KPMG Consulting

Final Report

MEASURING AND ENSURING EXCELLENCE IN GOVERNMENT SCIENCE AND TECHNOLOGY: CANADIAN PRACTICES

Prepared for

Council of Science and
Technology Advisors

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Executive Summary

This report examines the current practices employed by Canadian government science-based departments and agencies (SBDAs) to measure and ensure excellence in the S&T performed by their research organizations. The term "excellence" in this study is being used broadly to include both quality (scientific merit) and relevance (usefulness and impact) of S&T work. The study approach followed was to find out how excellence is "ensured" (i.e., to identify management practices and other mechanisms in place to achieve excellence), and how it is "measured" (i.e., to identify measurement methods for assessing the extent of excellence). The study approach presumes that there are prerequisites to achieving excellence in government S&T organizations. These prerequisites include related mechanisms for ensuring excellence involving: leadership, people, management practices, and resources. Only the first three of these prerequisites were examined in this study. The study also looked for measurement methods used at all stages of the S&T process—i.e., from predictive assessments at the pre-project and program planning stage, through to post-project and program follow-up assessments. The focus was on in-house government S&T work (i.e., not including contracted out, or R&D grants and contributions). Six federal government departments, nine research institutes and establishments, and three provincial research organizations were consulted for this study. These organizations are listed in the report (Chapter 1).

Ensuring Excellence

A. Leadership

Strategic and business planning—Based on the interviews conducted for this study, there has been a great improvement in government leadership in S&T strategic and business planning during the past five years. Best practices in leadership that have been observed involve a work environment which emphasizes project-oriented and results-based priority setting processes that engage the scientists and managers of S&T projects, and that clearly respond to the demands of stakeholders and clients (within and without the research establishment). In addition, good S&T leadership in SBDAs is deemed to be a best practice if it provides clear prioritization and distinction between what is considered to be "mission-oriented" R&D versus "non-mission".

Program and project delivery—Programs and projects cannot be successfully delivered without appropriate methods and processes in place that deal with questions of scope, purpose, criteria for ensuring relevance and organization. These are all precursors to measurement of excellence in government S&T work. All organizations consulted appear to have increased their capacity for measuring excellence of program and project delivery processes. They have done this by integrating ongoing methods for measuring performance as part of their overall program and project delivery systems. Modern management practices are being integrated into the program and project delivery process. New government-wide internal audit and evaluation policies are being developed by Treasury Board Secretariat that will contribute to the integration of modern management practices in SBDAs.

Stakeholder and client involvement—Generally, within SBDAs, there does not appear to be any structured or formal mechanism/guideline for clearly defining "stakeholders and clients" of S&T government organizations. The terms "the public", "consumers", "industry", "the private sector", "academia", "partners", "experts", "regulators", "non-government organizations", etc., are often used by scientists and government officials to refer to stakeholders or clients, in a fairly general manner. Notwithstanding, SBDAs get lots of advice from all sources on who the relevant players are (or should be) for scientific initiatives and programs. There are lots of effective advisory groups with various representations and mandates and at different interface levels in federal government organizations (e.g., technical, management, executive, and Cabinet levels). This is one area of government S&T activities that has experienced a great improvement over the past decade or so, particularly in establishing formalized procedures and structures for interactions with stakeholders and clients, and for getting expert advice on S&T initiatives.

B. People

Identifying and developing core competencies—In the SBDAs examined for this study, the identification of core competencies required is generally built into the formal planning process. The experience of SBDAs in developing and applying core competency criteria has grown over the past decade or so. Several federal government departments now have detailed documentation (guidelines and definitions of core competency requirements). These organizations also occasionally do gap analysis to determine their recruiting requirements over their planning horizons.

Recruiting and retaining qualified people—Generally, a recruiting best practice for scientists means that an organization is able to identify, attract and hire outstanding candidates by understanding and adapting effective and innovative practices that top organizations (in government, academia, or the private sector) are already using. A significant weakness in recruiting and retaining qualified people, consistently raised by scientists and managers within the SBDAs, is that the S&T groups and laboratories within government are constrained by having to play by the same rules of other government human resources systems. Scientists and science managers are subject to the same policies that apply across the government. For example, salary freezes a few years ago had a big effect on job attrition. The process of recruiting highly qualified personnel for S&T is much more strategic and long term in nature, and requires a significant investment of time and effort to recover from down periods, as experienced during the past decade or so. It was suggested that the old job classification system for scientists was antiquated, and this did not help the recruiting/retention issue. Notwithstanding, it was also suggested that the new Universal Classification System (UCS) does not sufficiently take into account issues of recruitment and retention of scientists in a highly competitive science and technology job market (e.g., salaries, professional training, and flexible work guidelines).

C. S&T Management

Management practices—As we consider the strengths of the federal SBDAs in ensuring excellence, one of the features of the current systems that are in place for managing science and technology programs and projects is the combination of "top-down" mission-oriented management with "bottom-up" investigator-initiated research projects. Increasingly over the past five-years or so (in the post "program-review" era) this has become more of a norm within the SBDAs examined in this study. The combination of these two approaches has created a powerful research and development planning and prioritization environment that is seen as one of the strengths of the emerging environment of government S&T.

Collaboration and leverage of resources—Co-location or clustering of government scientists with other users/clients (internal or external) is seen as a good practice for government-based S&T. For example, there are benefits to having the program and regulatory staff who deliver government program services—particularly Related Scientific Activities (RSA) and S&T—co-located with the scientists. One of the benefits, as suggested by some of those interviewed in this study, is that this improves the planning process, keeping SBDAs focused on mandated priorities, and preventing "mission-drift". Another benefit of co-location (or clustering) is that by having scientists in close proximity with users/clients, a dynamic and purposeful work environment evolves that is more creative. It should be noted, however, that this kind of co-location (or clustering) is not possible in all cases in geographical terms. There are many exceptions (such as hydrographic services, building and construction R&D, aerospace) in which co-location (clustering) may not be possible, in a physical sense.

Communicating results of government S&T—Communication of results represents the culmination of the work carried out within S&T government organizations, but it should also include sharing information on "work-in-progress" and strategic and operational data about the work. One of the objectives, generally, for communicating/disseminating information on results and activities is to achieve the highest degree of transparency with regards to government S&T activities. There is a consensus now within the SBDAs consulted that this transparency is a benefit to them, in that it is one mechanism for ensuring that excellence is achieved within government. Only in making what you do and how you do it available for scrutiny can you ensure that quality and relevance is achieved.

The communication or dissemination of government S&T takes on a variety of forms in SBDAs, and depends on the kind of science and technology being done—for example, it depends on whether the science is mission-oriented science involving R&D or RSA. This study has demonstrated that there are indeed many ways by which SBDAs communicate/disseminate the information about S&T activities, but that there is a paucity of research on the effectiveness of this communication/dissemination.

Measuring Excellence

When and how are quality and relevance measured?—Generally, within the SBDAs that were examined, at the "front-end" pre-program planning stage the focus is on assessing scientific merit and relevance of the work internally, within the department or agency. However, some external assessments are also made at this stage. At the "back-end" of the process, at program completion, there is much greater use of external assessments. Since "the proof of the pudding is in the eating", most of the measurement of excellence is done at program (or project) completion phases. Client satisfaction, relevance, socio-economic impacts, and research impacts on the scientific community are all measured with varying emphasis, but mostly at the program (project) completion phases. Much of this measurement is done in the context of program evaluations, reviews, or one-off case studies, bibliometric analyses, and scheduled performance reporting exercises.

Peer reviews—Peer review is still an important and necessary review procedure for the assessment of ongoing government research programs, even for research programs that have a fairly applied (i.e., industry-oriented) mandate. Canadian government reviews of S&T policy, from the Lortie Review in the late 1980s to the S&T Policy Review of the mid-1990s have consistently found that peer review is an important and necessary practice for Canadian S&T departments and agencies. When possible, peer reviews are integrated with other complimentary reviews such as program evaluation. The advantage of integrating peer review with other reviews, such as program evaluation and audit, is that it places the issue of scientific achievement in the context of other issues such as program legitimacy, client relevance, and the adequacy of the management environment. This is necessary in all the departments that we studied because they are all mission-driven.

International benchmarking—International benchmarking has become an increasingly used technique to measure and compare performance and results of scientific laboratories and science-based institutions. International benchmarking studies provide an opportunity to assess one country or region's leadership status in research and development against world standards of excellence. Though this approach has been *ad hoc* within federal SBDAs, it does seem to be gaining increased recognition and acceptance (e.g., at NRC).

Bibliometric methods—The most basic literature-based technique for measuring excellence is counting publications. The bibliometric method aggregates publications by individual, group or institution. Publication counts constitute a key (though partial) element in evaluations and their use was found to be quite prevalent in Canadian government SBDAs over the past decade. While relatively easy to count, it is a harder task to determine the significance of publications, especially if the questions of quality and impacts are involved. Nonetheless, publication counts can be good indicators of excellence – for example, if tied to the peer review element in publication by examining the numbers of accepted articles in the three top journals in a particular field.

Given the limitations of publication counts, evaluative bibliometrics has also traditionally relied on citation analysis, to determine, for example, the degree of relevance of the work to the research community. This technique rests upon the fact that scientists cite earlier publications because the work contained in them is, in some way, relevant to their own. While publications counts and citation analysis were seen to be used to supplement peer reviews and other measurement techniques within government SBDAs, other bibliometric methods such as journal impact factor analysis, co-citation analysis, and co-authorship analysis are much less frequently used.

Advisory committees—The use of advisory committees has become very prevalent in Canadian SBDAs. At all levels of management, science and technology advisory committees have been involved in shaping government programs and policies. Advisory councils provide SBDAs with technical and non-technical advice on a wide spectrum of issues involving matters such as technology transfer, risk management, recruiting policies, governance, resource prioritization, international trends in science, sustainable development, ethics, communications, and public concerns. There are also advisory committees that have provided advice on cross-government S&T issues and strategies concerning, for example, climate change, biotechnology, geomatics, northern science, and space.

As a method to ensure excellence in government S&T (relevance and quality), advisory committees are usually made up of members who are expert scientists, stakeholders, clients, and/or users of government products and services. During the 1990s, as described above, federal government SBDAs have increasingly used advisory committees as a regular feature of their management systems, with a focus on improving the relevance and quality of S&T.

Amount of measurement activity—A study of the measurement activities of federal SBDAs was carried out in 1993.[1] That study focused primarily on the measurement of relevance and impacts, but it also dealt with the measurement of quality. In comparing the findings from the current study with the 1993 study, we found that, in general, the amount and quality of measurement activity within federal SBDAs has increased over the past seven years. This includes the increased use of approaches such as: user and client surveys, socio-economic impacts analysis, cost-benefit analysis, and quantitative indicators/benchmarks for measuring accuracy and consistency of results (the latter having particular significance for RSA activities). Those departments that were the most active in 1993 are still the most active, but they have broadened the scope of their measurement activities and improved their methodologies—to include, for example, measurement of the indirect impacts of research. Those departments that were doing very little in 1993 have now embarked on the development of more systematized measurement policies—for example, through the development of guidelines on using performance measurement and the conduct of pilot projects.

[1] *Methods for Assessing the Socio-Economic Impacts of Government S&T*, the ARA Consulting Group, May 1993. See, in particular, Appendix B, which summarizes the practices of six federal SBDAs.

Use of key indicators—The use of department-wide key indicators to complement program or project-specific indicators of excellence is an area in which SBDAs are currently evolving. Some of the key indicators being considered are in the following categories: expenditures on research and development; quantification of scientific activities; personnel working in science and technology; research output (e.g., publications, citations, patents); and selected economic impacts.

Other Findings

Key issues for ensuring excellence in SBDAs—There are of course many issues that were discussed on how to ensure excellence in SBDAs as presented in this report. However, the key issues that scientists and managers focused on, in the consultation process for this study, centre around the following themes:

- keeping the work current;
- the adequacy of S&T funding;
- making the place of work more desirable for researchers/scientists; and
- introducing more flexibility to allow researchers to participate in external research activities (e.g., joint projects with other scientists outside and inside government).

Adopting principles for measuring excellence—Some "principles" for measuring excellence can be identified as an outcome from the consultation process of this study as follows:

- In measuring excellence, the measurer should address relevant and significant questions.
- The method of measurement should be credible.
- Cost-justification should be taken into account when deciding on the method of measurement.
- The approach should not impinge on the actual delivery of the conduct and outcomes of the government S&T activities.
- More than one source of measurement increases credibility of the assessment (i.e., for credible assessment one needs multiple lines of evidence).
- Assessing the capacity and mechanisms available to SBDAs for achieving excellence is as important as measuring the results of S&T programs and projects.

A renewed interest in relevance—Finally, if there is a trend to be observed in the mechanisms and measures of excellence, that are present in government SBDAs in Canada, it is that relevance is now expected to be demonstrated in a very tangible way as part of the S&T management process. It is not always possible to do this in quantitative terms, but a case (a justification) for the research has to be made as part of the management and planning process. Ensuring relevance of S&T within a government SBDA is in part a matter of making appropriate decisions within a strategic and business planning framework that is linked to the mandate of the organization.

Government SBDAs in Canada have become very adept at producing strategic and business plans over the past few years. All the organizations reviewed for this study have articulate plans that identify S&T priorities over short and long timeframes. These plans do appear to provide clear directions towards relevant S&T programs and projects. The successful planning processes, however, appear to be the ones that have clearly articulated linkages between strategic requirements of stakeholders and clients (internal and external to government) with their individual work programs.

Provincial Organizations

The provincial organizations examined for this study all have a similar preoccupation with measuring and ensuring that excellence in S&T activities are achieved. Their strategic intent is to achieve success within the framework of their mandates and prescribed objectives. While they differ in what they do they are all committed to achieving good management practices that result in world class competitive advancement of S&T in Canada. InNOVAcorp facilitates the emergence, development, and intended success of science-based businesses through incubation services; the Centre de recherché industrielle du Quebec (CRIQ) provides specialized services in product testing and certification, standardization, and R&D; and Alberta Research Council (ARC) performs applied research and development, and provides expert advice and technical information to a diverse range of clients from small start-up firms to large multinational corporations, and government departments and agencies. Two of these organizations (CRIQ and ARC) use the "stage gate" approach to technology development. This approach is an iterative process that entails a thorough assessment at each "stage" before the "gate" opens to the next stage (i.e., from idea to project definition, from project definition to work plan, from work plan to implementation, and from implementation to evaluation). Officials in both CRIQ and ARC believe that "stage gate" is a successful approach that provides appropriate structure and a sound decision-making process for the S&T and technology development projects supported by these organizations.

The three provincial organizations examined in this study also make use of "bottom-up" and "top-down" planning processes, relying on the expertise of managers and scientists in developing S&T-related priorities for products and services, while ensuring alignment with provincial government strategic directions in S&T support. All three provincial organizations also pay close attention to the requirements of their clients by conducting surveys and gathering feedback through personal contact with stakeholders, and through advisory committees and governing boards that involve representation from an appropriate cross-section of interests.

Summary of Noteworthy Practices

The following summary is a consolidation of the considerable amount of information contained in this report on noteworthy government practices for ensuring and measuring excellence in S&T. These noteworthy practices have been identified as "best practices" through the consultation process on the basis of "self-assessments" indicated by SBDA scientists and managers.

Strategic and Business Planning

The National Water Research Institute (NWRI) planning process: At the NWRI, Canada's largest freshwater research establishment, priorities that evolve out of their planning process are very much integrated into the daily activities of their scientists and technicians. A set of *five key planning questions* is addressed for each project. Applying these five key planning questions to each project helps guide the selection of projects and ensures relevance and quality. [Page 10][2]

Health Canada (HC) system for prioritizing projects based on what looks like very sound criteria: At the Food Health Branch there are currently 32 project areas identified with clear criteria that meet the requirements of the Department's mission with respect to legislative obligations; risks to health; commitments to partners and clients; public health obligations; and effectiveness of program delivery. The projects are actually ranked from 1 to 32 in order of significance based on how they respond to these criteria. This system of prioritization results from a process that engages the researchers and champions of the S&T work. Scientists present their projects in a "symposium setting", which provides an opportunity for dialogue about the priorities and rationale of the research, including its merits and relevance. [Page 11]

National Research Council's (NRC's) strategic planning process at the research institute level: Here planning is based very heavily on the results of extensive peer review and evaluation exercises carried out every five years. [Pages 11-12]

The Scientific Priority Setting Process of Department of Fisheries and Oceans (DFO): This process starts off by identifying the DFO's science core activities that form the basis of the three-year work program that the department sets out for itself. A three-tier process focuses on key stages in the prioritization process: environmental scanning and setting strategic directions; setting program priorities; and developing scientific programs and projects. [Pages 13-14]

The use of "call letters" by the ADM of Agriculture and Agri-Food Canada, which require each branch to submit research proposals aligned with the goals of that branch. [Page 15]

The use of Program Object Level (POL) plans by the Energy Sector of NRCan: The advantage of POLs is that they require R&D projects to specify how the R&D results relate to the strategic directions of the Department. [Page 17]

The selective use of technology roadmaps at NRC: These are used for charting out long-term trends in technology development. One of the benefits of the process of developing technology roadmaps is that it leads to reduced risk through collaboration. [Pages 18-19]

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[2] References to page numbers after each noteworthy practice refers to the relevant page in the body of the report where more details are provided.

Program and Project Delivery

The use of a performance measurement framework by DFO: This performance measurement framework is used to assess S&T programs on an on-going basis. If indeed this is done on an ongoing basis at DFO the advantages, particularly for managing risks and monitoring impacts, are significant. [Pages 20-21]

NRC's performance framework for monitoring its programs on an on-going basis: Noteworthy is the fact that the performance information is not just used for external reporting, but is also used for internal management – e.g., for re-allocations of budgets between research institutes. Also noteworthy is the quality and comprehensiveness of the performance framework and the measures used. [Pages 21-22]

Stakeholder and Client Involvement

NRC, NRCan, DFO, AAFC, and EC all seem to have pretty good systems of advisory bodies made up of stakeholders and clients. Client feedback surveys and personal contacts with stakeholders appear to play a significant role in these departments, but this is not based on a systematic and regular schedule (except for the advisory bodies which do meet on a regular basis). [Page 23]

Identifying and Developing Core Competencies

The AAFC system for identifying required core competencies: This system appears to be comprehensive. AAFC aligns its core competencies with its core business as outlined in its broad five-year business plan. Lab-by-lab assessments are identified and alignments of competency requirements are done at individual project levels. [Page 29]

The NWRI practice for identifying individual competency assessment: This seems to be related mainly to individual competency assessments and personal traits required for recruitment. Competency assessments at NWRI are not just used for identifying gaps and hiring new staff, but also, most importantly, for personal development of current staff. [Pages 27-28]

Recruitment and Retention

Alberta Research Council's (ARC's) use of headhunters for recruitment: This suggests a more aggressive approach to seeking out highly qualified personnel. [Page 55]

Retention: Generally, all departments seek to create an environment conducive to world class scientific investigation, but none stood out as particularly good at this (with the possible exception of NWRI).

Management Practices

The Objective-Based Management System used at DFO is noteworthy: This system is particularly promising for applying risk management principles and for integrating management processes within the department. [Pages 38-39]

The Study Management System (SMS) used at the Saskatoon Research Centre: Resources are identified through conducting gap analyses for specific science projects. An SMS analysis involves tracking projects and activities and measuring returns from the Centre's R&D activities, identifying on an ongoing basis the Centre's R&D capacities and its ability to capture the benefits of its work. This system has also been applied in CSIRO in Australia. [Pages 40 and 41]

The Project Management Process (PMP) used by CANMET also seems noteworthy: This process seems particularly conducive for developing a continuous improvement work environment, and provides a basic recipe for monitoring and managing projects. [Page 40]

The "Stage Gate" approach of Alberta Research Centre and Centre de recherché industrielle du Quebec (CRIQ): This appears to be a successful approach that provides appropriate structure and a sound decision-making process for the S&T and technology development projects supported by these organizations. [Pages 53-56]

Collaboration and Leveraging of Resources

NRC's requirement for reporting on collaborations: This requirement reinforces the culture of collaboration (mainly with industry) in the research institutes. [Pages 40-41]

Communications

The requirement in the Study Management System (SMS) of AAFC's Saskatoon Research Centre that each lab have a technology transfer plan: This requirement involves most of the staff of the Saskatoon Research Centre, and the effectiveness of communications is assessed based on tangible results. SMS requires that the goals for communications and technology transfer be laid out clearly, and that they be measurable. [Page 48]

General Measurement System

NRC's comprehensive system (Exhibit 3-2) is clearly a best practice: The use of multiple lines of evidence, including peer reviews, benchmarking, socio-economic impact assessments, and surveys, provides a complete system for assessing quality and relevance of S&T.

AAFC's comprehensive measurement system (Exhibit 3-3): AAFC also has a very comprehensive measurement system that includes peer reviews, performance benchmarking, bibliometric methods, expert committees, and measures of impacts and return on investment indicators.

Peer Reviews

NRC's peer review process: This is a very comprehensive package and is integrated with program evaluations. Also noteworthy is that NRC benchmarked their peer review practices with other similar organizations around the world. [Page 64]

DFO also makes extensive use of peer review committees: This seems to be the case particularly for its Atlantic and Arctic fisheries programs.

