US Environmental Protection Agency (EPA), every major scientific or technical work produced must undergo peer review. As a result, the EPA has developed a Peer Review Policy and published the *Peer Review Handbook* for staff and managers. The goal of the handbook is to “enhance the quality and credibility of Agency decisions by ensuring that the scientific and technical work products underlying these decisions receive appropriate levels of peer review by independent scientific and technical experts.” The handbook provides guidance, checklists, and practical information for managers who are conducting peer reviews.

Canada — Environment Canada

The Science and Technology Management Committee of Environment Canada has developed a *Framework for External Review of Research and Development*. The document sets out the department’s policy on conducting external review of R&D, attempts to clarify where and how the policy would be applied, and provides guidance on implementation to science managers.

United States — Agricultural Research Service

Within the U.S. Agricultural Research Service (ARS), the Office of Scientific Quality Reviews conducts simultaneous external reviews of all projects in a particular program, rather than just one project at a time. This allows review panels to understand the overall program balance and generate better advice. Projects are evaluated based on quality and relevance, as well as the capability of the proposers to do the project. External panels are used to make decisions on individual projects and to recommend changes as needed. All panel members are PhD scientists with excellent research credentials who work outside ARS.

Canada — Department of Fisheries and Oceans

The Science Sector at the Department of Fisheries and Oceans (DFO) used an external peer review panel to assess the quality and relevance of its greenhouse gas (GHG) research program. The panel assembled an inventory of the projects the department had undertaken in the previous 10 years and provided guidance on ongoing projects and future research directions and requirements. The panel included experts from the US, the UK, and Canada.

The work of the panel was instrumental in the GHG national research strategy. DFO researchers valued the opportunity to have their research activities reviewed by external peers.

The concept of review extends beyond the traditional concept of peer review to assess scientific quality. Review processes that include clients and stakeholders are used to improve the *relevance*, *transparency*, *openness*, and *ethics* of government S&T. Increasingly, multi-stakeholder reviews are employed to assist strategic planning and management, to guide new program directions, to support project selection decisions, and to assess the results and impacts of the S&T. Performance-based management approaches focus on the evaluation of the results of government S&T against the objectives of the S&T program. An increased emphasis on accountability reinforces the position

United Kingdom — Department of Trade and Industry

In the UK, the Department of Trade and Industry pioneered an integrated approach to managing programs. Rationale, Objectives, Appraisal, Monitoring and Evaluation (ROAME) statements are used by the department and have been adopted, and adapted as necessary, by several others to approve, target, monitor, and evaluate programs.

ROAME statements set out the overall justification for a program, a hierarchy of objectives, targets, and milestones for projects or programs. By clearly defining the objectives, the statements can be used as a basis for monitoring, adjusting, and evaluating projects. The use of ROAME statements has stimulated more of an evaluation culture, including learning from experience, and has encouraged the incorporation of feedback into the new policies and programs. Its potential drawbacks are that the process can lend itself to rigidity and undue bureaucracy.

that if government does not have the resources to assess the S&T, then it should not be initiated in the first place. Limited resources can no longer be used as an excuse not to conduct a post-project review.

Germany — Projekttrage

In Germany, government ministries have taken the review process beyond traditional post-project review. Ministries use a pool of *Projekttrage* to manage projects, undertake monitoring, and conduct evaluations. The *Projekttrage* are third-party government organizations independent of both the sponsoring ministry and the researchers.

UK — Department of Trade and Industry

At the UK Department of Trade and Industry there is a separate unit that undertakes most S&T evaluations. This unit is detached from activities immediately under its scrutiny and enjoys a tradition of independence. It has the advantage of greater access to project information and is able to apply a relative insider's understanding of the S&T projects and programs evaluated.

Review is also used to consider ethical issues when evaluating S&T excellence. Where ethical considerations are important, the review process should involve a wide range of experts in areas such as health, safety, social impacts, ethics, and law. Moreover, including an ethicist in the review process can improve the framing of appropriate

Canada — National Water Research Institute

To identify the skills required to operate its research laboratories, the National Water Research Institute has developed and published a core competency framework for identifying its staffing needs. Competency assessments at the Institute are not just used for identifying gaps and hiring new staff, but for individual professional development of current staff. The framework also includes criteria to judge the effectiveness of the core competency development process.

questions. Ethical considerations can include, but are not limited to, the following:

- Are the means employed to conduct the S&T acceptable?
- Are the ends worthwhile?
- Is there respect for the autonomy, dignity, and rights of research subjects?
- Are gains likely to outweigh costs for all relevant parties?
- Is the distribution of burdens and benefits fair?
- Is there meaningful consultation so that affected parties are well-informed?
- Is risk assessed and adequately communicated?
- Who has the onus of proof of no harm?
- Is this the most efficient use of resources? Have the potential lost opportunities been evaluated?