Benchmarking

NRC benchmarking studies: Noteworthy is the fact that NRC's Council has mandated performance benchmarking (comparisons of quality of research, impacts of research, management practices, program delivery, etc.) as a required part of all program evaluations.

Bibliometric Methods

Nothing noteworthy to highlight here other than various bibliometric studies have been conducted in SBDAs over the past decade, to quantify published output from government S&T organizations. The impact of these studies on the quality of S&T is not clear, but they do provide useful statistics that complement other measurement methods.

Other Methods

Client surveys are used by most departments, often as a part of program evaluations of S&T programs.

Socio-economic impact assessments and benefit-cost analysis are being increasingly used across government departments. They are extensively used at AAFC and NRC, and somewhat at NRCan.

I Introduction

The federal government's Council of Science and Technology Advisors (CSTA) was established in May 1998, to provide the Cabinet Committee on Economic Union (CCEU) with external expert advice on internal federal government science and technology (S&T) issues that require strategic attention. This report is one of a series commissioned by CSTA to describe government practices to measure and ensure excellence in science and technology.[3]

1.1 Objective

The CSTA has recently been asked by the CCEU to examine the issue of excellence in federally performed S&T. As part of this process KPMG Consulting was contracted by the CSTA to "examine the current practices employed by key [Canadian] federal science-based departments and agencies [SBDAs] and provincial research organizations to measure and ensure excellence in the S&T performed by their research organizations".

1.2 Background

The 1996 Canadian Federal Government S&T Strategy, *Science and Technology for the New Century*, recognized the importance of "scientific excellence" to ensuring the effectiveness of federally performed S&T. The Auditor General of Canada, as part of his November 1999 report, stressed the importance of good management for federal S&T by describing the "Attributes of Well-Managed Research Organizations".[4]

A key message in the CSTA's report *Science Advice for Government Effectiveness (SAGE)* is that the government must have the capacity to access and/or deliver excellent science as the basis for government decision-making. The *SAGE* report called for science advisory processes that include "due diligence procedures for assuring quality and reliability,

[3] Some noteworthy government practices are identified in this report as "best practices", but these have not been verified as such except to say that, through the consultation process, these practices have been deemed noteworthy on the basis of "self-assessments" indicated by SBDA scientists and managers.

[4] Chapter 22 of *Report of the Auditor General of Canada*, Ottawa, November 1999. See reference to the "attributes of well-managed research organizations" (i.e., leadership, people, management) on the next page.

including scientific peer review".[5] CSTA's second report, *Building Excellence in Science and Technology (BEST)*, identified "excellence" as one of the three principles[6] that are key to ensuring that the government remains a credible contributor to the national innovation system and fulfills its responsibilities to Canadians. According to the *BEST* report, government S&T must be of the highest quality, must demonstrate that it meets or exceeds international standards for S&T excellence, and must deliver social or industrial relevance.[7] At the same time, the *BEST* report acknowledged that criteria for excellence of government S&T may need to be different than those for university or industry research, and may require a range of different measurement techniques and processes.

In the November 1999 *Report of the Auditor General of Canada* (referred to above) well-managed research organizations were found to share a number of attributes grouped under four themes as follows:

- They **show leadership**, aligning themselves with the needs of those who depend on them for results, achieving buy-in of the vision, values and goals, and undertaking the right research at the right time and at the right investment.

- They **focus on people**, recruiting, developing and retaining the right mix of talent in a positive and supportive environment.

- They **manage research** to ensure excellence and results at the right time and at the right investment.

- They strive for a high level of **organizational performance**, being widely known and respected, and meeting the needs of those who depend on them for results.[8]

To ensure excellence in government S&T, these attributes can and should be assessed on an ongoing basis—i.e., through mechanisms that assess an organization's management practices, people, and physical and financial resources. [9]

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[5] *Science Advice for Government Effectiveness (SAGE)*, a report of the Council of Science and Technology Advisors, May 5, 1999, page 5.

[6] The other two principles are "alignment" and "linkages"—see *Building Excellence in Science and Technology (BEST): The Federal Role in Performing Science and Technology*, a report of the Council of Science and Technology Advisors, Ottawa, 1999, pages 24-25.

[7] *Ibid.*, page 25.

[8] Chapter 22, *Report of the Auditor General of Canada,* November 1999.

[9] It should also be noted here that the recent Treasury Board Secretariat report *Results for Canadians: A Management Framework for the Government of Canada*, 2000, has emphasized similar requirements (or attributes) for good government including: managing for results and providing a coherent framework for

1.3 Approach

The term "excellence" in this study is being used broadly to include both **quality** (scientific merit) and **relevance** (usefulness and impact). This broad definition of excellence is consistent with the focus on excellence as described in the *BEST* report. The study approach followed here is to find out how excellence is "ensured" (i.e., to identify management practices and other mechanisms in place to achieve excellence), and how it is "measured" (i.e., to identify measurement methods for assessing the extent of excellence). With regard to the latter (measurement methods), this study looked for methods used at all stages of the S&T process—i.e., from predictive assessments at the pre-project and program planning stage, through to post-project and program follow-up assessments.

Exhibit 1-1 provides an illustration of the research framework set-up for this study. Segments of Exhibit 1-1 are numbered for ease of reference.

Mechanisms for Ensuring Excellence:

The study approach presumes that there is a set of **prerequisites to achieving excellence** in federal-based S&T organizations (reference #1 in Exhibit 1-1). These prerequisites (and related mechanisms for ensuring excellence) involve the following activities and resources (reference #2 in Exhibit 1-1).

Leadership

- methods for setting overall organization-wide priorities based on mission, vision, client needs, future S&T priorities, challenges and opportunities;
- involvement of employees in both strategic planning (e.g., setting overall priorities) and operational planning (for S&T projects and programs);
- methods for developing program plan(s) – criteria used to ensure relevance and relationship to overall priorities;
- extent to which client groups and stakeholders have been clearly identified and methods for doing this; and
- methods of identifying needs of client groups and stakeholders, and approaches for incorporating these in the planning process.

People

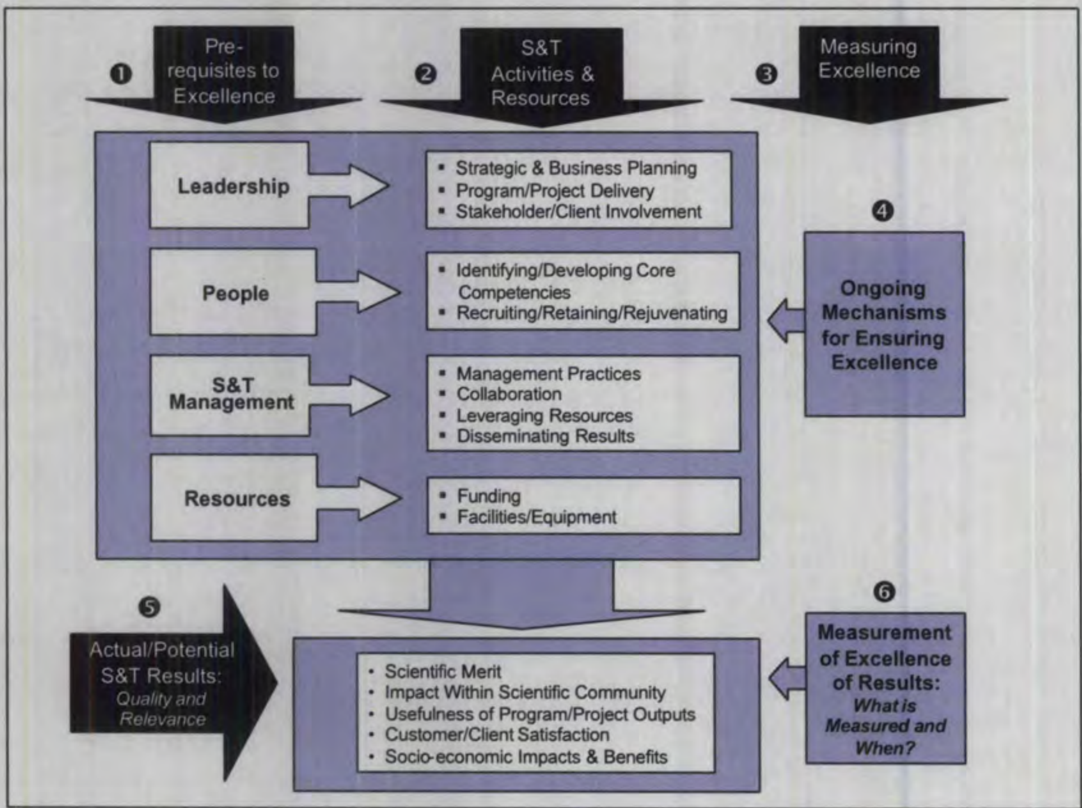
- existence of a system for identifying key core competencies in line with current and future needs and S&T priorities; and
- existence of recruitment, retention and rejuvenation management practices that are aligned with core competency requirements.

S&T Management

management in the Government of Canada. The aim is to modernize government management, including leadership, people, and management practices.

- management mechanisms used for ensuring the prerequisites to excellence are in place (i.e., qualified people, appropriate equipment and facilities, adequate supporting resources) to embark on S&T projects and programs;
- mechanisms used for ongoing management of S&T projects and programs – for monitoring progress and ensuring adherence to budget, schedule, quality, and continued relevance;
- methods used to ensure appropriate research collaboration and leveraging of resources; and
- methods used to ensure effective communication of S&T outputs (e.g., published reports, online dissemination of information, formal and informal networking events).

Exhibit 1-1: Research Framework



Resources[10]

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[10] While "resources" are included in the description of mechanisms and prerequisites for ensuring excellence, this was not an area that was investigated during the consultations with scientists and managers in SBDAs. The research team did not specifically ask questions about the adequacy of resources, nor systematically gather information about issues such as "rust out" of equipment and facilities.

- funding mechanisms (e.g., cost-recovery, government appropriations, partnership arrangements, contributions in-kind); and
- facilities and equipment (access to state-of-the-art facilities and equipment which frequently define the capabilities of an organization to achieve excellence).

The research framework presented in Exhibit 1-1 also presumes that the S&T activities and resources that are required to achieve excellence need to be assessed on an ongoing basis (reference #4 in Exhibit 1-1), not just when the results are achieved. Ongoing mechanisms for ensuring excellence, as defined for the purpose of this report, involve assessing the capacity of the organization (including management practices, people, and physical infrastructure) to produce excellence.

Measurement of Excellence:

The study approach also involves identifying how selected government SBDAs measure excellence of results (actual and potential) (reference #5 in Exhibit 1-1), focusing on what is measured and when (#6). For example, scientific merit (an actual or potential result) could be measured during the pre-project planning stage, during project selection and initiation, as an ongoing project monitoring activity, or following project completion. The "measurement" of excellence, as discussed in this report, is therefore focused on measuring the results of S&T, as compared to the "mechanisms" for ensuring excellence, which are focused on measuring the effectiveness of the prerequisites for excellence (leadership, people, management, and resources).

To summarize, the research framework for this study focuses on *ex-ante* and *ongoing* mechanisms for ensuring excellence in S&T conducted, and *ex-post* methods for measuring excellence of the results of S&T.

1.4 Government SBDAs Examined

Government S&T is broadly defined in this study to include research and development (R&D) as well as related scientific activities (RSA). This study examined practices in six federal SBDAs involved in R&D and/or RSA activities as follows:

- Agriculture and Agri-Food Canada
- Environment Canada
- Fisheries and Oceans Canada
- Health Canada
- Natural Resources Canada
- National Research Council

The consultation approach for this study included getting an organization-wide perspective from senior management in the SBDAs listed above, as well as the perspectives of specific establishments from within these departments. Scientists and managers from the following establishments were consulted:

- Steacie Institute of Molecular Science (SIMS), NRC
- National Water Research Institute, EC
- Institute for Marine Biosciences, NRC
- Meteorological Services of Canada, EC[11]
- Saskatoon Research Centre, AAFC
- Canadian Hydrographic Service, DFO
- Nutrition Research Division, Food Directorate, HC
- CANMET Energy Technology Centre, NRCan
- Fisheries Research Branch, Canadian Stock Assessment Secretariat, DFO

In addition, the following provincial research organizations were consulted:

- Alberta Research Council
- Centre de recherche industrielles du Québec
- InNOVAcorp

The set of federal and provincial organizations and establishments listed above were picked for their diversity in terms of mandate, base of stakeholders/clients, industry context, and types of research programs and projects (e.g., basic, strategic, regulatory). Scientists, project and program managers, and senior executives in these organizations were consulted as part of this process. Relevant documents describing the S&T practices in these organizations were also reviewed.[12]

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[11] While senior management at Meteorological Services of Canada, Environment Canada, were interviewed for this study, it was not possible to schedule a meeting at the establishment level (e.g., Atmospheric Monitoring and Water Survey, in Downsview, Ontario) within the consultation timeframe of this study.

[12] The documents reviewed for this study are listed in Appendix A. The people interviewed are listed in Appendix B.

1.5 Focus on In-house Government S&T

In this study there is a distinction made between delivery mechanisms of different government S&T activities (i.e., in-house, contracted out, grants or contributions). The focus in this report is on in-house government S&T. Appendix C provides a brief description, for the interested reader, of the various ways in which government supports R&D.

II Mechanisms for Ensuring Excellence

This section of the report focuses on mechanisms used by SBDAs to ensure that excellence is present in these organizations. Of the four prerequisite areas for ensuring excellence described in Chapter I (leadership, people, management, and resources) only the first three are dealt with in this report. Funding, facilities and equipment (i.e., "resources") were not investigated during the consultation with scientists and managers in SBDAs. The research team did not specifically ask questions about the adequacy of resources, nor systematically gather information about issues such as "rust out" of equipment and facilities.

2.1 Leadership

An SBDA should be able to set its overall organization-wide priorities based on its mission, vision, client or stakeholder needs, and anticipated S&T challenges and opportunities. Involvement of staff in both strategic planning (e.g., setting priorities) and operational planning (planning of S&T programs and projects) demonstrates that leadership is present and that the organization is on track and relevant to its reasons for existence. Methods for developing program plan(s) – including criteria used to ensure that there is a relationship to overall priorities, to prevent "mission drift", need to be present.[13] The extent to which client groups and stakeholders have been clearly identified, and the extent to which their priorities have been incorporated in plans and planning processes, are important indicators of good leadership in making federal S&T organizations relevant.

2.1.1 Strategic and Business Planning

Ensuring relevance of S&T within a government SBDA is in part a matter of making appropriate decisions within a strategic and business planning framework that is linked to the mandate of the organization. Government SBDAs in Canada have become very adept at producing strategic and business plans over the past few years. All the organizations reviewed for this study have detailed plans that identify S&T priorities over short and long timeframes. These plans do appear to provide clear directions towards relevant S&T programs and projects. The successful planning processes, however, appear to be the ones that have clearly articulated linkages between strategic requirements of stakeholders and clients (internal and external to government) with their individual work programs. Those organizations able to convincingly build project

[13] One interviewee from the National Water Research Institute, Environment Canada, used the phrase "mission drift" when describing their approach to stay relevant – i.e., to prevent "mission drift" from happening.

priorities based on real and perceived needs of stakeholders and clients appear to have best practice planning processes in place.

The distinction needs to be made, however, that strategic plans are usually associated with broad government mission statements, which signal government-wide, or department-wide, priorities. The specific "business planning" process of a science-based establishment such as an R&D laboratory, on the other hand, provides the scientists and managers within these establishments an opportunity to translate strategic plans into specific projects and programs that define their S&T work within the broader strategic framework. It is clear that the scientists and S&T managers interviewed for this study make a clear distinction between strategic and business planning, and focus on relevant priorities in the course of their S&T work.

Environment Canada, National Water Research Institute: At the National Water Research Institute (NWRI), Canada's largest freshwater research establishment, priorities that evolve out of their planning process are very much integrated into the daily activities of their scientists and technicians. To ensure that there is no "mission drift" they have organized their establishment around twelve "projects". The planning process is structured around these projects. Each project is situated within a clear component of the Institute's mission, reflecting the Institute's priorities. Exhibit 2-1 lists each of the twelve projects as it fits within the mission components. The three components are: aquatic ecosystem protection research, aquatic ecosystem management research, and aquatic ecosystem impacts research.

A set of five *key planning questions* is addressed for each project. This process provides an ongoing mechanism for ensuring relevance of the S&T work. So what is the "best practice" for ensuring excellence at NWRI? The NWRI planning process requires that the following key characteristics of their "mission-oriented" research is achieved:

- a high percentage of targeted or directed research,
- an emphasis on setting priorities,
- a flexible structure to respond to changing priorities,
- a focus on results delivering knowledge needed to achieve the mission,
- an emphasis on communication of research, and
- a greater accountability for decisions linking research activities to projected needs, and for delivery of key research.

These goals for research at NWRI are achieved through the project planning process described above and by addressing the key questions within the context of each project.

The implementation of this simple yet effective framework is the best practice in ensuring that projects and business plans are relevant to the strategic goals of the organization.

Exhibit 2-1: Project Planning Best Practice

National Water Research Institute:
Project Planning Framework

Mission: *NWRI generates scientific knowledge through ecosystem-based research to support the development of sound government policies and programs, public decision-making, and early identification of environmental problems.*

Planning questions addressed for each project (to ensure relevance and quality):

1. What are the priority results that NWRI will achieve?
2. To what extent are existing NWRI resources currently directed towards these priority results?
3. What organization/operational changes are necessary to achieve these priority results?
4. How will the results be communicated and to whom?
5. What are the appropriate performance indicators for NWRI and how will the impacts of NWRI activities be assessed?

Projects:

Aquatic Ecosystem Protection Research
- Priority Substance Exposure
- Priority Substance Effects
- Atmospheric Contaminant Impacts
- Ecosystem Health Assessment

Aquatic Ecosystem Management Research
- Priority Substance Exposure
- Priority Substance Effects
- Atmospheric Contaminant Impacts
- Ecosystem Health Assessment

Aquatic Ecosystem Impacts Research
- Priority Substance Exposure
- Priority Substance Effects
- Atmospheric Contaminant Impacts
- Ecosystem Health Assessment

Health Canada, Nutrition Research Division: The planning process at the Nutrition Research Division (NRD), of the Health Products and Food Health Branch of Health Canada, like NWRI, is very much project and results-oriented. As a group, the NRD is focused on S&T work in three areas: macronutrients, micronutrients, and surveys. Research activities focus on ensuring that the Canadian food supply is safe of nutritional hazards and meets nutritional requirements. Surveillance activities provide important information on food consumption by Canadians. Planning processes for this

Division are very focused on these three areas of research, and particularly in defining appropriate projects to address their priorities.

The planning process of the NRD is in synch with the way the Health Products and Food Health Branch establishes its priorities. The Branch sets priorities around *core activities* that reflect its mandate including: policy development; setting standards; risk-benefit assessment; research; pre-market review; and surveillance. Currently, there are 32 project areas identified with clear criteria that meet the requirements of the Department's mission with respect to legislative obligations; risks to health; commitments to partners and clients; public health obligations; and effectiveness of program delivery. The projects are actually ranked from 1 to 32 in order of significance based on how they respond to these criteria. Project descriptions and priorities are documented and distributed throughout the branch, to scientists and S&T managers.

This system of prioritization results from a process that engages the researchers and champions of the S&T work. Scientists present their projects in a "symposium setting", which provides an opportunity for dialogue about the priorities and rationale of the research, including its merits and relevance. The proposed projects are rolled up into a Food Management Reporting System that is then reviewed and prioritized by management. Resources are allocated on the basis of these priorities. The Nutrition Research Division is working on seven of the 32 prioritized projects in the Health Products and Health Food Branch.

The best practice in this establishment is that the prioritization system appears to work effectively. Scientists report that the process provides an opportunity to set priorities in an interactive way that builds on the expertise of the scientists, allowing for "bottom-up" shaping of projects while addressing "top-down" strategic directions. The balanced interaction between S&T staff and management results in a robust and effective priority-setting process.[14]

National Research Council (NRC): NRC's approach to ensuring that the planning process is well integrated (tying mission and research programs with projects and activities) involves identifying a series of *critical success factors* that tie the whole system together.

These critical success factors cover all the key planning components (pre-requisites of excellence), including people, strategy, funding, relevance, and management. Examples of the related critical success factors are as follows:

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[14] It should be noted that the views and advice of stakeholders are also taken into account at various stages of the priority-setting process, at the strategic level and at the project development phases of the S&T work conducted.

- *People*— e.g., "provide opportunities for continuous training and development to meet the future needs of the program and those of its staff."

- *Strategy— e.g.,* "adopt a balanced portfolio approach to program planning and management."

- *Funding*— e.g., "support and enhance corporate efforts to position NRC as a valued partner, an excellent investment and the backbone of Canada's innovation infrastructure by demonstrating and communicating the value of NRC's research investment."

- *Relevance*— e.g., "create powerful technology groups in biotechnology, manufacturing technologies and information and telecommunication technologies with national impact on the development of a knowledge-based economy."

- *Management*— e.g., "support a framework requiring uniform and superior management practices across NRC including a sound communication process to share best practices about business portfolio strategy.

Several other critical success factors have been identified for each of the components indicated above. These factors contribute to the manifestation of leadership within NRC, and in keeping the organization on track with its prescribed strategic directions.

The NRC strategic planning process, which involves NRC's role in strengthening the innovation system in Canada, places a great deal of emphasis on regional clustering and working with regional clients and stakeholders.

NRC is currently involved in its next strategic planning exercise—*Vision 2006*. The various advisory boards, including the NRC Council itself, all have input into the strategic plan. NRC employees are also heavily involved in the planning process through *leadership forums*. The consensus appears to be that the high-level strategic planning process is effectively translated into operational project planning terms.

At the specific establishment (i.e., institutional) level, strategic plans at NRC are developed on the basis of a five-year cycle, following an audit, evaluation, and peer review of the institute. Employees, advisory boards (including the Council) are heavily involved in the preparation of these strategic plans.

There is a strong sense of strategic intent for the NRC organization as a whole. A good performance framework is now in place, which is lined up with the Vision strategic document, and which is now used at the institute, group and NRC-wide levels for measuring and reporting on progress toward objectives. New structures at NRC, such as the "Strategic Planning Network", are seen as a positive step to share success stories across institutes for refinement of the organization's performance framework, to better line up with NRC's overall strategic directions.

On the other hand, NRC is made up of a variety of Institutes that have different kinds of S&T research activities, from basic to highly applied work. For example, the Institute for Marine Biosciences (IMB) considers that leadership is achieved only through the excellence of the science it conducts, and its relevance as defined not by policy but by developing the science needed for products and services required by the market, and nurtured by the quality of the research. In this case, the measure of excellence and relevance appears to be determined by demand and not by government policy as such. In other NRC institutes, some research priorities may be defined by regulatory requirements (e.g., the National Building Code of the Institute for Research in Construction).

Department of Fisheries and Oceans (DFO): The Science Sector of DFO has developed its own business plan that starts off by identifying its *science core activities*. These core activities form the basis of the three-year work program that the department has set out for itself (2000-2003).[15] The Science Sector's Business Plan is very focused on ensuring that excellence is achieved and maintained within the department. The key components of the plan are very results-oriented and are all about achieving the strategic objectives of DFO. They centre on:

- institutionalization of a stronger communications culture in DFO,
- building core capacities,
- reducing less-critical programs and services and generating new efficiencies,
- integrating planning and performance measurements for the future,
- rejuvenating the workforce by focusing on organizational health, recruitment and retention, and continuous learning, and
- mandate renewal.

DFO has developed a proposed Scientific Priority Setting Process (SPSP), developed by the SPSP Working Group within DFO.[16] This SPSP process has the following objective:

> "To ensure that our science programs have maximum impact with the public and with decision-makers, and to focus our work according to what is truly important to our mandate, a comprehensive priority setting process will be developed and implemented. It will be used to guide the key program and human resource shifts needed to deliver on our mandate. Programs will be aligned on DFO and government priorities."

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[15] *Science Sector: Business Plan, 2000-2003*, Department of Fisheries and Oceans, May 24, 2000.

[16] *Proposed Framework for a Scientific Priority Setting Process (SPSP)*, prepared by the SPSP Working Group for the National Science Directors Committee, Department of Fisheries and Oceans (no date).

The priority setting process within DFO is developed on a *three-tier basis*. This three-tier system focuses on the following stages in the planning and prioritization process.

- Tier 1: Environmental Scanning and Setting Strategic Directions.
- Tier 2: Setting Program Priorities.
- Tier 3: Development of Scientific Programs/Projects.

In the first instance, priority setting must rely on a solid scan by DFO scientists and managers of internal and external drivers. These could be captured from multiple sources ranging from advisory bodies and conferences, to strategic documents, to the *Speech from the Throne*, to the proceedings of key scientific workshops. Key drivers influencing science must be identified from different sources on an ongoing basis.

Secondly, based on the strategic directions set up in Tier 1, program priorities are developed along with an assessment of components of the programs needing realignment. Much of the program development and realignment is carried out on a multi-year time scale, but the need for changes in priorities are reviewed annually considering program performance and new strategic directions in the context of the importance of completing existing programs.

Thirdly, the development of scientific programs and projects is the phase of the process focused on scientific excellence, tractability, and relevance of the programs and projects. Peer reviews are done to assess quality and relevance of work programs and projects. Proposals using external funds are carefully assessed during this peer review process.

Agriculture and Agri-Food Canada (AAFC): At AAFC, overall priorities are set by the combined influence of external stakeholders, Parliamentary influences (e.g., Standing Committee on AAFC), Ministerial and DM influences, and internal planning processes. The Research Branch Advisory Committee (RBAC), in particular, provides a focus for food and agricultural research to support competitiveness. More specifically, the role of RBAC is to:

- provide advice on food and agricultural research programs and priorities,
- help foster more effective technology development, application, and transfer to client groups,
- encourage private sector investment in agriculture R&D,
- evaluate the business plan of the Research Branch, advising of operational issues,
- advise on strategic research directions and help coordinate existing activities of the private sector, universities, and the provincial governments in research and technology development,
- foster communication between public sector researchers and industry.

Generally, AAFC sees its strategic and business planning system as a multi-layered system. Deputy Ministers allocate research resources to R&D to meet their respective departmental mandates and goals.

Consultation with stakeholders occurs through consultation with advisory groups/committees at all levels and special forums. The ADM (Research) issues "call letters" which spell-out work plans that indicate the R&D goals of each Branch within the department.

Research scientists identify promising areas of research, and often use peer and/or external expert reviews to examine the quality and relevance of their proposals. A scientific proposal is always weighed against management considerations, including the following factors:

- What is the probability of success?
- What is the payback for Canadians?
- What is the cost of pursuing a given line of research?

Overall, the priority setting process runs "both 'up' and 'down' inside the department, and 'in' and 'out' from the external environment".[17]

Another key emphasis in the planning process within AAFC, which links strategic objectives with business plans (projects and programs) is the complete involvement of scientific staff in the process. Scientific knowledge at the lab and individual scientist level is paramount to planning and operations at AAFC. The planning environment is very "business-oriented", as opposed to academic (although excellence is assumed and required). Scientists are involved in the preparation of the business-plans.

One of the weaknesses in the planning process at AAFC over the past five years, as pointed out during the consultations for this study, was the lack of consumer/environmental representation. More recently, however, this has changed. Representation on two boards advising AAFC is now well populated with different stakeholder groups. These two boards are the Canadian Agri-Food Research Council (CARC); and the Research Branch Advisory Committee (RBAC), which will be discussed again in section 2.1.3 below.

Exhibit 2-2 summarizes some of the highlights of how AAFC established its priorities based on mission, vision and values.

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[17] As stated by a senior management interviewee at AAFC.

Exhibit 2-2: Highlights of AAFC Organization-wide Priority Setting Practices

- Centre-based advisory committees
- CARC/ICAR expert committee system
- Workshops with collaborators/stakeholders, and other science-based organizations
- Consultations with industry.
- Centre management knowledge of the industry and of issues and opportunities.
- An emerging emergency such as a new pest, a health threat (e.g., pesticides in drinking water), or an environmental threat (e.g., greenhouse gases).
- ADM and DG call letters.
- Periodic in-depth reviews of issues.
- Mandated activities (e.g., regulatory mandate).
- Strategic planning retreats by Management.
- Strategic planning with management of collaborating organizations.
- Expert panels.
- Business and work plans (planning process and documentation).

Environment Canada (EC): The priorities of EC are set within the department's Management Framework document.[18] However, this document is now three years old and some of the drivers that EC responds to on an ongoing basis (legislation, international agreements, nationwide standards, and other regulatory obligations) play a big role in determining the department's current priorities.

The S&T Advisory Board reviews departmental papers on mission, vision, S&T priorities, etc., and provides their input regarding these. Note that the terms of reference of the Board require it to provide an external review and validation of the relevance of the Department R&D portfolio. However, the evaluation of the first three years of functioning of the Advisory Board, carried out earlier this year, found that the Board has not done this.

Natural Resources Canada (NRCan): Within the Energy Sector, at NRCan, there are two processes for planning and priority setting: top-down and bottom-up. The top-

[18] *Science and Technology Management Framework*, Environment Canada, November 1998.

down process involves input from NABEST,[19] at the level of the Energy Policy Group that develops the *Energy Policy Framework* (i.e., strategic plan). A companion document on energy policy for S&T and R&D is also created, called the "S&T Companion Document". This document outlines the strategic intents of all S&T investments. These two documents begin to cascade into actual workplans all the way to the laboratory level.

Interdepartmental commitments with respect to PERD are also primary sources of priorities setting. The Office of Energy Research and Development and CANMET jointly set the PERD priorities for NRCan, at the strategic and objectives-based levels. There are currently six strategies within the department: one each for oil and gas; transportation; buildings/communities; industry; electricity; and climate change. Specific directions are then identified (e.g., relating to emissions reductions or next generation vehicles), followed by specific objectives (e.g., relating to hydrocarbon fuels, or hydrogen powered vehicles). This kind of "top-down" process results in planning that ends up at the laboratory level.

The "bottom-up" process is more *ad hoc* in that program specifics are identified all the way to the "bench level", including contact with stakeholders (e.g., industrial energy R&D has its "own" consultation group). This process tends to be more objectives driven, and is accompanied by business-planning or operational processes to identify key outputs, accountabilities, reach, and delivery dates. The status of these "deliverables" are monitored semi-annually by Senior Management leading eventually to reporting in year-end status reports.

The backbone of the Energy Sector's planning and priority system is the Energy Priority Framework (EPF) that articulates the global energy policy upon which specific S&T programs and policy priorities are based. An "S&T Companion Document" (STCD) to the EPF identifies strategic intents, directions and Program Objective Level plans (POLs).[20] One of the Energy Sector's strengths, for program planning and delivery, is in the application of POLs. The POLs are directly linked to the strategic intents and strategic directions of the department. The rationale for each POL may be found within the "POL plan", along with R&D activities, and the results management framework, which includes outputs, outcomes and impacts (including performance measures).

Activities and resources, and expected outputs, outcomes and impacts are established using the POL planning process. Project-level deliverables are identified in divisional

[19] NABEST is NRCan's Advisory Board on Energy S&T. It is an industry led body that provides advice to the Minister of Natural Resources Canada on federal, non-nuclear energy science and technology and related programs and policies reflecting the needs and interests of the private sector and the priorities of the federal government.

[20] *Update on NRCan's Approach to Excellence: Energy Sector*, copy of briefing notes provided by NRCan official to KPMG study team.

business plans. Projects are identified using Technical Advisory Groups (TAGs), consortia technical committees, and through external private sector partnerships. Organizational key performance measures are employed to ensure a viable balance in the portfolio of energy projects.

Overall, within the Energy Sector (NRCan), priorities are set as above, and roll into specific management action plans, to identify one and two-year objectives that correspond with: corporate operations, program delivery, evaluation, quality, and human resources requirements. In each case, deliverables, responsibilities, reach, delivery dates, outputs and outcomes are identified and assigned to people.

One of the best practices techniques that has been used successfully by NRCan, to help guide strategic and business planning processes is the use of "technology roadmaps". A good example of this is in the geomatics field. The Remote Sensing Geomatics Division, produced its own technology roadmap to identify long-term goals and relevant initiatives needed to respond to challenges in the sector. The best practice technology roadmap process, as a way of ensuring excellence in government S&T is outlined in Exhibit 2-3.

Some successful examples of technology roadmaps produced under the auspices of the federal government, in collaboration with stakeholders and users, include the following:

- *Canadian Aircraft Design, Manufacturing and Repair and Overhaul*
- *Forest Operations in Canada*
- *Lumber and Value-added Products Technology*
- *Wood-Based Panel Products Lumber and Value-added Products Technology Roadmap*
- *Geomatics Virtual Technology Roadmap*
- *Electrical Power*
- *Medical Imaging.*

Although Canadian governments and private sector enterprises have generally not been very successful in developing appropriate technology foresight roadmaps,[21] the Energy Sector at NRCan embarked on this process several years ago through its Energy Technology Futures 2030 (ETF 2030) initiative. ETF, through a comprehensive consultation process, has created scenarios[22] of possible energy economies by developing a shared understanding among Canadian stakeholders of the potential range of long-term technological futures that could fundamentally alter the relationship between economic growth and GHG emissions. These scenarios and analysis are being

[21] Partnership Group for Science and Engineering, *Setting Priorities for Research in Canada,* April 2000.

[22] For further detail consult http://www.nrcan.gc.ca/es/etf.

incorporated into energy S&T planning through the S&T Forward Plan (STFP) and S&T Companion Document (STCD) to the Energy Priority Framework (EPF).[23]

Exhibit 2-3: Technology Roadmaps as a Best Practice to Ensure Excellence in S&T

A technology roadmap is a practical business-forecasting tool, which gives government SBDAs and stakeholders in a given industry sector a way to predict future technological and product needs, and map out how best to attain them.
The technology roadmap process provides: ▪ pooling of resources of stakeholders and users; ▪ working together with users to look into the future (typically 3 to 10 years); ▪ determining what specific areas of scientific knowledge and applications will require R&D initiatives today, to meet the requirements of tomorrow.
The benefits of technology roadmaps include: ▪ reduced risk through collaboration ▪ increased efficiencies ▪ better networking opportunities for researchers ▪ development and retention of resources and expertise ▪ better ability to address challenges in the scientific fields in which they are developed.

2.1.2 Program and Project Delivery

The methods and process for developing program plans, and the criteria used to ensure relevance and relationship to overall priorities, are extremely important for achieving "excellence" as defined in this study. Programs and projects cannot be successfully delivered without appropriate methods and processes in place that deal with questions of scope, purpose, criteria and organization. These are all precursors to measurement of excellence. They must be settled before and not during a program or project delivery process. But once they have been settled, they can be measured by a set of relevant performance indicators, to monitor how well S&T programs and projects are being delivered, and to provide feedback into the system for improvement of delivery on an

[23] See "Update on NRCan's Approach to Excellence – Energy Sector", summary notes by Energy Sector, Natural Resources Canada, October 2000.

ongoing basis. So how do some of the organizations we examined tackle this ongoing monitoring and performance measurement question?

Department of Fisheries and Oceans (DFO): DFO's new Fisheries management planning process incorporates the principles of performance measurement through the adoption of clear, measurable objectives. The aim is to achieve an evaluation mechanism that is transparent, open and based on a participatory process of annual internal reviews that ensure alignment with ministerial and government priorities, external evaluations from partners and stakeholders, performance evaluations of staff, and peer review assessments of specific programs. DFO is implementing performance measurement to measure success in meeting its identified objectives. Its new Performance Framework identifies the department's responsibilities for reporting and measurement. Some key indicators have been identified to measure the department's overall performance. The performance measures and indicators are designed to focus on each science-based activity area of DFO, including:

- understand oceans and aquatic resources,
- protect marine and freshwater environment,
- manage and protect fisheries resources,
- maintain marine safety, and
- facilitate maritime commerce and ocean development.

For each of these activity areas, DFO has developed a set of performance indicators which involve, for example, narrative presentations of assessments, qualitative and quantitative indicators, public opinion polling, citation analysis, number and value of collaborative arrangements, response time, number of fisheries by conservation outcomes, accidents and incidents rates, lives saved, and contribution of Ocean industries to Canada's GDP. These examples of indicators are accompanied by measures involving direct outcomes and reach to clients, users, co-deliverers, and beneficiaries of DFO's programs and services. This performance measurement system within DFO is part of its broad objective-based fisheries management system.[24]

DFO is also involved in risk management and assessment activities. It is likely one of the most risk-oriented departments in the government as they deal with the conservation, protection, and stewardship of natural resources and habitats, as well as with a variety of marine safety responsibilities. Many decisions are science-based and involve formalized generation of advice based on risk assessment. DFO applies risk management in the development of fisheries plans by applying the precautionary approach. The "precautionary approach" aims at reducing the probability of occurrence of bad events within acceptable limits and is used when the level of uncertainty and the

[24] *Objective-Based Fisheries Management: An Evolution of the Integrated Fisheries Management Planning Process*, DFO presentation deck, October 20, 2000.

potential costs are significant, when full reversibility cannot be ensured (e.g., to address issues such as resource sustainability, over fishing, and protection of endangered species).[25] The precautionary approach is being operationalized at DFO by:

- establishing clear and measurable objectives for conservation, ecosystems, and socio-economic aspects of fisheries;
- establishing agreed upon reference points as milestones toward overall objectives;
- applying risk analysis principles to identify the threats to achieving those objectives;
- establishing effective control measures and monitoring procedures to reduce the impacts of threats;
- establishing predetermined corrective actions to be initiated when the reference points may be exceeded.

These measures, while necessarily focused on preventative practices, are nonetheless part of the overall program and project delivery system within DFO, intended to achieve excellence in terms of quality and relevance (specifically towards accuracy of results of DFO programs and activities, in assessing risks and making reliable and appropriate decisions).

National Research Council (NRC): The Council annually collects information on NRC's performance against a performance framework. A high standard is set in this regard. NRC considers that good performance information is not only important for management and inter-institute comparisons, but also to demonstrate the value and impact of NRC's investment to the outside world. Each institute at NRC is required to submit a performance report in accordance to its *Outline for Performance Report*. The outline is very detailed and contains attributes and pre-requisites for achieving excellence. Exhibit 2-4 provides the highlights of what is required reporting material for each institute's individual performance report.

By reporting on its programs, projects and service activities in this fashion, NRC is able to maintain an ongoing measurement system that monitors its performance towards achieving excellence. The performance indicators that feed this system are based on best practices and experience with NRC's performance framework. The outline indicated above is intended to streamline performance reporting and ensure consistency across NRC.

As part of this reporting mechanism on program and project delivery, NRC encourages the reporting of key "success stories". Success stories can involve economic, scientific, business, entrepreneurship, partnership, or social (e.g., health) impacts. These success

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[25] *Precautionary Approach to Fisheries Resource Conservation: Conceptual Framework*, prepared by Fisheries Research Branch, Science, Fisheries and Oceans, November 2000.

stories are usually presented in the form of case studies that provide narrative and quantitative analysis on lessons learned and impacts.

Exhibit 2-4: Performance Reporting at NRC

NRC institutes are required to report annually on the following:

- **Contributions to the development of knowledge and competency building**
  - Quantitative data on research outputs, reach and impacts
  - External recognition of research excellence
  - Main contributions to the development of knowledge and competency
- **Contributions to innovation and the application of technology**
  - Relevance of research investment to Canadian industry and partners
  - Technology transfer activities
  - Examples of technology transfer
  - Impacts of advice and services
  - Contributions to the formation of new companies
- **Contributions to strengthening the Canadian innovation system**
  - Dissemination of S&T information to industry
  - Measurement, calibration, codes, and standards activities
  - Strengthening of linkages and partnerships
  - Contributions to development of highly qualified personnel
  - Strengthening of regional innovation systems
- **Management**
  - Client focus
  - Leadership and management
  - Collaboration and synergy within NRC
  - Alignment of workforce with the NRC vision

Natural Resources Canada (NRCan): Managers and scientists at the Energy Technology Branch of NRCan were consulted for this study, including the CANMET Centre of Energy Technology (CETC) at Bells Corners, which does a majority of the research associated with efficiency in technology with conventional fossil fuels. Other centres are the CANMET Western Research Centre in Devon, Alberta, and the CANMET Energy Diversification Research Laboratory in Varennes, Quebec. This organizational set-up is a result of a 1996 merger of three divisions.

The Energy Sector is both a funder and performer of S&T. The Sector, through the Program on Energy Research and Development (PERD), provides funds to other government departments in support of energy S&T. The Office of Energy R&D manages this fund. The CANMET Energy Technology Branch contracts-out and performs in-house S&T using both A-base and PERD funds. Programs are undertaken in partnership with other government departments, other levels of government, the private sector and academia. A combination of in-house and contracting-out delivery mechanisms allows flexibility and an effective response to Sector goals and objectives.

The Centres of Energy Technology are moving towards a kind of "balanced scorecard approach" to managing, including the identification of key performance indicators (e.g., program portfolio balance, technology portfolio balance, revenue generation, R&D contracting-out, client reach, integration collaboration and cooperation, client satisfaction, and human resources development). These KPIs (Key Performance Indicators) are aligned directly with resource planning and projections. One of the drawbacks of this system, cited by scientists in the centres, is the paper burden for planning becomes quite onerous—i.e., there are a lot of system demands on the research scientists. However, the flip side of this is that it strengthens the process for planning and setting priorities, and provides a strong system for measurement of performance, an essential management tool to support program and project delivery.

2.1.3 Stakeholder and Client Involvement

Generally, there does not appear to be any structured or formal mechanism to identify stakeholder and client groups for specific S&T government organizations, but SBDAs get lots of advice from all sources on who the appropriate players are for scientific initiatives and programs. There are lots of advisory groups with various representations and mandates, and at different interface levels in federal government organizations (e.g., technical, management, executive, and Cabinet levels).

National Research Council (NRC): At the NRC, for example, there are lots of advisory groups of various types throughout the organization, and many *ad hoc* mechanisms to identify client groups and stakeholder requirements. NRC is also governed by a Council that is made up of stakeholders and clients. All the technology groups and many of the institutes at NRC have advisory boards, and many of the major research programs have separate advisory committees also made up of stakeholders and clients.