- Are the evaluators of the science and ethics qualified, independent, and free of conflicts of interest?[2]

The integrity of the review process requires the selection of qualified reviewers (whether internal or external to the organization) who possess the appropriate personal credentials (in terms of the expertise they are expected to contribute to the review) and independence from the S&T being assessed. Government must consider the potential for “peer fatigue,” particularly in a country such as Canada, where there are a limited number of qualified experts who can serve on review panels. Countries such as Sweden, Australia, and New Zealand make substantial use of international experts to ensure independence of their review processes and to counteract peer fatigue.

Quantitative Metrics and Indicators

Countries are placing increased emphasis on the development and use of quantitative metrics to complement the subjective nature of review. Included in this category are measures of:

- productivity, e.g., counts of publications, conference presentations, and patents;
- relevance and impact, e.g., citations, licenses, royalties, level of cost-sharing, number of prizes, and other forms of recognition; and
- the functional health of the S&T organization, including human resources and funding statistics.

These metrics can attest to the quality, relevance, and to some extent the transparency of the S&T but are not designed to ascertain whether it meets standards of ethical conduct. The selection of specific metrics should be guided by the type of S&T (e.g. research, technology development, testing, monitoring).

United States — Army Research Laboratory

To evaluate the functional health of the US Army Research Laboratory’s research environment, management turned to indicators and metrics. Existing data collection and monitoring methods such as fiscal and personnel systems already tracked dozens of key metrics. Metrics are monitored by the respective functional offices and are only reported to the director if they fall outside of appropriate bounds. Goals are set for these metrics using peer organizations as benchmarks. A smaller collection of metrics is studied by the director to determine specific information about the research environment. While no number or set of numbers can specifically guarantee that excellent science is being conducted, high values across the board indicate whether there is fertile ground in which excellent science can be done.

2. As phrased here, these questions could be asked by a review committee before conducting the S&T. In a modified form, they could also be used in a post-project evaluation; for example, Were the ends worthwhile? Was there respect for research subjects?

The CSTA acknowledges the guidance of Dr. Michael McDonald, Director, Centre for Applied Ethics, University of British Columbia, in developing these questions.

Canada — Natural Resources Canada

The Centres of Energy Technology at CANMET are moving towards a "balanced scorecard" approach. Key performance indicators are aligned with resource planning and include revenue generation, R&D contracting-out, client reach, integration, collaboration and cooperation, client satisfaction, and human resources development. Researchers have found that this system can create a measurement burden, but that it has strengthened the planning and priority setting and provided a strong system for the measurement of performance.

Bibliometrics

Bibliometric analysis can assist the assessment of S&T excellence by providing quantitative measures of published research outputs such as journal articles, books, citations, and patents. Traditionally, scientists are expected to publish their work not only to facilitate the dissemination of new ideas but as a means of maintaining scientific excellence within the scientific community through continuous self-evaluation and correction. As Stephen Cole relates, "because scientists know that their work can and will be replicated, they are motivated to do the work carefully and are inhibited from publishing sloppy or outright fraudulent results" (Cole 1992).

Publication counts have long been used as an indicator of scientific productivity. They are objective, relatively easy and inexpensive to track, and independently verifiable. However, publications vary greatly in their relative significance. To assess the quality of publications, evaluators often look at whether publications appear in high-profile, peer-reviewed journals. Another indicator of the impact of a publication is the importance placed on it by other scientists, as indicated by their citing the work in their own publications. Thus, citation analysis has become a useful tool to assess excellence.

A major disadvantage of bibliometric analysis is its limited usefulness in making comparisons across various disciplines, sectors, and countries. This is due to the different cultures that exist with respect to the norms of authorship and citation, pressure or incentives to publish, or access to journals. Another concern is that too much emphasis on publication and citation counts can inappropriately modify researcher behaviour to emphasize those activities that will increase counts, perhaps at the expense of the other pillars of excellence (quality, relevance, and ethics).