NRC also has an "Advisory Policy", which lays out the general principles regarding the involvement of advisory groups that comprise stakeholders and clients. The overall principle is:

> *Good management practices involves ongoing, direct, and external feedback on the relevance, impact, and operational performance of programs, the quality of program delivery and services, and client/partner proposals for program and service improvement.*

The Advisory Policy leaves the mechanisms used for obtaining client/stakeholder input up to the various institutes' Director Generals. The following possibilities are suggested:

- formally constituted advisory committees;
- periodic meetings with clients;

- formal program evaluations and follow-up procedures; and
- client surveys.

The Corporate Services Branch of NRC keeps an eye on the advisory system, to provide oversight and to ensure that it is effectively practiced.

Natural Resources Canada (NRCan): The document *Compendium of Science and Technology Management Practices*[26] states that the involvement of clients and stakeholders in the planning of S&T programs is important, and outlines some very general guidelines regarding how this can be done. Each sector has its own strategic plan which identifies the clients and stakeholders. The extent to which stakeholders are involved in the development of these strategic plans varies by sector—except that all sectors involve their sector advisory boards. For example, Canadian Forest Service (CFS) has both informal consultations with clients and systematic client surveys (including provincial governments) every 3 to 4 years, dealing with a number of items which feed into their strategic plan, such as the perceived relevance of their work and required future directions. They have also initiated a plain language newsletter, which is partly intended to generate input from clients regarding what they are planning.

CANMET is one of the main research and development arms of Natural Resources Canada. In the past, CANMET used to plan their priorities with an emphasis on broad government-wide strategic objectives (e.g., energy-efficiency technology development). During the past few years, however, CANMET has moved towards developing priorities both from a "top down" and "bottom up" perspective. Input from clients and partners, and feedback from individual scientists and project managers, internal and external to the department, are factored into the priority-setting process. Broad policy directions and strategic intents are set at the industry sector level, but in practical terms specific research projects also respond to feedback from stakeholders and clients.

CANMET has a set of well-identified clients and stakeholders. In part stakeholders are identified by mandate, in part by demand, and in part by knowledge partnering. The people of Canada represent the broad client group of NRCan. For CANMET clients are also the other departments, as part of the interdepartmental Program for Energy R&D (PERD); intra-departmental clients such as the Energy Policy Branch, the Office of Energy Efficiency; the Renewable Energy and Electricity Division; and the Office of Energy Research and Development. In addition, CANMET clients include academia, large, medium and small firms in the energy sector, utilities, municipal/provincial organizations, and representative policy and advisory groups such as the National Advisory Board for Energy Science and Technology (NABEST).

[26] *Compendium of Science and Technology Management Practices*, Natural Resources Canada, March 1997.

Department of Fisheries and Oceans (DFO): DFO's objective-based fisheries management planning process involves all stakeholders and clients, including:

- resource users,
- conservation bodies,
- NGOs,
- provinces, and
- all branches within DFO.

DFO management committees such as the Deputy Minister Committee (DMC), regional management boards and zonal committees, as well as regional scientific staff meetings all play important roles in the scientific priority setting process of DFO. Advice to all these committees from external and international advisory councils, boards and committees including representation from clients, stakeholders, academia, NGOs, and aboriginal groups are considered in developing DFO scientific priorities.

In addition, the management system of DFO strives to create an inclusive and cooperative forum where stakeholders can focus their expertise and experience to develop realistic, practical and achievable fisheries management plans. It also is intended to facilitate expansion of the role of resource users towards shared stewardship and co-management.

The objectives-based Fisheries Management initiative of DFO contributes to creating a forum for resource users to develop fisheries management plans consistent with the framework and objectives of Canada's Oceans Integrated Management strategy. It also helps implement an open and inclusive forum for resource users to articulate their needs and objectives.

Agriculture and Agri-Food Canada (AAFC): The extent to which client groups and stakeholders are involved in AAFC priority-setting is very strong. The Minister retains ultimate veto power and direction on all plans, but external advisory groups and peer reviews have a very strong role in determining the "business-lines" at AAFC. The process is based almost exclusively on the "public good" dimension of science as normally associated with government regulatory departments. The major stakeholder groups are farmers, the food processing industry, consumers, and environmental groups. These groups play a strong role in helping to identify and track pertinent issues that have a "known problem" impact. Moreover, the advent of partnership programming at AAFC, for research, makes identifying priorities and projects relatively easy and focused. In particular, the Matching Investment Initiative (MII) at AAFC has proved to be very successful in having partners get involved in a substantial and meaningful way.

There are two apparently effective board systems at AAFC that encourage involvement of stakeholders and clients in contributing to the S&T agenda of the department. National (Canadian Agri-Food Research Council (CARC), Research Branch Advisory

Committee (RBAC)); and Local (Research Centres advisory committees). Each of these is comprised of a cross-section of opinion leaders (from the various sectors, e.g., food crops, soil, and users; and from the various regions), to ensure equity in representation. The Boards run on three-year cycles to help identify key priorities for the department.

Environment Canada (EC): At EC there is deemed to be no organization-wide system for identifying clients and stakeholders. Interviews with scientists and management at EC, however, suggest that EC has a very broad client/stakeholder base, and that the department has a heavy emphasis on stakeholder consultations. Clients and stakeholders are well known to each of the S&T establishments. The EC *2000 Strategic Plan* provides information on EC's linkages and partnerships.

The S&T Advisory Board at EC, which has representation from stakeholder groups, is the main organization-wide mechanism for identifying client/stakeholder needs. At the establishment level, most of the EC establishments have management boards that include stakeholder representation.

2.2 People

The strengths of the successful S&T organizations in attracting and retaining qualified staff appear to be based in part on their portfolio of research, from fundamental to very applied, and the degree of recognition of their research programs among peers, the scientific community, industry and other stakeholders, and client groups. This helps to attract good people and keep them interested. However, the portfolio of research and the level of recognition are in turn dependent on the mechanisms in place that ensure excellence. The ability for an organization to recruit, retain and rejuvenate qualified staff is a necessary condition for excellence. Successful recruitment and retention depends on an organization's ability to be competitive in securing adequate resources and leveraging its scientific infrastructure.

2.2.1 Identifying and Developing Core Competencies

In the SBDAs examined for this study, the identification of core competencies required is generally built into the formal planning process. This experience of SBDAs in developing and applying core competency criteria has grown over the past decade or so. Several federal government departments now have documentation (guidelines and definitions) for core competencies. These organizations also occasionally do gap analysis to determine their recruiting requirements over their planning horizons.

Natural Resources Canada (NRCan): At NRCan the identification of core competencies required is part of the formal planning process. At the CANMET Energy Technology Centre, for example, core competencies are identified in concert with their Strategic Planning process (running over a long term basis up to a decade and more), and including subsequent "road maps" that identify shorter-term (annual) requirements.

In a general sense, core competency requirements do not really change very much over time. When there are specific changes required, however, these are identified mainly at the specific group or laboratory levels. The main competencies at CANMET are directly aligned with policy and program areas. As part of the competency development process, training is formalized and discussed annually at both the individual and organizational levels.

Department of Fisheries and Oceans (DFO): Core competencies are identified in a variety of ways throughout the organizations examined. At DFO's Canadian Stock Assessment Secretariat science managers are responsible for tracking and outlining necessary skills—e.g., marine biology, biological modeling, marine population ecology, quantitative methods, and so on. Overall, a "core mandate" scheme is applied directly to functional tasks. In the first instance, core competency requirements are very well defined, and then based on these definitions, staffing requirements are established. The system is very demand driven, but is characterized by relative stability over time—i.e., the core competency requirements do not appear to change radically over time (for example, measurement competencies for regulator purposes to determine sustainable harvesting levels has been stable over time). Some methodologies have changed (e.g., hydroacoustics; computer modeling), which has an impact on competency identification in these areas, but in a general sense most areas are fairly constant and core competencies need only be identified in terms of perhaps 2-4 year periods.

Environment Canada: At Environment Canada, the needs for specific competencies (i.e., scientists with specific skills) are identified at the laboratory level. NWRI, for example, has done some excellent work on the identification of general competencies required at different levels—e.g., the kinds of skills required at the S&T manager level. NWRI developed and published a core competency framework for identifying its staffing needs. The framework is guided by a set of principles that help maintain the Institute as a key R&D player. These principles include statements that focus on the following: succession planning; revitalization; employee participation in defining core competencies; development of existing staff; characteristics necessary for success in management; excellence in research performance; encouragement of multiple sources of input into the process; and linkage to the evolving vision of the Institute. These elements of the guiding principles combine to form a set of criteria to judge the effectiveness of the core competency development process. Competency assessments at NWRI are not just used for identifying gaps and hiring new staff, but also, most importantly, for individual personal development for current staff.

To measure competency, the NWRI has identified the following (Exhibit 2-5) five types of competency characteristics that have practical implications for human resources planning.

Exhibit 2-5: Identifying Core Competencies at NWRI

- **Skill:** The ability to perform a specific physical or mental task.
- **Knowledge:** Information a person has in specific content areas (e.g., facts or procedures).
- **Self-concept:** A person's attitudes, values, or self-image. Usually measured by respondent tests that ask what people value or are interested in doing.
- **Traits:** Physical characteristics and consistent responses to situations or information (e.g., self-confidence, self control).
- **Motives:** The things a person consistently thinks about or wants that cause action. Motives drive, direct and select behaviour toward certain actions and away from others (e.g., power, need for achievement).

The NWRI *Development Resource Guide* describes these competency characteristics in a way that underpins its people development program.[27] Core competencies, such as motives and traits are hard to develop; therefore it is most cost effective to select candidates who already possess these characteristics. Peripheral knowledge and skill competencies can be developed and training is the most cost effective way to ensure these capabilities. Self-concept, attitude, and value competencies can be changed, albeit with more time and difficulty; these attributes are most cost-effectively addressed by training through developmental job assignments.

In spite of the NWRI example, however, some of the feedback received from interviews with EC scientists suggests that there is no effective department-wide recruitment and retention strategies in place. Recruitment is a major challenge for many divisions within the department. Salaries are no longer comparable to salaries at universities, and the state of the facilities and equipment at EC are considered to be poor, compared with the 1980s when EC's facilities and equipment were considered to be state-of-the art. This situation affects recruitment, as well as retention of qualified staff. The department is in the process of developing a human resources action plan to deal with problem areas that have been identified in employee surveys.

National Research Council (NRC): In the late 1980s NRC did a study of required core competencies, organization-wide. They tackled questions such as which scientific competencies should they emphasize and which should they drop (due, for example, to insufficient critical mass, or not being in line with NRC's overall priorities). Such a study has not been done more recently, however, managers within NRC feel it is

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[27] *Development Resource Guide: R&D Management Positions,* National Water Research Institute, Environment Canada, 1998.

important to develop definitions of supporting competencies. They have developed behavioural competency profiles for four job clusters at NRC (which cover about 90 percent of the people in research institutes at the Council): managers/supervisors; technology extension; research staff; and research technicians and technologists. The profiles related to these job clusters, along with the job-related technical skills, are intended to be the key elements of all human resources activities related to recruitment and staffing, training and development, performance management, and succession planning.

At the **Institute for Marine Biosciences, NRC**, one viewpoint is that core competencies need to be identified primarily at the level of individual scientists. In other words, it is the individual's leadership that must drive the strategic and operational goals of the establishment, not the other way around. This is not to say that mandate and policy do not play a key role at the macro level, but rather that attracting and retaining world-class researchers must take precedence over specific policy obligations.

Proven excellence in scientific research in the individual is measured in terms of publications in leading journals, successes in competitive granting processes, invited lectures and conferences, and other traditional measures of scientific merit and excellence. This includes an increasing attention to success in multidisciplinary research, and respect amongst a multidisciplinary peer group. Moreover, the individual's ability to work well with others and to demonstrate individual leadership is an important consideration.

Agriculture and Agri-Food Canada (AAFC): In other broader settings, e.g., at research establishments at Agriculture and Agri-Food Canada, there is a tiered system for identifying core competency requirements. First, the AAFC aligns its core competencies with its core business as outlined in its broad five-year business plan. Second, annual work plans identify strategic competencies that have a shorter time dimension associated with them. Third, lab-by-lab assessments and alignments of competency requirements are done at individual project levels. The competency requirements are also defined on the basis of a fairly rigorous process involving five-year reviews that are done by external national and international peers in the relevant fields of research at the department. Each division within the department also has advisory groups to help identify new and changing competencies required, with input from specific industry stakeholders and clients who influence competency choices. Finally, sometimes "nature sets the priorities" for competency requirements – e.g., as the case of plum pox in Niagara which established demand for immediate competencies (in a crisis situation) where it was difficult to plan for in the abstract.

The 1995 program review and budget cutting and downsizing exercise has had an effect on AAFC in that it made it necessary for them (as it did in other departments) to consider the most effective and efficient ways to align staff with the organizational priorities (for example, which labs to close and which to expand, based on strategic goals).

Health Canada (HC): At Health Canada, core competency requirements are generally defined along consistent lines with the standard classification categories of scientific staff within federal SBDAs. These categories are summarized in general terms in Exhibit 2-6. Performance appraisals against these categories form the basis for promotion of staff, and provide guidance for recruitment. Competency requirements for scientific staff are assessed against these criteria at Health Canada.

Exhibit 2-6: Competency Criteria for Scientific Staff: Health Canada

Productivity: Identifiable outputs of a scientific or technical nature.

Publications: Papers of original work, technical notes or letters, books, investigative reports, unpublished confidential reports.

Reviews: Authoritative reviews in fields of knowledge significant in scope.

Innovation: Patents, improved designs/methods, improved processes or systems, improved materials.

Technology Transfer: Impact on technology transfer, technical publications, reports, presentations.

Cooperative Research: Record of significant contributions as a scientific authority (contracting *out* work), joint venture projects, collaborative and multi-disciplinary research, contracting *in* work.

Creativity: Imaginative approaches, concepts and ideas for the advancement of research and the development of technology.

Recognition: Stature in the scientific community; literature citation; honours, invitations, and awards; role in scientific societies and committees.

Leadership: Influence on scientific community and direction of scientific programs. This includes scientific leadership, and degree of influence in the scientific community.

Scope of Decision-making: Latitude in determination and control of work (including degree of supervision, independence, and judgement).

2.2.2 Recruiting and Retaining Qualified People

There is a great deal of concern about recruitment and retention in the government SBDAs examined. The system is threatened due to aging qualified staff, lack of or limited rejuvenation programs, and competition with other organizations in the private and academic sectors. "The situation is tough and getting tougher", indicates one senior SBDA manager. The main concern is competition from universities who have "lots of money" these days (e.g., due to research funding from government programs). In addition, university salaries are higher and most universities now appear to have better facilities and equipment, which attract excellent government research staff.

Generally, recruiting best practices mean that the organization is able to identify, attract and hire outstanding candidates by understanding and adapting effective and innovative practices that top organizations (in government, academia, or the private sector) are already using. Leading organizations in the private and public sectors, and in academia, understand how to best manage their recruitment and selection processes to meet short-term hiring goals as well as long-term strategic goals. In a recent report issued in the U.S., key findings about best recruiting practices include those listed in Exhibit 2-7.

Exhibit 2-7: Recruitment Best Practices[28]

- Manage and measure recruitment and selection as an ongoing core process to foster continuous improvement.
- Identify and target multiple, rich sources of candidates and actively market to them.
- Staff the ongoing recruitment process with line managers who are coached and informed by recruiting experts.
- Develop strong Internet recruiting capabilities to drive recruitment process efficiency and effectiveness.
- Manage recruitment promotions as an integrated marketing campaign to attract and to appeal to top candidates.

In the current competitive market of the knowledge economy, people, not products, distinguish an organization from its competitors. The highly competitive market for highly qualified people increases each employee's importance. In these conditions, innovative recruiting techniques set successful organizations apart from their counterparts. Among the key components of managing recruitment and selection as an ongoing core process are designing an automated front end to screen candidates, accurate corporate forecasting of recruitment needs, tracking key recruitment measures, and implementing strategies to deal with advancements and trends in the recruitment process. Organizations in the private sector still use traditional techniques to reach better candidates: on-campus recruiting, use of headhunters, and massive executive

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[28] *Driving Growth through Recruiting Excellence*, Best Practices, LLC, (www.benchmarkingreports.com), 2000.

search processes. While each of these sources still plays a key role in the recruitment process, less traditional sources, most notably the Internet, now play enormous parts. Marketing to each source is an increasingly important facet of the recruitment process.

National Research Council (NRC): Organizations such as the NRC institutes have taken steps to increase their flexibility in hiring—e.g., they are piloting a new system for performance pay, which they feel will help them keep their best people. They have made a lot of changes to their human resources policies in the past five years in order to help create an environment that will attract and retain people through incentive payments.

Agriculture and Agri-Food Canada (AAFC): There is a fairly large "pool" of non-public service scientists working at AAFC (estimated at over 1,000 persons, and could be as high as 2,500 persons), comprised primarily of contracted researchers, graduate students, post-docs, and adjunct professors that are aligned with universities. This pool of scientists appears to be a prime labour market for AAFC, and is drawn in to the AAFC research establishment when and if needed.

There is a concerted effort within AAFC to hire "best-of-kind" scientists for leading research labs (e.g., canola, wheat labs). This is not always possible, but getting leading researchers who are well regarded internationally does happen. Generally it is estimated that hiring from the "pool" of researchers indicated above, and the "best-of-kind" leading researchers is about a 70-to-30 percent split.

Within the department, there is a sense that AAFC scientists come "pre-trained", i.e., they are established and have experience. While on-the-job training—including for areas like management—does occur, there is a heavy emphasis on pre-selection criteria.

However, retention of qualified staff is an obvious concern at AAFC, especially with respect to issues such as salary differences between AAFC and industry. Money, however, is not the only concern. Scientists at AAFC appear to value the quality of the work environment, and the social impact and orientation associated with doing public science. Retention approaches that emphasize these characteristics of SBDA research are important at AAFC.

Department of Fisheries and Oceans (DFO): DFO has put in place a National Workplace Improvement Plan that is aimed at improving the workplace, and is aimed at turning DFO to become a desirable place to work for highly qualified people. Generally, the initiatives associated with the National Workplace Improvement Plan include:

- establishing internal and external recruitment plans,
- establishing a competency-based management framework,
- establishing a national career development and learning program open to all employees,

- establishing a mentoring program open to all employees,
- establishing a workplace health and wellness program,
- building a harassment-free, zero-tolerance workplace, and
- implementing a revised approach to internal communications.

These initiatives are currently underway and responsibilities are assigned to oversee their development, to ensure that DFO continues to achieve its goals in creating a work environment that attracts and keeps highly qualified people.

At the Canadian Stock Assessment Secretariat of DFO there is an internal Advisory Board to help identify recruitment and retention needs. A lot of recruitment comes from the other branches of the department. However, when the CSAS has the budget to hire from the outside they go through the regular talent search process stipulated by the Public Service Commission. Salary levels are an issue at DFO for attracting highly qualified people, but DFO is generally regarded as a very good place to work for scientist that are, for example, marine biologists.

Health Canada (HC): At Health Canada, as part of the Food Directorate Renewal initiative,[29] there is a strong recognition of the need to progress in the area of rejuvenating the work environment, to make the Directorate an attractive place for new recruits and for retention of the Directorate's highly qualified staff. The "directional statement" that most demonstrates this goal is the one that aims to turn the HC into "a diverse, learning organization that engenders teamwork, pride and passion."[30]

A rejuvenation/recruitment plan is now in place to help bring this about. The key components of this plan include: developing a short-term HR strategy; developing a long-term HR strategy; identifying critical positions that are at risk; develop a plan for continuous learning within the Directorate; and make continuous learning mandatory for each employee.

There are other important components of the Renewal Initiative not highlighted in this brief description. Generally, the approach of the Renewal Initiative is to strengthen the Food Directorate's capacity enabling them to more effectively and efficiently carry out their mandate, with a view of earning recognition as a national and international leader, with world class, internationally respected scientific and policy capabilities.

Generally, the view from within HC is that five years ago there was deterioration in the situation with respect to recruitment and retention of highly qualified staff because of government cutbacks. There seems to be a consensus that the situation has improved

[29] *Food Directorate Renewal Initiative: Results of Strategy Planning Workshops*, Health Canada, November 9, 2000.

[30] *Ibid*, page 2.

considerably. There appears to be more flexibility and financing for S&T project initiatives, while having mechanisms in place that ensure an appropriate focus is kept on the mandate and objectives of the department. The R&D carried out is policy driven, but specific project initiatives are also based on technical and scientific input from the scientists and researchers within and outside the department (i.e., both a "top-down" and "bottom-up" approach).

One of the "people" practices that scientists suggested was a good practice conducive to a healthy work environment (contributing to retention) is co-location or clustering people in appropriate office and laboratory venues. Co-location or clustering of government scientists with other users/clients (internal or external) is seen as a good practice for government-based S&T. For example, there are benefits to having the program and regulatory staff who deliver government health program services co-located with the scientists. This was particularly cited as a benefit at the Nutrition Research Division. One of the benefits, it was suggested by some of those interviewed in this study, is that this improves the planning process, keeping SBDAs focused on mandated priorities, and preventing "mission-drift". Another benefit of co-location (or clustering) is that by having scientists in close proximity with users/clients, a dynamic and purposeful work environment evolves that is more creative.

Natural Resources Canada (NRCan): At CANMET recruitment is done in a variety of ways: individual-level experience creates direct knowledge of the labour market; very active university co-op programs creates a pool of young qualified professionals; a relatively large pool of contract researchers provides another source of recruitment; S&T exchange programs and seconding (from industry, and from other departments and universities) also provides a source of qualified people for recruitment. Some hiring of "best of kind" scientists is tried, but it is not often successful.

Training is completed as part of the annual performance review of individuals and the organization – i.e., training is offered as required to individuals, and to strengthen competencies in strategic organizational areas (e.g., specific tasks, management, career development).

Recruitment is directly linked to policy and program goals and requirements. Research scientists are recruited at all degree levels (e.g., PhD, BSc, BEng, and MSc), on a full-time or project-basis. Recruitment is also based on interpersonal networks.

Retention is a challenge within NRCan for similar reasons as in other SBDA organizations: salary differences between government and non-government organizations (i.e., universities, private sector) and the deteriorating sate of facilities and equipment.

The main strength at NRCan is the work environment that is characterized by an open dialogue with staff. This allows for constant communication, and hence better understanding of and ensuring that staff needs are met (although this must be done within the confines of the Public Service Commission rules).

Both recruitment and retention of scientists are obvious challenges for NRCan. In order to attract and retain qualified people you need competitive salaries and a reputation for doing world-class research. On both these counts NRCan has a lot of competition with universities and the private sector. The department is finding that most of its qualified young people are attracted away from the department after a few years. In order to deal with these issues, NRCan uses the following methods:

- the S&T Management Development Program (this is new and just being implemented);
- the Graduate Opportunities Program;
- Learning Plans for all staff;
- Mentorship programs in place at all the labs;
- realistic promotion criteria, which give credit for contributions to industry in addition to just scientific publications;
- recognition programs, which scientists feel have been very helpful.

The main challenge with the retention and recruitment practices is in the lack of resources and the negative effects that this has had. The practices listed above are considered to be strong points of CANMET's approach.

2.3 S&T Management

Achieving excellence in S&T is increasingly motivated within Canadian SBDAs by the desire to achieve good management and allocation of R&D resources. There are of course many reasons for identifying good management practices in S&T – for example, to improve performance through a process of self-scrutiny, to verify the relevance of the work, to be accountable to clients and stakeholders, to plan for the future by building on achievements of the past, to rationalize (or terminate) an S&T work item. The excellence (quality and relevance) of S&T is the ultimate goal, and only by integrating a sound S&T management system with the measurement of results can SBDAs ensure that excellence can be achieved.

2.3.1 Management Practices

Good management practices are a fundamental requirement for effective delivery of any government program or project. In government S&T, good management practices require a number of mechanisms in place to ensure that the prerequisites to excellence (qualified people, equipment and facilities, and supporting resources) are in place and are well managed to achieve excellent results.

The building blocks of a good management model for an organization is a system that integrates all the components of decision-making and management practices. Two-and-a-half years ago a Canadian *Independent Review Panel*, which studied modern management practices in the federal government, indicated that effective management and decision-making as an integrated function depends on having a system in place which:

> "bring[s] information together into a meaningful whole and communicate[s] it to all those who have need of it to discharge their managerial responsibilities. It should also ensure that important gaps and deficiencies in information are identified and rectified. Few organizations that are 'information driven in their decision-making processes' have reached this position without an ability to integrate and communicate performance information."[31]

In another document, from the Office of the Auditor General of Canada, the recommended management system for government organizations is one that provides "a cyclical process that systematically links an organization's objectives, action plans and results."[32] A good management system with an integrated decision-making process is one that provides a structured process for continual improvement. "It is a tool that enables an organization to achieve and control the level of performance it sets for itself."[33]

Exhibit 2-8 below graphically depicts the "continual improvement" management system approach that provides a framework for an effective, integrated decision-making system. Any good management and decision-making model should be equally focused on results as it is on process. This is why, as indicated in the left-hand-side of the chart in Exhibit 2-8, there is a strong emphasis on performance checking and management review of results.

While the management model in Exhibit 2-8 admittedly is not unique to S&T, it provides an illustration of the building blocks for a complete and integrated system required to achieve excellence. Some of the methods used to ensure excellence in government S&T at the different stages of this management system include, for example, *technology roadmaps* to help frame policies and develop strategic and business plans. At the other end of the management system, to measure performance and to provide feedback to management, program evaluations are frequently carried out by SBDAs, to measure the quality and relevance of the results.

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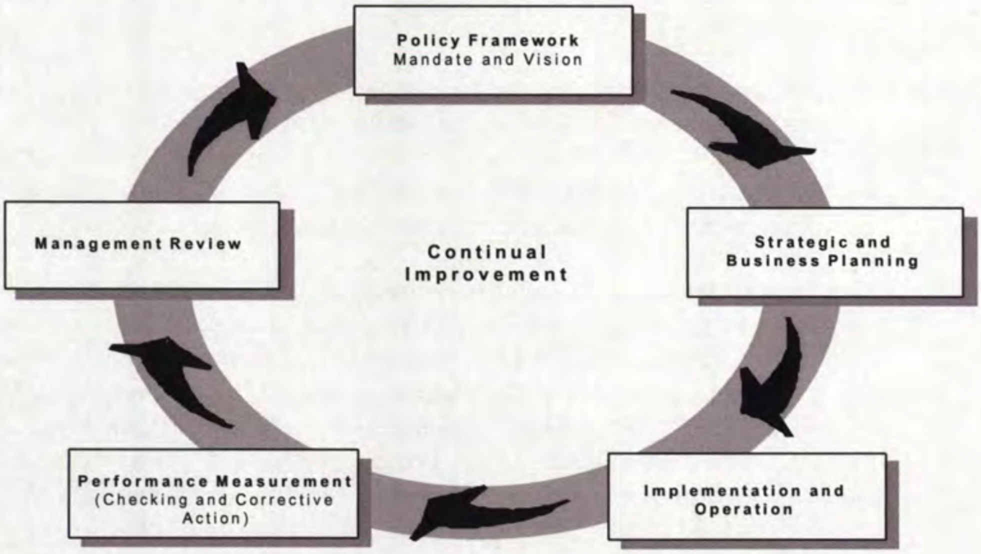
31 *Report of the Independent Review Panel on Modernization of Comptrollership in the Government of Canada*, report to Parliament, 1998, page 26.

32 *Report of the Commissioner of the Environment and Sustainable Development – 1999*, Office of the Auditor General, pages 1-13.

33 *Ibid,* pages 1-13.

Exhibit 2-8: Management System Approach to Achieve Excellence



Program evaluation studies, with all the supporting methodologies that these entail (including surveys, expert advice, stakeholder consultations, and impacts analysis) provide a good example of feedback systems. In the past, evaluation studies were not always timely enough to become an integral part of the management cycle as depicted in Exhibit 2-8. Now the Treasury Board Secretariat seems more intent on building evaluations "to be seen less as a check on management and more as an aid to good management".[34] A positive feature of program evaluation as an S&T management tool is when it can provide feedback to help shape strategic and program directions, and to improve the chances of achieving excellence (quality and relevance) of the S&T conducted by government.

Environment Canada (EC): Environment Canada has in place it's own management system that mirrors that shown in Exhibit 2-8. The Science and Technology Management Framework of EC provides for all the requirements of a continual improvement system. The elements of the EC S&T management framework include the following:

- various committees that discuss S&T management issues, develop and implement S&T policies;

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[34] *Study on the Evaluation Function in the Federal Government: Summary Report*, Treasury Board Secretariat, Draft, March 2000, page 3.

- strategic planning, coordination and integration processes for long-term requirements and for establishing and prioritizing S&T objectives and priorities;

- accountability to establish the responsibility for the delivery of S&T programs and services;

- partnerships and alternative service delivery mechanisms to provide innovative ways to enhance EC's policy and service capacities; and

- S&T operating practices that include best practices and methods used by the department for delivering programs and services.

EC is one of the SBDA organizations examined that have well documented what they consider to be good S&T management practices. For example, Environment Canada's Management Framework describes principles and guidelines regarding management of S&T programs. In addition, principles regarding S&T partnering and collaboration are outlined in the EC documents: *Science and Technology Partnering: Principles and Practices*; and *Collaborative S&T Positions Policy.* The leveraging of external resources has been heavily emphasized at all of EC's S&T establishments as a necessity due to budget cuts. Organizations within EC, such as the NWRI, publish lists of their partner arrangements, to give them recognition and buy-in into the organizations constituencies. Communications also plays an important role in the EC management process. The document *Science Communication Framework for Environment Canada* outlines some general principles regarding science communications. This was developed by the S&T Advisory Board and accepted by the department. The most concrete result of this has been the implementation of a training program in communications for scientists in the department. The main challenge for EC is consistency in application of S&T management practices. The department has the principles and models outlined for S&T management within their organization, but these need to be applied consistently as well.

Department of Fisheries and Oceans (DFO): The Department of Fisheries and Oceans has developed a management planning process that is objectives-based. So-called Integrated Fisheries Management Plans (IFMP) were introduced at DFO in the mid 1990s. The original goals of the IFMP were to:

- improve program delivery,
- ensure greater integration of functional and technical expertise within DFO,
- increase linkages within DFO,
- standardize the fisheries management plan process, and
- identify performance outputs for individual fisheries management plans.

This planning process has evolved into the current Objective-Based Fisheries Management system which stresses the following:

- formal documentation of clear and measurable management objectives,
- application of risk management principles,
- operationalizing the precautionary approach,
- introducing ecosystem concerns in fisheries management,
- incorporating the principles of performance measurement,
- continuing to expand and develop shared stewardship models,
- clarifying the working relationships between fisheries management and science, and
- expanding integration processes within the department.

Fisheries management and science branches of DFO have been working together to develop this relatively new management system within the department. It incorporates many of the best practices and lessons learned over the past two decades, in managing and ensuring that quality and relevance is achieved. The prospects seem very good and the management of DFO is optimistic as their Objective-Based Fisheries Management system progresses.

Institute for Marine Biosciences (IMB), National Research Council: In one of the SBDAs examined, the Institute for Marine Biosciences of NRC, far and away the most important dimension in S&T management was noted to be good scientific methodology—i.e., not the "usual formalized bureaucratic process of government departments". The management's choice at this Institute is to emphasize the role of the individual scientist as a champion, as an accountable leader in his/her S&T field of research. The major requirement for good S&T management, in this sense then, is ensuring that qualified scientists are the designated champions of research programs and projects.

Generally, within NRC, most ongoing management occurs at the individual institute level. Support tools to help NRC managers manage their S&T programs are continuously being improved. NRC has been working on installing SAP for at least four years now, and SAP is supposed to provide much of the required information needed for managing the business—particularly information regarding adherence to budget and schedule. However, they have been having problems with SAP, and in this regard, they recognize that they are nowhere near being a best practice in providing their managers with the appropriate financial and non-financial information management system that is needed.

Meteorological Services of Canada (MSC): One Branch of EC where the principles of good management appear to be prevalent is the Meteorological Services of Canada Branch (MSC). MSC is very client oriented due to the nature of its services. As part of its management process it is in the process of setting up a Client Advisory Board. Several major clients of MSC (e.g., NavCanada, Coast Guard, Defence Canada) are reliant on the weather services of this organization, and so they are being built into the planning and management processes of MSC. MSC is developing a Charter of Service, to improve and manage its service development process, including managing risks and improving the delivery of the information required by its clients.

Saskatoon Research Centre (SRC): Other management practices worth noting are those of the Saskatoon Research Centre of Agriculture and Agri-Food Canada. Resources are identified through conducting gap analyses for specific studies. Individual scientists identify resource needs as part of their budgeting processes and these are rolled up and priorities are set through the so-called SMS system. SMS is a management tool/system introduced into SRC over the past five years that has made a significant difference in S&T management practices at the Centre. The SMS (Study Management System) is a computerized study database and management system for managing research studies. SMS tracks information on each of the SRC studies. SMS permits managers to make investment decisions in research at the project level. The SMS information feeds into an assessment framework that is part of the process for identifying and managing for excellence in the S&T activities of the Centre. The assessment framework measures returns from the R&D carried out, the R&D capacity of the organization, the relevance of the scientific or technical results from the work, and the ability to capture the benefits. More discussion on SMS is provided below in the segment about Agriculture and Agri-Food Canada.

Natural Resources Canada (NRCan): At CANMET, it was emphasized that good S&T management practices really depend on how well each S&T project is managed individually. The Project Management Process (PMP) at CANMET Energy Technology Centre is designed to monitor/manage in four key steps:

- assessing objectives against capabilities to do the work;
- initializing/making the deal (e.g., setting budgets, contractual terms, setting deliverables and objectives, establishing collaboration goals and responsibilities and communication plans);
- doing the science with constant monitoring (ongoing assessment of adherence to budgets and schedules); and
- measuring the outputs/outcomes (i.e., *ex post* monitoring and follow-up, including client satisfaction surveys).

This PMP process of CANMET Energy Technology Centre is complemented by quality management practices resulting from ISO 9002 certification. The PMP has allowed the Centre to develop best practices in controlling its resources, and to develop a continuous improvement management culture. The ISO 9000 series of quality standards have also been adopted in several other labs at NRCan.

Agriculture and Agri-Food Canada (AAFC): AAFC feel they are very responsive to government-wide initiatives that seek to improve good management practices in

SBDAs. This starts from the top at AAFC. At the ADM level, the ADM reviews every research project, to identify "winners" and "losers" and to identify the operational context. The main criteria used to select "winners" and "losers" are the benefits and costs as defined in terms of project costs, probability of project success, and scientific and commercial spin-off activities and products. A study evaluation process that relies on benefit-cost analysis has been developed by the department to evaluate research studies.[35] This approach also includes a step-by-step process for economic evaluation of research studies in an *ex ante* mode.

Ongoing management of S&T programs, for monitoring progress and ensuring adherence to budgets, schedules and quality, is primarily the responsibility of the Director Generals who travel across the country to sit with project teams, to ensure that the system is on track and that excellence in management is practiced. This helps create cohesion at the Branch and laboratory levels within the department. Constant monitoring is increasingly the norm within the department.

S&T management within AAFC is generally guided by the department's "Study Management System"[36] (SMS). This is a systematic decision process to optimize investment in research (see above). Expenditures on new research are chosen with the aid of this project prioritization system. The SMS system starts with a "feasibility" and "attractiveness" analysis based on a set of critical questions asked of each initiative. Ultimately, the return to Canada from the R&D initiatives need to be assessed. "Feasibility" and "attractiveness" are defined as described in Exhibit 2-9.

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[35] *Study Evaluation Process: Benefit/Cost Analysis*, Research Branch, Agriculture and Agri-Food Canada (no date).

[36] *Study Management System Overview*, Research Branch, Agriculture and Agri-Food Canada (June 1995).

Exhibit 2-9: SMS Assessment Framework to Measure the Return to Canada from R&D

Attractiveness (likely benefits of research) to Canada is based on:

- Potential benefits: the maximum returns possible from technological improvements.
- Canada's ability to capture the benefits: the ability of Canada's organizations to convert technological progress into commercial or other returns.

Feasibility (ability to achieve technical progress) is based on:

- R&D potential: the scientific or technical potential of relevant research areas.
- R&D capacity: Canada's ability to realize the R&D potential in a timely way.

The assessment is based on the premise that the highest priority research should be that which has the potential to return the highest economic, environmental, social, and other benefits to Canada. The outputs from the SMS analysis is of three kinds:

- A **feasibility/attractiveness matrix** that highlights the relative overall benefit to Canada of each study in the establishment research portfolio.
- An **expected value** analysis that provides a relative estimate of the return to Canada per unit of investment in the research for each study in the establishment portfolio.
- Where appropriate, an **economic analysis** of each study that estimates the relative value in dollar terms of each study in the establishment research portfolio.

The SMS assessment framework was adapted from a model used by CSIRO in Australia to assess priority areas of research at different levels of aggregation.[37] CSIRO in turn adapted it from the U.S. Industrial Research Institute. As a "best practice", some form of SMS has therefore been used in other organizations.

Health Canada (HC): Management of S&T functions/programs within Health Canada is supported by peer review groups (internal and external). Quality management

[37] *Setting priorities for research purposes and research projects: a case study involving the CSIRO Division of Animal Health*, CSIRO, Australia, November 1993.

initiatives are also in place (e.g., accrediting laboratories against ISO quality standards—such as ISO 9000 series or ISO Guide 25 for laboratories). Standard operating procedures exist for specific functions at the department, from the Branch level down to the activity level (e.g., regarding project management, risk management, dealing with proprietary issues). A Chief Scientist has been hired to fulfill the role of ensuring excellence in the management of the S&T function in the department. The Chief Scientist will report directly to the Deputy Minister, and will be recruited from outside government. The CS is expected to provide fresh ideas for managing S&T within the department, to act as a catalyst to invigorate the S&T work environment, and to provide science advice when appropriate.

Co-location or clustering of government scientists with other users/clients (internal or external) is seen as a good practice for government-based S&T. For example, there are benefits to having the program and regulatory staff who deliver government program services (particularly RSA-related S&T activities) co-located with the scientists. One of the benefits, it was suggested by some of those interviewed in this study, is that this improves the planning process, keeping SBDAs focused on mandated priorities, and preventing "mission-drift". Another benefit of co-location (or clustering) is that by having scientists in close proximity with users/clients, a dynamic and purposeful work environment evolves that is more creative. It should be noted, however, that this kind of co-location (or clustering) is not possible in all cases in geographical terms. There are many exceptions (such as hydrographic services, building and construction R&D, aerospace).

2.3.2 Collaboration and Leverage of Resources

As has been discussed earlier, ensuring and measuring excellence of government S&T requires an assessment of the prerequisites for excellence (i.e., leadership, people, facilities, equipment, and good management). Perhaps one of the most obvious areas that needs to be assessed on an *ex ante* and ongoing basis is the formation of collaborative links for research and technology development and transfer. Much of the benefit of these collaborations occurs during the normal course of ongoing S&T project work. *Ex post* evaluations of collaborations often fail because it is difficult to be objective about events that occurred in the past (sometimes evaluations look back, up to five years into the past). The benefit of hindsight provides an opportunity to rewrite history. It is also sometimes difficult or even impossible to collect relevant data after the events. Thus, collaborative arrangements need to be looked at as they happen. The benefits and costs of these arrangements, admittedly, may not accrue immediately, but usually the participants in a collaborative arrangement can determine whether they are in a mutually beneficial situation, leading to results commensurate with the effort and resources being expended. It is for this reason that good management of collaborative arrangements is required, if and when these form an integral part of S&T activities within government SBDAs.

Leveraging the resources of an organization to fulfill its mandate involves: expert exchange programs with partners and collaborators; and cost-recovery activities involving, for example, fee for services rendered including testing products. In-kind assistance and working with private sector partners on joint projects are also ways for leveraging resources to fulfill an organizations mandate.

National Research Council (NRC): One way an organization demonstrates that its resources have been successfully leveraged is when it has contributed to the formation of new companies. These can be in the form of spin-off companies, start-up companies, or incubation services. NRC measures how it's programs/services have contributed to the creation of new companies. Indicators used for this include: NRC technology used, number of NRC employees in the new establishment, the role of the specific NRC institute in creating the new company. Tracking the growth of the new company is also an indicator of success.

NRC requires its Institutes to provide annual profiles on their respective *Collaborative Research Portfolios*. These profiles comprise the items shown in Exhibit 2-10.

Exhibit 2-10: Reporting on NRC's Collaborative Research Portfolio

Collaborative Portfolio:

- Total value of collaborative research (both partner cash and in-kind contributions and NRC's contributions) over the lifetime of all active formal agreements.
- Number of formal collaborative agreements with industrial partners and name of partners.
- Number of formal collaborations with public organization and name of organizations.
- Number of formal collaborations with Canadian universities.
- Number of formal collaborations—international organizations (multi-national or foreign).

Collaborative Profile (Annual):

- Total number of collaborative agreements signed during the year.
- Total value of collaborative agreements signed during the year.
- Total cash contributions of partners to collaborative agreements signed during the year.
- In-kind contributions of partners to collaborative agreements signed during the year.
- In-kind contributions of partners to agreements signed during the year.
- Leverage impact of NRC's investment (ratio of net institute contribution both cash and in-kind to partner contributions).
- Results of client satisfaction and impact surveys.

Agriculture and Agri-Food Canada (AAFC): The point was made at AAFC that "collaboration" is often equated with "free" within the department, and this is seen not to work to the advantage of the collaborating parties.[38] The word "partnership" is preferred in that this denotes some proportionate share in responsibilities and commitment to resources for initiatives. Partnerships are seen as contractual-based initiatives (and all contracts that AAFC gets involved in with its partners contain "escape clauses", to protect AAFC's interests).

The Matching Investment Initiative (MII) of AAFC is by far the most successful of the partnership initiatives that AAFC has embarked on in recent years.