As part of its examination, the CSTA commissioned a bibliometric study of the Canadian government's scientific output. The report analyses government publications in the most prominent peer-reviewed journals. The authors make the important point that much valuable work of government S&T is actually published in other types of highly specialized journals or various official publications, generally referred to as "gray literature" (e.g. proceedings from conferences and symposia, in-house research reports) (Observatoire des sciences et technologie 2000). Thus, bibliometrics provide only a partial measure of government S&T output. In addition, bibliometrics cannot be applied to much of federal S&T that falls into the categories of technology development and related scientific activity.

Prizes and Recognition

Another important indicator of S&T excellence is the recognition of one's scientific peers. A quantitative metric is the number of prestigious prizes awarded to researchers within an organization. Other forms of recognition include memberships in learned societies, participation on national or international expert panels, journal editorships, invitations to make presentations, queries and requests from client and stakeholder groups, and attention from the popular media.

Patents, Licensing, and Technology Transfer

Counting numbers of patents, licenses, invention-disclosures, etc., is a measure of excellence that can be applied to areas of technology development. Indicators of quality and broader impacts include the amount of royalties from licences, the sales of new products and services, etc. The amount of technology transferred to industry and the degree to which industry partners are willing to engage in cooperative R&D projects and cost-sharing are other indicators of excellence in government S&T.

Benchmarking

Benchmarking is becoming a popular approach to help organizations determine how their programs and S&T compare against world standards of excellence in similar work settings. Benchmarking is most commonly defined as the process of continuously measuring and comparing an organization, product or process against leaders anywhere in the world to gain information that will help the organization take action to improve its performance (Government of Canada, *Business Diagnostic and Benchmarking Tools*). Benchmarking is based on discovering the specific practices responsible for high performance, understanding how these practices work, and adapting and applying these "best practices" to the organization.

Assessments are typically made by a panel of national and international experts from academe, industry, and government in the relevant and related fields. Benchmarking can provide a timely and broadly accurate "snapshot" based on the available quantitative and qualitative data. It provides an independent, disinterested evaluation of S&T performance, typically at higher levels of focus (e.g. programs, research fields or disciplines, national systems of innovation).

Benchmarking is applied to all types of S&T functions, including basic and applied research, development, and the development of S&T human capital. It can also be particularly useful in assessing related scientific activity, such as testing and monitoring, which is less amenable to other mechanisms such as bibliometrics or peer review. According to the US National Academy of Science,

> . . . benchmarking can probably only detect important changes in quality, relevance, and leadership in

fields when conducted at significant intervals, say of three to five years. Annual benchmarking is not likely to detect changes (Schulz 2000).

Canada — Canada Institute for Scientific and Technical Information

In 1999, the Canada Institute for Scientific and Technical Information conducted a comprehensive benchmarking study that compared its strategic and management practices, policies, partnerships, client relations, marketing activities, and impacts against nine different organizations in the US, the UK, Australia, and Taiwan. The results of this study provided senior management with feedback on best practices and lessons learned.

Satisfaction and Impact Analysis

The 1996 federal S&T strategy stated that "where it makes sense to do so, the government intends to put its intramural R&D activities to a market test in order to generate research that is relevant and has a high potential for yielding economic or social benefits." The strategy calls for science-based departments and agencies to use client-based advisory boards to assess the relevance of their S&T activities. Indicators of client or customer satisfaction with the outputs and relevance of government S&T can provide useful information to government managers regarding the perceived excellence of their departments' S&T activities. Examples of satisfaction measures include surveys of the satisfaction of clients, users, or stakeholders; public opinion polling; return clients and partners; and a willingness to share costs.

United States — Army Research Laboratory

To measure how well it was serving its customers, the US Army Research Laboratory instituted a targeted survey process. Clients are now sent a brief survey card to gauge their satisfaction with the lab's productivity and the relevance of the completed product to the customers' needs. Any completed survey that is returned with poor scores or negative comments is immediately sent to the senior-level directorate head responsible for the project. Within five working days, the directorate head must contact the client to inquire about the nature of the problem and steps that can be taken to address the problem. This response system, along with a goal for the directorate's aggregate score, is placed in each directorate head's performance standards.