Under the MII, companies or organizations interested in research partnerships with AAFC may increase the impact of their contribution through joint funding of research and development. AAFC's objective for this program is to carry out research that can readily be transferred to the client for generation of new business and economic growth

[38] This is one interviewee's perhaps cynical way of describing that the value-added from collaborations are not always that apparent, and that collaborating parties are often expecting to "get something for free".

in Canada. Expenditures covered by joint MII agreements include, staff hired to undertake the project, operating costs (e.g., materials and supplies), and pilot plant costs.

Natural Resources Canada (NRCan): Collaboration at NRCan happens at the individual scientist level. Because of the fiscal situation, program managers are constantly trying to leverage whatever outside resources they can. Also, some programs (e.g., IERD) have formal leveraging requirements. Approximately 90 percent of CANMET's R&D activities, for example, are carried out in partnership with users/clients. This varies by sector, however. For example, in the Energy Technology Branch there is lots of emphasis on cost recovery and leveraging. The Geomatics sector has some emphasis on cost recovery (which could be considered a form of leveraging). On the other hand, the Canadian Forest Service (CFS) has no formal guidelines regarding collaboration or leveraging, but proposals are more likely to be approved if they involve partners. Most of CFS projects have at least one external partner. In fact, most of the technology development work done by CFS is done in partnership with privately led R&D institutes to which CFS contributes (e.g., FORINTEK, PAPRICAN).

Health Canada (HC): Increasingly, the research projects conducted in Health Canada are of a collaborative nature with partners both inside and outside of government. For example, method development, evaluation and validation are standardized as much as possible at Health Canada through established authorities such as CODEX, the International Organization for Standardization (ISO), and the Association of Official Analytical Chemists (AOAC). In this context, Food Program scientists actively work with others in developing collaborative studies to validate new methodologies.

Another example of collaborations at Health Canada involves surveillance activities for which formal partnerships with provincial health departments and various universities exist. Part of the surveillance activity is the Canadian Nutrient File (CNF). The CNF is a computerized database of the nutrient values of over 4,000 foods. The File is required to support the survey work, but is also essential for other activities such as risk assessments. It is also widely used by various government departments, food industries, marketing agencies, hospitals, universities, private nutrition consultants, the media and the general public. It is the basis of the popular publication, *Nutrient Value of Some Common Foods* (by Health Canada).

Generally, Health Canada has collaborative activities that manifest themselves in different ways:

- *Setting priorities*—For setting priorities, the department has established a Secretariat that consults with HC partners, with the goal to ensure that the health interests of Canadians are addressed—i.e., to set the national health priorities (this is new and just starting).

- *Partnerships with universities, hospitals municipal and provincial governments*—For example, partnerships of this kind come together in "centres of excellence" dedicated to specific project work in relevant thematic areas of research and development.

- *Individual researcher-level relationships*—This involves active participation of HC researchers in the scientific community, but it also involves a peer review system with involvement of individual expert researchers (internal and external) to ensure excellence.

2.3.3 Communicating Results of Government S&T

Communication of results often represents the culmination of the work carried out within S&T government organizations, but it should also include "work-in-progress" and strategic and operational information. One of the objectives, generally, for communicating/disseminating information on results and activities is to achieve the highest degree of transparency with regards to government S&T activities. There is a consensus now that this transparency is a benefit for SBDAs, in that it is a mechanism for ensuring that excellence is achieved within government. Only in making what you do and how you do it available for scrutiny can you ensure that quality and relevance is achieved.

The communication or dissemination of government S&T takes on a variety of forms in SBDAs, and depends on the kind of science and technology being done—for example, depends on whether the science is mission-oriented science involving R&D or RSA. Exhibit 2-11 summarizes some of the communications/dissemination techniques involved in R&D and RSA as practiced in federal SBDAs.

This section of the report provides specific examples of communications of the results of S&T, and demonstrates that there is a wide variety of approaches taken, largely dependent on the intended audiences and the purpose of the communications (e.g., R&D-related or RSA-related objectives). There are no specific guidelines, however, that were identified as best practices for communications or dissemination of S&T results to specific audiences. Generally, experts and scientists want to have an opportunity review the technical documents, and they value the interpersonal communications that occur during events such as workshops, seminars, and conferences.

Exhibit 2-11: Examples of Techniques for Communicating Results of S&T Used by Practically all SBDAs

R&D	RSA
Workshops, seminars, conferences.	Information databases (e.g., meteorological services); information documents (e.g., "Understanding Codex Alimentarius" by Health Canada).
Study reports and monograms.	Published test results (e.g., results of product/material tests by Institute for Research in Construction).
Published articles in scientific journals.	Guidelines and procedures documents for regulatory practices.
Web-based downloadable reports, announcements and lists of publications.	Organization-wide and establishment profiles and trends analysis.
Expert review groups, interdepartmental task forces, private sector roundtables, technical committees, and other similar groups	Strategic and business plans.
Patent applications.	Media reports and press releases.
Proceedings of meetings and research documents.	Web-based downloadable reports, announcements and lists of information services and publications.
Status reports on main activities and products within SBDAs.	1-800- telephone numbers for rapid response to client requests for information.
Ad hoc science policy meetings with scientific community.	Marketing initiatives.
Publication of scientific books and education kits.	Public forums.
	Targeted popular reports (e.g., bulletins).
	Science documentaries (audio/video).
	Public consultations.

Natural Resources Canada (NRC): Methods for assessing the effectiveness of communication activities are exemplified by the National Research Council. For example, NRC institutes report on their workshops, seminars, conferences, and other communication and information dissemination events on a regular basis. NRC institutes organize these events with the purpose of disseminating S&T information to industry. The reach of these activities and the extent to which the intended results/impacts have been achieved are measured. Examples of these measures are as follows:

- *Example 1*: IRC, in partnership with CMHC and HRAI, delivered seminars on Residential Mechanical Ventilation in seven Canadian cities. Reach: The seminars were attended by a total of 336 building officials and homebuilders.

- *Example 2*: INMS organized the fourth annual general meeting of the Association for Coordinate Metrology Canada, which was founded by INMS in 1995 to share knowledge related to coordinate measuring machines. Reach: 50 participants from universities and manufacturing firms (particularly firms related to automobile manufacturing).

To ensure that excellent S&T results and activities have been well communicated to stakeholders, users and clients, the effectiveness of communications need to be measured periodically by SBDAs. For an organization to be able to measure the effectiveness of its communications strategies and techniques, it needs to build into its performance measurement system some indicators that measure how well it has communicated and disseminated the relevant information.

Agriculture and Agri-Food Canada (AAFC): One of the "best practices" identified in this study for examining the effectiveness of dissemination of S&T outputs involves the Study Management System (SMS) of AAFC. The SMS system requires a technology transfer plan. For example, the Saskatoon Research Centre of AAFC has a communications plan describing various processes to extend information and transfer of technology. This involves most of the staff of the Centre through news releases, publicly available reports, media contacts, etc. The effectiveness of information dissemination is assessed based on tangible results towards this end as laid out in the technology transfer plan. SMS requires that the goals for dissemination and technology transfer be laid out clearly, and that they be measurable.[39]

Environment Canada (EC): At Environment Canada, a document has been prepared that outlines some general principles regarding science communications. This document was developed by the S&T Advisory Board and accepted by the

[39] See Section 2.3.1, under the segment for AAFC, for description of how the Study Management System (SMS) works.

department.[40] The most concrete result of this has been the implementation of a training program in communications for scientists in the department. Exhibit 2-12 provides a listing of the principles that are intended to guide communications at EC. Environment Canada has also been able to identify some "best practices" for science communications. The best practices identified by EC are highlighted in Exhibit 2-13.

[40] *Science Communications Framework for Environment Canada*, S&T Advisory Board Report No. 2, Environment Canada, March 2000.

Exhibit 2-12: EC Guiding Principles for Communications

Key principles that guide Environment Canada's science communication effort and activities include:

- Taking an anticipatory and precautionary approach.
- Encouraging participation.
- Generating influence through credibility.
- Pitching messages at the right level.
- Providing perspective.
- Linking to the policy context.
- Strengthening the relationship between scientists and professional communications.

Exhibit 2-13: Science Communications Best Practices[41]

- **Technical and popular publications:** Publication in the scientific literature and presentations at technical conferences generate professional credibility.
- **Issue life cycle analysis and issue forecasting:** Life cycle analysis and issue forecasting yield vital input to science communication planning.
- **Media relations:** Relationships between the departmental scientists, policy and communications staff, 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.
- **New media:** Use of new media such as the Internet and specialized television channels expands audiences and leads to new science communication tools.

[41] From *Science Communications Framework for Environment Canada*, S&T Advisory Board Report No. 2, Environment Canada, March 2000, pages 9-10.

Health Canada (HC): For Health Canada a simple roll up of communications and dissemination of approaches are summarized in Exhibit 2-15. This represents the various ways in which S&T results and departmental activities are communicated to stakeholders, users, and clients.

Exhibit 2-15: Highlights of Communications and Dissemination Practices at Health Canada

- Web sites
- "Dear Dr." letters
- "It's your Health Bulletins"
- Newsletters
- Federal-Provincial contacts (formal and informal)
- Annual S&T activity reports
- Special reports on specific issues (monogram and other documents)
- Lots of publications involving guidelines and procedures (e.g., Canada Food Guide)
- Databases (e.g., surveillance results)
- Information dissemination through partnership arrangements (e.g., Canadian Health Network)
- Consumer and public information forums and other venues and events
- Science Advisory Board (e.g., records of decisions is on the Web)

Natural Resources Canada (NRCan): At Natural Resources Canada, main methods for communicating/disseminating results of departmental S&T and R&D work to management, interdepartmental committees, stakeholders and clients, as highlighted during the interview process for this study, include the following:

- technical and other reports to clients and stakeholders on technology;
- economic, social, scientific impact assessments over time for major projects;
- documentation on client satisfaction survey results and other feedback mechanisms;
- literature publications (i.e., peer reviewed articles, conference presentations, proceedings).

However, NRCan also uses many of the other communication/dissemination techniques highlighted earlier in Exhibit 2-11. The Energy Sector itemized their communications vehicles as follows:

- Stakeholders/internal clients (available for management, interdepartmental committees, central agencies, program and policy staff, scientists/researchers, and in some cases for the public):
    - *Plans*: ETF, EPF, STFP (under development), STCD, POL plans, Branch and Divisional business plans.
    - *Annual Reports*: Performance Report to Parliament, S&T Annual Review, Sustainable Development Action Plan.
    - *Weekly reports*: significant events.
    - *Reviews*: mid-and year-end review reports.
    - *Evaluation reports*: benefit-cost analysis, case study reports, Audit and Evaluation Branch evaluations, Auditor General evaluations.
    - *Advice* (i.e., through committee participation and one-off requests).
- Stakeholder/external clients (widely available communications materials for stakeholders and clients outside government):
    - *Reports/Publications*: technical reports, journal publications, conference proceedings, textbooks – editors and chapter authors.
    - *Presentations/Profiles*: conferences presentations and booths.
    - *New and Traditional Media*: Internet web sites/government on line, press announcements/releases, public ministerial events.
    - *Advice*: to direct clients, responses to public inquiries.

As part of its *Managers' Guide to S&T Impact Assessment*, NRCan has distilled the experience of the department in communicating results of S&T work into highlights on "what works" and "what does not work".[42] Exhibit 2-15 summarizes NRCan's findings on this matter. Clearly, in reading the information in this Exhibit one must put it in the context of who the audience is. The communications methods and strategies depend on the audience. The practices identified in Exhibit 2-15 are intended for

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[42] *Managers' Guide to S&T Impact Assessment*, Natural Resources Canada, 1997.

communications to a general audience, not necessarily the scientific community. Best practices in communications methods should be identified in context of the intended audiences.

Exhibit 2-15: Communicating the Results of S&T at NRCan[43]

What Works

Objectives. A clear objective to communicating the impacts of an S&T initiative is essential for identifying audiences and messages.

Simplicity. Technical and scientific detail of the project must be kept to a minimum. Public material should be easy-to-understand and use layman's terms. Using keywords will also help keep audience attention.

A hook. Good communications places prime importance on something the audience can identify with and relate to. Examples include using a local or regional angle, or emphasizing why the audience should care about the impact. In using a regional angle, however, special consideration should be give to provincial/local government sensitivities.

Consistency. Figures and arguments must be the same in all public material relating to the project. If they differ, there should be a simple explanation why.

Success stories. These are the best means to give a short, lively, concrete example of benefits for any projects.

Special events. Events bring attention to the benefits of a project because they draw media interest and build on partner or client involvement. Events can also benefit from the profile of a "champion", such as a Minister or local scientist.

Photos. Providing a photo opportunity for the media usually draws their attention.

Timeliness. Old news is not news at all! Timeliness will also prevent a scoop from another, possibly competitive, source.

Media analysis and evaluation. Analyzing the results of a communications approach is invaluable in ensuring future success in dealing with similar situations.

What Doesn't Work

Jargon. Extremely technical language can be confusing.

Communications for projects with no public demand for demonstration or relevance. Innocuous news stories that say nothing are a frustration to reporters, who learn to ignore these items and may even criticize the department for wasting their time. This does not build good relations for coverage of our real news stories!

Late night or Friday releases. The media does not pick up on communications reaching them at these times.

Unsuccessful projects. These should be avoided because, while they can provide lessons learned, they are obviously bad news. From time to time, however, a communications

[43] *Managers' Guide to S&T Impact Assessment*, Natural Resources Canada, 1997.

approach will have to be developed for an unsuccessful project. ...

2.4 Provincial Organizations

The provincial organizations examined, Centre de recherché industrielle du Quebec (CRIQ), InNOVAcorp (Nova Scotia), and Alberta Research Council (ARC), are three different types of organizations involved in S&T activities.

Centre de recherché industrielle du Quebec (CRIQ): CRIQ was created in 1969 and today is a leading innovation and technology organization in Quebec, with various collaborative S&T activities with other research centres, industrial associations and private and public sector partners. The areas of expertise and S&T activities that CRIQ is involved in include specialized services in:

- Research and development for:
  - automation of manufacturing processes
  - environmental technologies
  - development of industrial equipment
- Product qualification tests and certification
- Industrial and technological information
- Standardization, including certification and registration for ISO quality systems (ISO 9000 series).

Two-thirds of CRIQ's employees (350 workers in total) are engineers, technologists, chemists and agronomy scientists. Each year, these professionals undertake some 800 projects on behalf of approximately 1,000 clients.

In order to ensure relevance, CRIQ undertakes a "technology survey", which is a client survey that is systematically done to find out what is and will be needed by its clients and partners. They also have a team of 20 research advisors who approach existing and potential clients on a one-on-one basis, to determine what their requirements are. The last Technology Survey done by CRIQ was in 1996. They anticipate doing a similar survey in the near future.

In order to develop program and project priorities, CRIQ utilizes a method it calls "stage gate". At each stage of the S&T process—i.e, idea, project definition, work plan, market research and implementation, and analysis and evaluation—a careful assessment is made by management and scientists together (in a joint brainstorming effort involving "bottom-up" and "top-down" consultations). Most of the decisions are finally made at the Director level, but group leaders for each section of the organization and project managers and researchers are also involved in the process. The "stage gate" approach, as described by CRIQ officials, is an iterative process which entails a thorough assessment at each "stage" before the "gate" opens to the next stage (i.e., from idea to project definition, from project definition to work plan, from work plan to implementation, and from implementation to evaluation).

The "stage gate" process is seen by CRIQ as having strengthened their planning approach, giving them more structure that leads to a greater degree of success in achieving relevance and quality.

InNOVAcorp: InNOVAcorp is a Nova Scotia Crown Corporation reporting to government through the Economic Development portfolio. InNOVAcorp facilitates the emergence, development, and intended success of science-based businesses. In particular, two types of science broadly defined are targeted: life science and information technology. These are supported by InNOVAcorp in three ways: business advice, investment (i.e., venture capital), and incubation services (which is the major function of InNOVAcorp).

InNOVAcorp encourages successful development and commercialization of technology products and services through the delivery of industry-oriented programs and services. For example, InNOVAcorp delivers the Industrial Research Assistance Program (IRAP) on behalf of NRC. InNOVAcorp works with companies in their start-up and early growth phases to make sure their business skills match their technological promise. As such, InNOVAcorp is very much focused on understanding the mechanisms (or prerequisites) for excellence. InNOVAcorp does not carry out research and development itself, but in carrying out its support activities to incubate facilities and businesses involved in S&T it needs to assess the quality and relevance of these mechanisms. InNOVAcorp tries to make sure that members of the incubation community benefit from the spectrum of shared experiences and networking opportunities available in the incubation environment. They help and are helped by their peers throughout the process. As a result, companies that have been helped by InNOVAcorp are expected to be far better equipped to survive on the open market.

A defining characteristic (prerequisite) for success that InNOVAcorp mentioned in terms of its own operations is leadership. Leadership is seen as an important attribute required at all levels of the organization, as there is seen to be a wide variety of integrated individual specialties that play an important role in InNOVAcorp's decision-making process (e.g., science, banking, business, law, corporate development). Leadership and core competencies in these areas are required if InNOVAcorp is to facilitate success in other business organizations.

At the strategic level, the success of InNOVAcorp as a government agency is thought to rest on the extent to which a full integration between business and science is achieved: good science and good business are viewed as being mutually dependent. The emphasis on good business is not necessarily as clear-cut in other government organizations (e.g., SBDAs with a regulatory agenda involving health, safety, or environmental issues).

Alberta Research Council (ARC): ARC performs applied research and development, and provides expert advice and technical information to a diverse range of clients from small start-up firms to large multinational corporations, and government departments and agencies. ARC bridges the gap between basic research and market development. They work closely with industry, universities and other groups in a variety of arrangements, including strategic alliances, contract research, joint ventures, consortia and licensing arrangements.

ARC is organized into four market-focused divisions (Energy Technologies, Forest Technologies, Industrial Processes and Systems, and Life Sciences) and seventeen business units. ARC is a very industry-oriented research organization. Research is only undertaken at ARC if it has commercial potential, and this is assessed throughout S&T project stages of development (by means of a "stage gate" approach that is similar to that described above for CRIQ). Each of ARC's seventeen business units has client revenue targets, which drive their operations. There is a lot of emphasis put on identifying and retaining clients at ARC.

Strategic planning is done at the direction of senior management, which meets every week. According to one ARC manager, ARC does "not [tell] people what to do – but [tells] them where ARC would like to go". Therefore, the strategic planning process draws on the knowledge of the employees. The business units bring forward the key issues facing them. In order to address these issues, senior management, through a visioning exercise, sets the long-term strategy and direction. Based on this, each business unit develops its own operational plan.

ARC is run by a Board of Directors, which involves senior representatives from industry, government and academia. This Board meets at least quarterly and reviews progress and operational issues and practices (e.g., human resources, health, safety, environment). It approves all major new initiatives.

ARC's recruitment practices are centralized in their human resources department (HR), which handles all recruitments and terminations. For special, difficult-to-find core competency requirements, HR can seek the assistance of external headhunters. Such competencies are retained through the use of market supplements and performance-based compensation. Annual reviews of business unit succession and replacement plans take place. Special initiatives for recruitment and retention have included a Strategic Hiring Program, a revised Awards and Recognition program, a Distinguished Scientist Program, improved staff communications and participation, revised salary and benefits ranges. Additional recruitment and retention initiatives are currently under consideration, e.g., use of website for recognition, web advertisements.

In 1998, in response to a continuing program of renewal and relevancy to its stakeholders, ARC undertook a major benchmarking study to compare itself to thirteen leading R&D organizations. This study showed that ARC was above average in its practices with respect to generating new scientific and technical knowledge and intellectual capital management.

Client and stakeholder needs are identified through several means, including reviews of client's strategic plans, networking, regular one-on-one meetings, interactions through board and consortium meetings, periodic workshops, client surveys and annual technical presentations and tradeshows. A new Competitive Intelligence system is being developed to centralize and share such information.

ARC's stage-gating process for developing new technologies is well-established and has gained acceptance in the organization. Investment criteria considered during this process are: alignment with corporate strategies, a strong business unit technology champion, private sector support and an appropriate return on investment to ARC and to the province of Alberta.

A "gate", or decision point on whether or not to proceed to the next stage, follows each stage in the process:

- Stage 1 is for preliminary evaluation of technical concepts that may have strategic value and market potential.
- Stage 2 is for a detailed evaluation of the technology and its market.
- Stage 3 is for technology development, usually in association with an industry partner.
- Stage 4 is for final design and evaluation, again with an external partner.

This four-stage process ensures that there are always good projects in the pipeline – and that only the best ones proceed along the commercialization path.

III Measuring the Excellence of S&T

S&T indicators of excellence may be defined as measurements that describe the creation, dissemination and application of science and technology. "As indicators, they should help to describe the science and technology system, enabling better understanding of its structure, of the impact of policies and programs on it, and the impact of science and technology on society and the economy."[44] Ensuring and measuring excellence of government S&T requires an assessment of the pre-requisites for excellence (i.e., leadership, people, facilities, equipment, and good management). The quality and relevance of the results also need to be evaluated, at different stages of program or project delivery (proposal, implementation, and outputs).

3.1 When and How Are Quality and Relevance Measured?

Exhibit 3-1 provides a summary of measurement of quality and relevance of government S&T, at the different stages of work. Results can be assessed at the "front-end", anticipating excellence. Generally, within the SBDAs we examined, at the pre-program planning stage, the focus is on assessing scientific merit and relevance of the work, internally within the department or agency. However, some external assessments are also made at this stage. At the "back-end" of the process, at program completion, there is much greater use of external assessments. Since "the proof of the pudding is in the eating", most of the measurement of excellence is done at program (or project) completion. Client satisfaction, relevance, socio-economic impacts, and research impact on the scientific community are all measured with varying emphasis. Much of this measurement is done in the context of program evaluations, reviews, or one-off case studies, bibliometric analysis, and performance reporting. The evidence suggests (as confirmed by individuals consulted for this study) that much of the results of this measurement work has an impact on the planning process for future S&T work, mainly informally through discussions in management and staff meetings and through the iterative business planning processes characteristic of the federal government departments examined.

National Research Council (NRC): Exhibit 3-2 provides a best practice highlight of measurement of excellence at National Research Council. The NRC's institutes are varied in their focus in terms of field of research, but also in terms of emphasis on basic research versus applied and mission-oriented research. Generally, however, the summary in Exhibit 3-2 provides the key elements of NRC's approach at assessing the relevance and quality of the S&T.

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[44] See Preface by Martin B. Wilk (Chief Statistician of Canada) in *An Indicator of Excellence in Canadian Science: Summary Report*, by James B. MacAulay (Statistics Canada: May 1984).

Exhibit 3-1: When and How Canadian Federal Departments Assess Results (Actual and Potential)

Pre-program planning	Program selection and initiation	Program monitoring	Program completion
Scientific merit (generally assessed informally internally). *Relevance* (assessed internally but often in consultation with advisory boards or stakeholders).	*Scientific merit* (generally assessed internally, but some use of external peer review). *Relevance* (same as pre-program planning but may involve more formal criteria). *Socio-economic impact* (some occasional forecasting of potential socio-economic impacts).	*Scientific merit and Relevance* (both are assessed internally, but there is also fairly frequent use of external peer review).	*Client satisfaction* (generally assessed informally in consultation with clients, but some use of client surveys). *Relevance* (varies by department—in some cases this is a required part of the performance reporting). *Socio-economic impact* (varies by department—in some cases this is done for major programs via a case study type of methodology). *Research impact* (rarely assessed; some occasional use of bibliometric analysis).

Exhibit 3-2: A Best Practice – The Measurement Practices of NRC

- **For all research institutes:**
  - External peer review of ongoing research programs every 5 years.
- **Program evaluation of the institute every 5 years, which includes:**
  - Performance benchmarking, and
  - Socio-economic impact assessment
  - The peer review and the program evaluation feed into the institute strategic planning process.
- **Annual performance reporting, which includes:**
  - Measures of research quality (see Exhibit 2-4 for related performance measures)
  - Measures of relevance (see Exhibit 2-4 for related performance measures)
  - Measures of impact

Environment Canada (EC): *Scientific merit*—at EC is measured at pre-project planning and project selection stages through internal review processes. With regard to project monitoring, prior to the *Framework for External Review*[45] there was no policy regarding the review of scientific merit during the ongoing phase, but this was fairly commonly done through external peer review. The *Framework* formalizes this practice by calling for external peer review of "applicable R&D programs" as part of project monitoring. The Framework specifies that large, significant ongoing R&D programs should be externally reviewed every 5 to 15 years. Following project completion, scientific merit is assessed indirectly by the practice of having scientists publish their results in peer-reviewed journals. The department encourages this practice.

Research impact—There are no guidelines at EC regarding the assessment of research impact, and this is rarely done. However, the department has done a basic bibliometric analysis of their publications over the period 1980-1997 (based on number of publications, analysis of specializations, and journal impact factors).

Relevance—As noted above, EC's S&T Advisory Board is supposed to assess the relevance of the department's R&D program as a whole, but this has not happened. With regard to individual programs and projects:

- For the pre-project planning and project selection stages, relevance is currently most commonly assessed through internal review processes. The Framework calls for the external review of relevance at this stage by "knowledgeable stakeholders".

- Relevance is not assessed as part of on-going project monitoring. For completed projects see the comments under impact assessment below.

Client satisfaction—Not assessed, except informally through stakeholder consultations and ad hoc survey.

Socio-economic impacts—Rarely assessed in current practice. The Framework states: "On a selective basis, impact analyses should be conducted on large, significant research initiatives".

There is currently a fair bit of use of advisory boards of stakeholders (mainly for project selection) and external peer review (mainly for on-going monitoring and review of post-project publications). The Framework formalizes these practices a bit by calling for:

- the external review of relevance by stakeholders for program proposals;

- periodic external peer review for project monitoring for large, significant projects.

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[45] *Op.cit.*

- post-project impact assessment for large, significant projects.

This policy is new, but scientists at the department that were consulted noted that, so far, "these are just words".

Another challenge noted was the difficulty of impact assessment for public good oriented R&D. It's very difficult to do this past the output stage, since the application of the knowledge is several steps down the road, and evaluation in quantitative terms is also difficult.

Agriculture and Agri-Food Canada (AAFC): The methods listed in this study to measure scientific excellence (peer reviews, benchmarking, bibliometric methods, expert committees, etc.) are used by AAFC at different stages of the R&D process. However, officials at AAFC were quick to point out that these methods are all "proxy" measures, and are "not nearly as good as 'real measures' such as return on investment (ROI), matching investment indicators, and analysis of benefits compared to costs. Exhibit 3-3 summarizes how AAFC measures excellence at different stages of S&T projects.

Clearly this tabulation of what is measured at AAFC, and when it is measured, indicates that this department is actively engaged in measuring its S&T activities at all stages.

Department of Fisheries and Oceans (DFO): At the Canadian Stock Assessment Secretariat of DFO, scientific merit is measured at all stages of projects. Pre-project planning and project selection and initiation are part of the strategic and business planning process. Peer reviews are used to provide assessments of ongoing projects and to evaluate the projects when completed. Performance appraisals also deal with scientific merit of the work carried out by researchers being appraised. The potential impacts within the scientific community are usually assessed at the beginning stages of projects, but not so much at concluding stages. Usefulness of the project outputs, however, is assessed by users and client queries and surveys (both web-based and traditional) are conducted, to assess the quality and relevance of the results.

Natural Resources Canada (NRCan): Measurement of excellence at the NRCan Energy centres examined can be summarized as follows:

Scientific merit and research impact—The measurement of scientific merit and impact within the scientific community is not done in a formal or consistent way for S&T in the Energy sector, in that the work carried out by NRCan centres such as CANMET does not involve basic research. The merit of the work is mostly judged by stakeholders and users of the research, particularly in the context of practical requirements for performance and accuracy of results, involving energy technologies developed.

Exhibit 3-3: Measurement of S&T Excellence at AAFC

	When			
What	**Pre-project planning**	**Project selection and initiation**	**Ongoing project monitoring**	**Following project completion**
Scientific merit (methodological soundness, rigor, reliability, scientific importance, etc.)	Discussions between project team and other stakeholders.	Assessed through Study Management System (SMS).[46]	Assessed through SMS.	Assessed through peer review for scientific papers, books/chapters, etc. Assessed through requests for reprints, scientific citations by others; extent to which the technology developed is used in other labs.
Actual or potential impact within the scientific community (if applicable).	Assess through discussions between scientists participating on the team. Assessed by discussions with scientists at universities & other establishments.	Assessed through SMS.	Assessed through appeal milestones in SMS outputs section.	Success in publishing in peer reviewed journals. Success in having the technology or process used in other laboratories.
Actual or potential usefulness of the project outputs, such as maps, reports, etc.	Assessed through peer review and stakeholder consultations. Assessed through consultation with other scientists.	Assessed through SMS evaluation process. (Peer review/scoring techniques/benefit-cost analyses)	Assessed through annual reviews, through SMS milestone assessments, through degree of extension of projects results to stakeholders.	Assessed through proxies for usefulness such as papers, patents, reports, etc. Assessed through degree to which other labs use a technology or technique.
Customer/client satisfaction with the project outputs.	Assessed through discussions on possible project development with stakeholders and reaching a common understanding of the research to be done and outputs to be developed.	MII requires client involvement in the research to be done and the outputs to be developed. Client must be happy with the proposed outputs.	SMS annual (ongoing) review of projects may involve clients/stakeholders. Scientists prepare annual reports on MII projects and projects from granting agencies.	Acceptance of final reports by granting agencies. Feedback from agencies with respect to quality of work. Agency willing to fund additional projects. Satisfaction surveys of MII clients.
Actual or potential socio-economic impacts and benefits resulting from the use of the project outputs.	Discussed as appropriate with stakeholders in the pre-planning stage or with potential collaborators.	Assessed through SMS as part of the project approval process.	Assessed through annual reviews of projects.	Assessed through ex post analysis. Assessed through proxies for impact. Assessed through direct measures of jobs and other economic criteria.

[46] See Section 2.3.1, under the segment for AAFC, for description on how the Study Management System works.

Relevance—The NRCan document *Science and Technology Management Framework* [47]states that: all S&T activities will undergo evaluations to ensure that they: meet departmental and federal objectives; address client and stakeholder needs; and reflect departmental and federal priorities and strategies. The main method currently used for assessing potential usefulness is advisory committees. Actual usefulness is selectively assessed through impact studies. Within the Energy sector, each of the major POL levels now has performance measurement frameworks, which include indicators related to usefulness and impact. However, these are just now in the process of being implemented.

Client satisfaction—The main method for assessing client satisfaction is the use of advisory committees and feedback from NRCan's R&D partners. They feel they "get this as part of the process". There have been selective telephone follow-up surveys of clients, focused on specific issue areas—e.g., climate change

Socio-economic impacts—NRCan has done several forecasts of potential impacts (e.g., for the upgrading programs, climate change, geomatics, conversion of renewable energy, energy efficiency), but most of their impact assessment is post-project impact assessment. In 1994, the Energy sector did a "cost-effectiveness" study of their programs using case studies of "big winner projects" to see if the economic benefits covered the cost of the program. This work was repeated in 1998. Since then, they have done in-depth case studies of the economic benefits from approximately six major projects.

NRCan are generally very positive about formal impact studies as a way of objectively demonstrating the impacts and benefits of their work. The main challenge associated with carrying these out is finding people to do them who have a sufficient degree of technical expertise to fully understand what the impacts are. Generally, it can be concluded that NRCan has in fact increased their emphasis on impacts assessment, and on developing reliable performance measurements. The NRCan document *Managers' Guide to S&T Impact Assessment*[48] is a general "how-to-guide" on impact assessment. This document emphasizes the stages at which the impacts of S&T projects need to be assessed: i.e., at the outset of a project; at one or more predetermined intervals during the project; upon completion of the project; and at a predetermined time after project completion. While this may seem onerous, much of this is already being done in NRCan's S&T sectors.

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[47] *Science and Technology Management Framework*, Natural Resources Canada, May 1996.

[48] *Managers' Guide to S&T Impact Assessment*, Natural Resources Canada, 1997.

3.2 Measurement of Excellence: Peer Reviews

"Peer review is the name given to the judgment of scientific merit by other scientists working in, or close to the field in question."[49] Generally, a "direct" or pure peer review process will focus primarily on scientific merit. This can occur at the outset of a project proposal, or it could be a monitoring or an *ex-post* evaluation exercise. The practice of peer review often guides the acceptance of papers by journals and conferences, and it also is an important factor in appointment and promotion decisions.

For those cases where a broad view of science is required, and where strategic and applied fields of endeavor are concerned, criteria other than scientific merit must also be considered. Notably, when criteria concerning the socio-economic impact of the research or its potential for utilization is added to the review process, scientific expertise alone is not sufficient to make judgments about these criteria. When this is the case (as is clearly so in many of the Canadian SBDA S&T activities), a "modified" peer review is applied. The "direct" peer review system has been adapted in various ways to deal with the strategic or applied S&T initiatives. One approach, the most frequently used, has been to include the users of research on committees and panels. This modified review technique usually establishes guidelines for a tiered process, which in the first instance determines that whatever projects are funded will first of all have passed the test of being judged "good science". Then, in the second instance, "relevant" science is determined based on a broader set of criteria with a view in which scientific possibilities are related to the social, economic and political costs of attaining them. The latter type of peer review (modified) is usually associated with "mission-oriented" research and development done by scientists in Canadian government SBDAs. Mission-oriented R&D is done with a clear purpose in mind (e.g., pollution control, air traffic safety). Mission-oriented R&D programs will usually involve applied research and experimental development activities.

The structure of peer reviews can vary widely. The number of experts can range from one to hundreds; the range of peer expertise can vary from narrowly-focused in the identical field being reviewed to very broad for encompassing the many facets of research; the review can be done by mail, *in situ*, or a combination of both; the length of the review can range from few hours to months; and so on.

Environment Canada (EC): At Environment Canada external reviews by experts, stakeholders, clients and others forms a part of the process in assessing proposed R&D programs and projects. The Department has developed a *Framework for External Review* that is intended to guide its use of scientific peer review as a way to assess R&D results.[50]

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[49] *Evaluation of Research: A Selection of Current Practices*, Organisation for Economic Co-operation and Development (OECD) (Paris: 1987), p. 28.

[50] *Science and Technology Framework for External Review of Research and Development in Environment Canada*, S&T Management Committee Report No. 4, Environment Canada, February 2000.

Scientific peer reviews are to be done of ongoing research programs and of completed research results prior to publication. The purpose of these reviews is to ensure "quality, merit, productivity, progress and direction of the science". Peer reviews are used to assess the degree to which the R&D is progressing in line with the overall program goals and productivity requirements of the research and researchers.

The objectives of peer reviews of ongoing R&D activities at EC are listed as follows:

- appropriateness, quality and merit of the R&D;
- soundness of the scientific methodology;
- capability of the research team in performing the work, and their productivity;
- adequacy of the resources and timelines, and the effectiveness of resource use;
- efficacy of management and scientific leadership;
- probability of success and the potential impact on the department and the broader scientific community; and
- scientific credibility of the results.

Thus, peer reviews are conducted at different stages of implementation of scientific R&D initiatives of the department.

National Research Council (NRC): NRC has carried out peer review of its research programs since the mid-1970s. Research activities were originally examined on an *ad hoc* basis by peer review committees that visited NRC laboratories and provided their perspective on the quality of the research. As NRC's mission evolved and became increasingly focused on industrial relevance, peer review practices were revised and systematized and integrated with other, newer review processes, such as program evaluation and internal audit. NRC currently has a comprehensive review process, which provides for an examination of all facets of the research, from its quality and relevance to management and organizational issues.

NRC is among the best organizations that use peer reviews in all the organizations we studied. They have developed an integrated review process whereby peer reviews of programs or Institutes within the agency are integrated with the findings of program evaluations and internal audits carried out concurrently. The first step in the organization of an NRC peer review is the identification of reviewers. Managers and scientists in the program or Institute are consulted and asked to submit a list of researchers most qualified to carry out the review. The reason for this is to ensure that the results of the peer review are considered credible by the research managers and scientists whose work is being reviewed. The list of proposed reviewers is then vetted and approved by senior managers within NRC to ensure that there is no conflict of interest. A Secretary is appointed to ensure that committee members get the necessary support and information to carry out their work. The Secretary is typically a program officer or scientist within NRC who is seconded to the review process.

NRC peer review committees, in addition to the quality of the science, are asked to address such subjects as the quality of R&D management, the receptive capabilities of research clients or partners, and the relevance of the research. In addition, scientists and engineers from industry are included on peer review committees. The aim has been to achieve a balance between issues of research quality and relevance. NRC has benchmarked its peer review practices with other comparable organizations worldwide, and the results of this benchmarking suggests that NRC, in the area of peer review, is among the best practitioners in the world.

Department of Fisheries and Oceans (DFO): The Science Sector at DFO uses peer reviews to assess the quality and relevance of its work. A recent application of peer review at DFO involves the Greenhouse Gas Research Program (GHG).[51] The department conducted an external peer review of its GHG research program to seek guidance and rationale for continuing projects that are considered essential, to identify any re-direction needed and to chart future paths. The Review Panel that was brought together for this work included experts from the U.S., the U.K., and Canada. The Review Panel assembled an inventory of DFO GHG research programs for the last 10 years and provided candid assessment of these efforts. This work was instrumental in making recommendations to the department about developing a national strategy for greenhouse gas research with members from universities and other pertinent agencies, about personnel rejuvenation in the relevant workforce to address the departure of aging employees, about funding GHG research, about international cooperation in this field, and about other related issues.

It was noted that DFO researchers appreciated the scientific value of having their research activities reviewed by external peers. It serves to focus their goals and offers an opportunity for self-assessment. They interacted in a very open and enthusiastic manner with the peer Review Panel.

Agriculture and Agri-Food Canada (AAFC): At AAFC peer review is seen as a "proxy" measure. AAFC does conduct peer reviews on projects it supports, but is seen as "second-best", because it is based on promises to achieve results as opposed to real performance in achieving results. Officials at AAFC point to a trend in the U.S. government to move away from "a peer reviewed system based on a review of promises" and towards "a results-based system based on a review of performance achieved", after the study has been completed. AAFC suggest that findings on this matter show that implementation of a results-based system is resisted by the university community in the U.S., since it is seen as different from their current practice. On the other hand, results-based systems are accepted by government departments, since they are seen as close to their current practice.

Health Canada (HC): External and internal peer reviews are used at Health Canada at all stages of project planning, monitoring, and evaluation. A Science Advisory Board also contributes to strategic prioritization, and to assessments of quality and relevance of the HC

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[51] *Report of the Peer Review Panel on DFO Greenhouse Gas Research Programs,* Department of Fisheries and Oceans, Ocean Climate Program, February 25, 2000.

program and project portfolio. In the health R&D area, peer review is one generally accepted mechanism to address the quality of scientific work, and has been conducted within government health laboratories. Within the Health Protection Branch, peer review has only been systematically applied to publications, although in some areas certain elements of peer review have been applied during the annual review of projects. There is a more recent impetus for systematizing and strengthening the peer review system at HC which can be traced back to the *Auditor General's 1994 Report* and the subsequent *1995 Federal S&T Report*, which recommended that "...each federal research facility and program 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."

Peer reviews have been consistently endorsed by the Department of Health's Science Advisory Board. In its October 1998 meeting the SAB stated in general terms:

> "Credibility, independence and currency are key features for the performance of science in the Branch. ... Integration of [the] process of systematic peer review for expanding existing research is fundamental to the Branch's science programs."[52]

Health Canada has organized several peer review initiatives. An *ad hoc* peer review committee was formed in 1999. This group initiated some pilot peer review projects of cross-cutting "programmatic/thematic" areas of the Health Protection Branch. One of these pilot projects involved a peer group for endocrine disruptor substances. This group involved the assessment of both the quality of the management and the appropriateness of the direction taken by the department in this area of S&T. Careful attention by the review group was given to written materials and oral presentations that resulted in a rigorous and consistent evaluation of endocrine disruptor substances work of the department. Some relevant comments made by this review group on the peer review process relevant to government S&T are highlighted in Exhibit 3-4.

[52] As quoted in *Report of the Peer Review Team: The Endocrine Disruptor Substances Working Group*, Health Protection Branch, Health Canada, March 2000.

Exhibit 3-4: Selected Highlights of Comments on Peer Review Process, Health Canada

- "The peer review process will benefit from having senior management meet with the reviewers. It is clear that the review process enjoys high-level support. However, it was difficult for the reviewers to gauge Branch management enthusiasm either for the EDSWG [Endocrine Disruptor Substances Working Group] concept, or for the importance of the topic of EDS as a potential human health risk, and some of the comments within the [peer review] report may simply reflect this lack of information."
- "There was considerable variability in the extent to which EDSWG members had prepared for the visit of the reviewers. There were instances of both too much and too little information. ..."
- "While respecting the different perspectives which need to be represented in a review of HPB [Health Protection Branch] intramural research, selection of reviewers should result in a majority of active scientists."

These comments provide samplings of issues related to the use of peer review groups in ongoing S&T project work in government SBDAs (namely, senior management commitment, preparedness/readiness of departmental staff to interact with reviewers, and representation). How well a peer review works will depend on how the SBDA responds to these types of issues.

Natural Resources Canada (NRCan): Results of S&T at NRCan are reviewed by POL (Program at Objective Level Plans) committees, Technical Advisory Groups (TAGs), consortia steering and technical committees, and client experts. These reviews can be considered to be a form of modified peer review in that experts, stakeholders and users are involved in the process.