Canada — Natural Resources Canada

Every three to four years, the Canadian Forest Service (CFS) conducts both informal consultations with clients and systematic surveys of clients. The results of these surveys provide information on the perceived relevance of their work and future directions, and feed into the CFS's strategic plan.

Economic Rates of Return

Beyond the immediate satisfaction of clients and users, government must be able to demonstrate that its S&T efforts are having a positive impact in economic, social, or environmental terms. Economists have developed various methods to estimate the economic benefits of research such as cost-benefit analysis, technological balance of payments, consumer surplus, and rates of return. Rate-of-return analyses are especially popular in that they provide a quantitative measure of economic benefit that is well understood by policy makers. Rates of return are most useful in assessing the benefits of research at higher levels of focus, rather than at the program or project level (COSEPUP 1999).

Canada — Agriculture and Agri-Food Canada

S&T management at Agriculture and Agri-Food Canada is guided by the department's Study Management System. This system is designed to aid in priorizing projects and in optimizing investments in research.

Assessments are based on the premise that research projects should be ranked according to their potential to return economic, environmental, social, and other benefits. The results of the analysis produce a matrix that highlights the relative overall benefit of each study, a relative estimate of the return to Canada per unit of investment, and where appropriate an economic analysis that estimates a study's relative value in dollar terms.

There are several disadvantages to rate-of-return analyses. With respect to government S&T, the principal disadvantage is that they place heavy emphasis on private financial benefits. Social benefits, often the target of government S&T, are more difficult to quantify and thus may be undervalued in economic rates of return. Analyses of the social rates of return on research investments are still in their infancy.

Another problem is that it is much easier for economists to measure rates of return in the aggregate or to determine the "average effect." It is much more difficult to measure impacts "at the margin," which are the benefits that flow from an additional dollar invested. These marginal rates of return would be of more interest to policy makers facing tough budgetary decisions.

Finally, there is the problem of when to measure. With a potentially long period between R&D and any economic benefits, the rate-of-return mechanism is best used for longer term evaluations of excellence.

Retrospective Analyses: Case Studies and Tracer Studies

Retrospective analyses of the developments flowing from the conduct of S&T can provide a rich understanding of the discovery process and a broad indicator of excellence. Tracer studies attempt to trace the history and impacts of federal investments in S&T. Typically, they explore whether government S&T investments have contributed to economic development by spawning new commercial products, technological processes, or entire new

industries. Case studies can be used to highlight the effects of various institutional, organizational, and technical factors on the conduct of S&T. They can also identify important outcomes of the research process that are not purely intellectual, such as collaboration among researchers or the training of young researchers (COSEPUP 1999). Such "success stories" are useful in communicating how government S&T produces benefits for the public. Case studies can be expensive to conduct, however, and their validity depends on the independence, investigative skills, and knowledge of the analyst.

For both case and tracer studies, long time-lags add to the problem of attribution where it becomes increasingly difficult to determine what impact the government's initial investment played in the eventual outcome. Also, funding decisions often need to be made before such retrospective analyses can be initiated or completed. Due to these problems, retrospective impact analyses have limited value as short-term management and evaluation tools, but can be useful as long-term measures of S&T excellence and in communicating the benefits of government S&T to the public. They are most often used at the government-program or field/discipline level to assess and demonstrate, for example, the impact of government support of genomics or materials science.

All satisfaction and impact analyses address the quality and relevance of S&T, i.e., it must be good and useful if it produces a benefit to stakeholders and the public. Case studies and success stories can be structured to also assess transparency, openness, and ethics.

A Balanced Approach

Government must address some key challenges in employing these mechanisms for ensuring S&T excellence. First, it must appropriately balance the desire to conduct excellent S&T with the need to evaluate and demonstrate its excellence. Assessment mechanisms must be cost-effective, time-efficient, and not create an unnecessary evaluation burden for researchers.

Second, assessment frameworks must guard against unintended consequences. Too much emphasis on any single measure (especially quantitative measures) may lead to a skewing of behaviour toward the production of immediate outputs (e.g. publications) at the expense of the desired longer-term policy outcomes. The fact that no one indicator or measure is likely to be adequate suggests the need for a balanced approach. At the same time, the importance of avoiding an evaluation burden suggests the need to choose "a vital few" measures. The key is for government to be able to ensure and demonstrate the excellence of its S&T.

In addition, the extent to which measures of S&T excellence are employed should be guided by the scale of the program or project and the level of complexity of the

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issue. The following levels of complexity suggest differing intensities of measurement to ensure and demonstrate S&T excellence:

Low complexity — Where the S&T supports non-controversial, relatively routine functions of government, and where the science is mature and relatively stable.

Medium complexity — Where the S&T informs relatively low-profile issues but may involve some potential controversy or a medium level of uncertainty in the science, or both.

High complexity — Where the S&T informs issues or decisions that are controversial, high-profile, high-risk, large-scale, or involve a high level of scientific uncertainty (Smith 2001).

The greater the complexity and potential controversy, the greater the need for government to invest greater effort to ensure and demonstrate S&T excellence.

Appendix II: Communications

Public confidence is elusive and fragile. It is influenced by the incidence of crises and opportunities lost. It is therefore not enough to communicate the results, impacts, and excellence of federal S&T. The communications challenge for government is to demonstrate to the public that S&T has enhanced the government's ability to respond to challenges and capitalize on the opportunities afforded by S&T. In addition, by widening channels of communication between government, industry, academe, and the public, the government can better translate scientific and technological advances in support of a strong national system of innovation and improved quality of life for Canadians.

Developing a Strategy

Among S&T personnel, there are often well-established means of communicating research such as journals, other publications, and conferences. However, there are other audiences, including industry, stakeholder groups, departmental policy and decision makers, and the lay public that are interested in the results, impacts, and excellence of government S&T. Developing an S&T communications strategy or plan that understands and anticipates the information needs of these groups is essential. Such a plan should build on the relationships that exist and encourage partnership-based approaches that stimulate transparency and openness in government S&T. Communication plans should also be incorporated in departmental, program, or project level S&T strategies to strive for excellence.

New Zealand — Department of Conservation

The integration of communication activities with the development and use of government S&T is an emerging focus at the New Zealand Department of Conservation, where a major review has been launched to explore and strengthen communication of research findings. Also, the department is tracking public attitudes on major science issues and working to improve science communications as part of its efforts to realign its science research plan with its strategic business plan.

Audience

Successful communication requires identifying and understanding the needs of the audience. There are a number of audiences for information regarding government S&T, both externally and within the government. They include members of the public, stakeholders and clients, policy makers, scientists and science managers, the scientific community, ministers, Members of Parliament, and Senators. It is important that each of these audiences be aware of the nature and calibre of the S&T conducted, as well as how it is used.

Communications Products

There is a wide spectrum of communications products and media that can be targeted to the various audiences. All forms of communication should take into consideration the level of scientific knowledge of the intended audience, as well as the purpose of the communication. For instance, publication in scientific journals not only disseminates the results of government S&T to the scientific community, but also helps to ensure its excellence. Other channels of communication that can be used include Web sites, reports, newsletters, press releases and public fora.

Sweden — Environmental Protection Agency

At the Swedish Environmental Protection Agency (EPA), scientific committees are responsible for funding research. The EPA stipulates that supported researchers must provide two reports:

- an overall review of the science conducted, and
- a "popular" summary for a non-scientific audience, summarizing the potential and role of the scientific information produced.

While disseminating timely, accurate, and relevant S&T information is crucial, it is also important to consider how communications strategies and media can be used to encourage excellence through feedback and openness. Workshops, presentations, town hall fora, and external advisory boards are mechanisms that can be used to provide information and engage the public and stakeholders in discussion of federal S&T issues. Internal communication tools within the federal government can include departmental intranet sites, internal publications, networks, and meetings.

Canada — Environment Canada

A number of federal science-based departments and agencies have developed communications strategies and plans. Environment Canada has produced a Science Communications Framework that highlights the following best practices for science communications:

- **Technical and popular publications** — Publication in the scientific literature and presentations at technical conferences generate professional credibility.
- **Issue life-cycle analysis and issue forecasting** — Both yield vital input to science communication planning.
- **Media relations** — Relationships between departmental scientists, communications and policy staffs, and journalists continue to be an important aspect of science communications.
- **Coordination** — Messages from departmental officials responsible for science, policy, regulations, and communications must be coordinated to ensure strategic and consistent science communications that are linked to policy actions and ministerial decisions.
- **Cooperation with citizens and stakeholders** — Scientists and citizens participating in cooperative community-based science programs have developed collaborative means for communicating science.

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