3.3 Measurement of Excellence: Benchmarking

International benchmarking studies provide an opportunity to assess one country's or region's leadership status in research and development with world standards of excellence. Benchmarking has become an increasingly used technique to measure and compare performance and results of scientific laboratories and science-based institutions. As a best practice technique, the use of international benchmarking was advocated in 1995 by the National Academy of Sciences report *Allocating Federal Funds for Science and Technology* for the purpose of providing objective information for the United States executive branch and

Congress.[53] The need for objective evaluations had intensified as a result of the passage in 1993 of the Government Performance and Results Act (GPRA), which requires annual performance reports by all federal agencies, including those which support research. In a recent study by the Committee on Science, Engineering, and Public Policy (COSEPUP), on how to evaluate the status of research and development, a set of experiments on international benchmarking were undertaken.[54] Although the use of international benchmarking is not new, it had not been attempted on a scale large enough to contribute to national policy. Accordingly, COSEPUP decided to undertake a set of experiments to test the efficacy of international benchmarking. The committee chose three areas of research—mathematics, immunology, and materials science and engineering—that are quite different from one another in size, funding, numbers of sub-disciplines, and other qualities. The results of the experiments suggest that research leadership status by field can be assessed in a timely fashion at reasonable cost. It was also concluded that international benchmarking might also help federal agencies to comply with GPRA by evaluating the quality of their own performance.

Some of the specific conclusions of the committee about use of benchmarking as a tool for measuring performance in science and technology include the following:

> "Benchmarking allows a panel to determine the best measures for a particular field while providing corroboration through the use of different methods, as opposed to the 'one-size-fits-all' approach of some common evaluation methods."
>
> "Benchmarking produces information that administrators, policy-makers, and funding agencies find useful as they make decisions as to what activities a federal research program should undertake and respond to demands for accountability, such as the Government Performance and Results Act."
>
> "If federal agencies use benchmarking, the wide variation in agency missions dictates that each agency tailor the technique to its own needs."
>
> "Benchmarking can produce a timely but broadly accurate 'snapshot' of a field".[55]

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[53] *Allocating Federal Funds for Science and Technology*, Committee on Criteria for Federal Support of Research and Development (National Academy of Sciences, National Academy of Engineering, Institute of Medicine, National Research Council), National Academy Press (Washington, D.C., 1995).

[54] *Experiments in International Benchmarking of US Research Fields*, Committee on Science, Engineering, and Public Policy (COSEPUP), (National Academy of Sciences, National Academy of Engineering, Institute of Medicine, National Research Council), National Academy Press (Washington, D.C., 2000).

[55] *Ibid*, pp. 1-2.

The study also concluded that benchmarking seem well suited to "identifying institutional and human-resource factors that are crucial to maintaining leadership status in a field."[56]

It is worth noting here that the Report of the Auditor General of Canada outlining the attributes of well-managed R&D organizations is based on a benchmarking exercise that identified best practices in a number of organizations, including US R&D and RSA organizations such as National Institute of Standards and Technology (NIST), Office of Research and Development of the US Environmental Protection Agency (EPA), and the Army Research Laboratory (ARL).

National Research Council (NRC): Several NRC institutes have used benchmarking as an evaluation and policy tool, to measure performance against leading international and national institutes in similar fields. These studies have typically focused on issues of how other similar organizations manage their resources, conduct partnership arrangements, seek out and secure funding for their research work, recruit and retain highly qualified personnel, and maintain and upgrade their facilities and equipment. Three examples of these strategic benchmarking studies are as follows.

In 1999, the Canada Institute for Scientific and Technical Information (CISTI), carried out a comprehensive benchmarking study which compared CISTI's strategic and management practices, policies, partnerships, client relations, marketing activities, and impacts to nine different organizations (in the U.S., U.K., Australia, and Taiwan). The results of this benchmarking study provided feedback on best practices (and lessons learned, what works and what does not work) for senior management.

In a similar study carried out in 1998 for the Institute for Aerospace Research (IAR), several areas for improvement in management practices were recommended based on benchmarking findings in four organizations similar to IAR, in the U.S., U.K. Netherlands, and Australia. Through this benchmarking study improvements were identified in customer relations, strategic management processes, partnerships, human resource development, communications and marketing.

Finally, NRC is now conducting another international benchmarking study for its five biotechnology institutes. This benchmarking study is being carried out as part of a comprehensive evaluation of biotechnology research carried out by NRC. As noted in Section 3.1, performance benchmarking—comparison of the outputs and impacts of NRC institutes with other comparable organizations—is part of the regular program evaluation of every NRC institute.

Exhibit 3-5 suggests how a "best practice" in international benchmarking might work.

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[56] *Ibid*, p. 27.

Exhibit 3-5: Evaluating S&T Opportunities and Making International Comparisons: How it Might Work, An Example From the U.S.[57]

> Every five years, panels are convened to evaluate the fields in each major area of science and technology (e.g., physics, biology, electrical engineering), their standing in the world, and the resources needed to reach and maintain world-class position. Evaluation focuses on outputs, such as important discoveries, and also on certain benchmarks of best practice, such as number of scientists and engineers and their training or the current state of the laboratories and research facilities. To avoid conflicts of interest, at least half of the panel will include a few nonscientists plus experts from fields outside but related to the fields being evaluated. The panel will also include specialists in the evaluated fields who are recruited from the United States and foreign countries. If any field within a major area is performing below world standards but is judged to be a national priority, the panel will recommend that its budget be augmented or other changes made to bring it up to par. At the same time, the panel will identify the other fields with declining scientific opportunities and obsolete federal missions from which resources should be reallocated. Opportunities for international cost sharing will be examined to achieve optimal use of federal funds devoted to science and technology. The National Science and Technology Council or its equivalent will commission evaluations. The President and presidential advisors will make the selection of fields for clear U.S. leadership from among those recommended by the panels as part of the budget process. ...

Health Canada (HC): International benchmarking is a measurement tool used by HC, although more on an *ad hoc* basis. Areas in which international benchmarking has been particularly relevant for HC is in comparing regulatory and standards practices. For example, in its activities with CODEX Alimentarius, which oversees international food codes for consumer health protection, benchmarking is an important tool for measuring quality and relevance of HC's interventions/activities. Similarly, another area in which international benchmarking has been used by Health Canada is related to food radiation issues and research.

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[57] *Experiments in International Benchmarking of US Research Fields*, op.cit., page 47.

3.4 Measurement of Excellence: Bibliometric Methods

The most basic literature-based technique for measuring excellence is counting publications. The bibliometric method aggregates publications by individual, group or institution. Publication counts constitute a key (though partial) element in evaluations and their use is prevalent in Canadian government SBDAs. While relatively easy to count, it is a harder task to determine the significance of publications especially if the questions of quality and impacts are involved. Nonetheless, publication counts can be good indicators of excellence – for example, if tied to the peer review element in publication by examining the numbers of accepted articles in the three top journals in a particular field.

Given the limitations of publication counts, evaluative bibliometrics has also traditionally relied on citation analysis, to determine, for example, the degree of relevance of the work to the research community. This technique rests upon the fact that scientists cite earlier publications because the work contained in them is, in some way, relevant to their own. While bibliometric methods are used to supplement peer reviews, they are rarely used as the sole method for assessing quality. Other bibliometric methods occasionally used include journal impact factor analysis, co-citation analysis, and co-authorship analysis.

Department of Fisheries and Oceans (DFO): The Science Sector of DFO has used bibliometric analysis to determine its level and quality of scientific production. An overview of the volume of production of scientific publications by Fisheries and Oceans Canada from 1980 to 1996 was commissioned by DFO and published in November 1999. The results shown were drawn from the bibliometric data of the *Observatoire des sciences et des technologies* (OST). The scientific publications included in the database used for the report are not the only aspect of the departmental effort in the area of science. However, they represent the most visible aspect of its work for the Canadian and international scientific communities. They are relatively easy to quantify and therefore produce reliable indicators of the department's research effort and the collaboration networks to which it belongs.[58]

Health Canada (HC): HC uses bibliometric methods (based on counts of publications and citations) for appraisals and promotion. Mostly this is done at the project completion stage of the R&D work.

Environment Canada (EC) and National Research Council (NRC): Both EC and NRC have also used bibliometric methods to measure the excellence of its work. *Observatoire des sciences et des technologies* (OST), as with DFO, has undertaken and published department-wide bibliometric analysis on behalf of EC and for institutes of NRC.

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[58] *Scientific Production by Fisheries and Oceans Canada,* Observatoire des sciences et des technologies, November 1999.

3.5 Measurement of Excellence: Advisory Committees

The use of advisory committees has become very prevalent in Canadian SBDAs. At all levels of management, science and technology advisory committees have been involved in shaping government programs and policies. Advisory councils provide SBDAs with technical and non-technical advice on a wide spectrum of issues involving matters such as technology transfer, risk management, recruiting policies, governance, resource prioritization, international trends in science, sustainable development, ethics, communications, and public concerns. There are also advisory committees that have provided advice on cross-government S&T issues and strategies concerning, for example, climate change, biotechnology, geomatics, northern science, and space.

As a method to ensure excellence in government S&T (relevance and quality), advisory committees are usually made up of members who are expert scientists, stakeholders, clients, and/or users. During the 1990s, federal government SBDAs have increasingly used advisory committees as a feature of their management system.

National Research Council (NRC): NRC has a long tradition of seeking external advice. NRC has established a corporate vision founded on being a key element in Canada's innovation system, and a national S&T organization responsive to the needs of partners and clients in the private sector, universities and government in communities and regions across the country. To realize this vision, NRC allies itself with the needs of its stakeholders, partners and clients. NRC realizes that external feedback is a recognized ingredient for excellent organizations. In 1995, the governing Council of NRC approved a comprehensive Advisory Policy reflecting the new NRC research programs and management framework, based on a portfolio of technology groups, specific technology centres, and the research institutes. In 1997, the Policy was revised to reflect further changes in the NRC program structure.

The NRC Advisory Policy (as of June 2000) is now aimed at aligning NRC's advisory system and procedures with the NRC program and management framework; and defining the components, roles and responsibilities of an advisory system which provides NRC's governing Council and managers with direct client and peer input. The Advisory Policy is also intended to help enhance linkages between the various advisory efforts of the different programs and institutes within NRC.[59]

In addition to defining the roles and responsibilities of members of advisory committees, the Advisory Policy includes a "conflict of interest code" with principles in how the members should carry out their duties. Interestingly, the Advisory Policy also includes a built in evaluation requirement of the policy itself: "This Policy will be evaluated in terms of its effectiveness and the achievement of its stated objectives."

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59 *NRC Advisory Policy, June 2000*, Secretary General of National Research Council.

The governing Council of NRC meets three times per year, and there are normally an additional three meetings of the Executive Committee each year. The Council is viewed by NRC staff as providing a valuable outside perspective on its activities. Planning for Council meetings is linked to NRC's key strategic management processes, including the assessment cycle.

Department of Fisheries and Oceans (DFO): The official mandate of the DFO Science Advisory Council is "to provide advice to the Department on broad strategic matters in science and technology". It advises the ADM Science and the ADM Oceans (who has responsibility for some science activities) on the Department's science program. Its role is to act as an external source of review of the program and to raise "probing questions" regarding what research is being done (e.g., the relative emphasis on different areas of research), why, and how it is being done (e.g., why certain research is not being done in universities).

The Council meets three to four times per year, sometimes by conference call. The meetings involve the discussion of various aspects of the Department's research program at an overview (strategic) level. The Council also gets involved in research planning. For example, they participated in the recent strategic planning exercise for the research program together with the science managers.

The recommendations of the Council are forwarded to the Deputy Minister. The Department also uses the Council as a source of advice between meetings.

Natural Resources Canada (NRCan): The main method for identifying needs and incorporating critical issues into the planning process at NRCan is the use of advisory groups and committees. The senior advisory group in the Energy sector is the National Advisory Board for Energy S&T (NABEST). NRCan, moreover, has an S&T advisory group for each of the sectors in which they are active—energy, minerals and metals, earth sciences, and forestry. NABEST provides input into the overall Departmental S&T strategic plan.

Below NABEST there are industry technical advisory groups (TAGs) for most of the technical areas in which they are active—e.g., hydrogen. There are also steering committees (Consortia Steering Committees) involving industry representatives for the Department-industry consortia. Client groups participate on committees in the planning process at all levels.

There are also advisory groups for NRCan's other sectors, as well as a Ministerial Advisory Council made up of representatives of each of the sector advisory groups. This Minister's Advisory Council on S&T provides advice to the Minister on horizontal strategic issues relating to S&T in the natural resources sector. This is an "umbrella" organization with a three-fold role: to provide advice on strategic S&T issues of a horizontal government nature that affect NRCan; to provide advice on S&T issues from a client perspective; and to provide advice on strategic issues common to the four sector boards that could benefit from a broader perspective. This Council meets twice per year. The meetings of the sector boards vary from once per year to three times per year, depending on the board. Note that this means that some people are attending five meetings per year, and almost all members of the Council are attending at least three meeting per year.

Agriculture and Agri-Food Canada (AAFC): The official mandate of the AAFC Research Branch Advisory Committee is: "to provide advice and counsel on research and development priorities and programs to the Research Branch.... The RBAC will provide a focus for food and agricultural research priority setting to support the competitiveness of the agri-food sector by: identifying broad research needs; reviewing research activities; and recommending a balanced response to both regional and national needs."

The Committee consists of 10 industry representatives and three senior people from the Department. A representative from the Canadian Agricultural Research Council serves as an ex-officio member. It is chaired by one of the industry representatives. The ADM, Research, serves as the Co-Chair. Members of the Council are appointed as individuals, not as representatives of organizations. The members are selected to be people who have some involvement with one of the four business lines of the Research Branch of AAFC (Resources, Crops, Animal, and Food Production), with the representation from each of these areas roughly proportional to the Research Branch's effort in the area. There is also an attempt to have balanced representation from the different regions.

3.6 Measurement of Excellence: Other Methods

User and Client Surveys: It is difficult to conceive that any initiative to assess the excellence produced by an SBDA would exclude some assessment by users and clients of the scientific work produced. The measurement of quality and relevance of S&T, conducted by SBDAs, needs to include the feedback of users and clients.

Surveys, in the measurement context of this study, are systematic ways of collecting primary data—quantitative, qualitative or both—on the process and/or results from people (or objects such as files) associated with an S&T program, project or service (examples of government S&T services are provided by RSA organizations such as Canadian Hydrographic Service and Meteorological Services of Canada). The term "survey" is used here to refer to a planned effort to collect needed information from a relevant population (scientists, users, stakeholders, clients, etc.). When properly conducted, a survey offers an efficient and accurate means of getting answers to key issues about S&T initiatives (related to process or results).

Surveys are usually done by SBDAs on an occasional basis at various levels of interest—i.e., clients, stakeholders, experts; with regional, national, or international scope; and in context of program or project activities, and/or in relation to organizational sub-entities within the SBDAs. Client, stakeholder, and user surveys are done by Health Canada, for example, at the bureau and directorate levels. These surveys help determine the effectiveness of programs delivered by the department, and identify the needs of the public as well as stakeholders in the health industries. Other ways in which surveys are used by HC include the nutrition surveys activities, which provide an up-to-date database that is being used for risk assessment activities and public health promotion programs within the department and by external partners.

Quantitative Indicators: All the SBDAs use various quantitative (and often similar) indicators to ensure and to measure excellence at different stages of their S&T work. Quantitative analysis (of numbers of publications, citations, patents, and so on) is helpful in assessing some research programs or projects, especially when the goal of the research is an incremental improvement or achievement of a known goal. But expert judgment is required to analyze the relative importance of various journals, citations, and patents—some of the basic tools of quantitative analysis. Moreover, such quantitative tools offer little information about important aspects of research programs such as the impacts on society and economy. The current judgment of practicing researchers, managers, policy experts, and users of research is needed to answer such questions as where the most promising ideas are emerging, where to find the best new scientific talent, and what the comparative quality of research facilities in different areas is. Nonetheless, generally speaking, some of the basic indicators that seem to be most often used by SBDAs to measure/ensure excellence are as follows: the number of highly qualified researchers in the department; the number of external contracts/collaborations; number of papers produced; number of patents; citations; honours, invitations, and awards; technology transfer results (e.g., private sector spin-offs from government R&D work).

Most of the SBDAs examined have either developed, or are in the process of developing "department-wide" key indicators, to provide an overview of the excellence of the S&T conducted by their department (such as expenditures on research and development; personnel working in S&T research; and research output – i.e., publications, patents).

In some groups within federal government departments (particularly RSA organizations), gathering quantitative indicators is a core activity that is ongoing (as a part of their mandate). For example, at Health Canada, the Research and Method Development work involving quantitative indicators in the Food Program is a core activity. The research is done to generate information and data that is essential for other Food Program activities, such as policy development, standards setting, risk assessment and surveillance. Developing relevant quantitative indicators are an important part of this work, but it is in fact the product of the research. In this work, for example, one of the key clients of HC for method and indicator development is the Canadian Food Inspection Agency (CFIA). The role of HC in support of the CFIA's compliance and enforcement activity is identified in the Canadian Food Inspection Agency Act. The appropriate methods and indicators need to be available to the CFIA to carry out its mandate. Similar examples can be found of quantitative indicators as a core activity area in the Canadian Hydrographic Service (e.g., for the Coast Guard as a client), and in Meteorological Services Canada (e.g., for NavCanada as a client). In these cases, the quantitative indicators themselves are the product of the S&T work. As such, these indicators can be evaluated in terms of their accuracy and consistency with similar benchmarked information, making comparisons against "world class" or best standards. The degree of accuracy and the relative deviance from benchmarked indicators is how excellence is measured in these instances.

Socio-economic and benefit-cost studies: Approaches to measure the socio-economic impacts of S&T programs and projects are challenging, but the methodologies for carrying out these studies have improved considerably since the mid-1980s. Long time lags often exist between R&D outputs and the actual acceptance and use of any resulting technology. By their very nature research activities are not always repetitive; and by the time an R&D program outcome can be properly assessed, the program has usually moved on to new research. R&D work usually contributes only a small part of the total effort required to see new knowledge, or a new product or process fully developed and internalized in the marketplace or organization for which it was developed.

In spite of these challenges, Canadian federal SBDAs do use socio-economic and benefit-cost analysis to assess the impacts of their S&T activities. Of the SBDAs studied, NRC, NRCan, and AAFC are the most frequent users of socio-economic and benefit-cost analysis methods for studying the results of their work. For example, several comprehensive benefit-cost analyses were undertaken by CANMET and CETB over the last several years. NRCan has also done many *case studies* to examine socio-economic impacts of its S&T work. *Ex-post* and *ex-ante* impact evaluations involving external clients have been undertaken within CETB.

NRC has been very active in developing and testing methodologies for conducting socio-economic and benefit-cost analyses, most recently including methodologies for assessing the impacts of advice and assistance provided by government researchers. Environment Canada has carried out several studies on a pilot basis dealing with the socio-economic impacts of public-good-oriented R&D.

3.7 Provincial Organizations

Centre de recherché industrielle du Quebec (CRIQ): Scientific merit is examined at CRIQ research facilities at the pre-project stage, to identify potential quality of the results and relevance. The project selection process involves recommendations of committees (chaired by respective, relevant directors within CRIQ—i.e., R&D, product testing and certification, standardization). Some market research is done on an ad hoc basis, and client satisfaction studies are done regularly to ensure relevance and quality of CRIQ services. Generally, CRIQ official say that the organization tends to adhere to ISO quality management standards, and this is one way for ensuring and measuring excellence of its services.

InNOVAcorp: Scientific excellence at InNOVAcorp is but one variable amongst many that determine whether InNOVAcorp will advise, incubate or invest in a given enterprises—the others being contained in their business model (e.g., including equity analysis, venture management, expected return on investment, market analysis, entrepreneurships, and so on). Having said this, scientific merit plays a key role in the decision-making process at InNOVAcorp in the sense that any given venture must have a marketable product or service, often requiring excellence. The balance between the necessity for "good science" and "good business" does not follow a set formula, but is instead evaluated on a case-by-case basis.

Scientific excellence is measured by InNOVAcorp in a variety of ways:

- many of the enterprises are "graduates" from the IRAP program of NRC, where excellence is presumed to be a requirement for participation;
- there is some limited internal expertise in a variety of areas that can assess, in a non-technical way, the "fit" for potential clients (i.e., several InNOVAcorp personnel hold Doctorates in supported fields such as engineering technology, pharmacology, and so on);
- InNOVAcorp will act as a facilitator to convene external peer groups, such as from universities, other government research institutes (e.g., NRC) and industry, to determine viability (and chances of achieving success/excellence) of projects/initiatives to be funded.

Alberta Research Council (ARC): Scientific merit is expected to be present at ARC throughout the various S&T stages, but R&D achievement is measured primarily on the basis of success in developing new intellectual property, namely:

- licensing of new technology;
- "spinning-out" new companies and service-based activities (consulting firms, venture funds, mentors/consultants);
- "spinning-in" (into ARC) applications of technology from others; and
- moving people and skills (technology transfer) to realize incremental improvements in products and processes.

Relevance is assessed throughout the S&T process through the use of client relationships and advisory committees. Customer/client satisfaction is measured, following project completions, with client surveys that are designed to address the needs of the 17 ARC business units. In addition, impact studies are done through interviews with several of ARC's joint research venture clients. These surveys and interviews are used to obtain feedback on projects, as well as to increase the volume of client services.

A benefit-cost analysis was completed in 1999-2000 for several projects in the Agriculture division of ARC. The results of this analysis are currently being reviewed by officials in the Agriculture Division of ARC. A similar study for the Forestry Division is planned for 2001.

"Descriptive impact studies" (i.e., case studies) are carried out for all major completed projects. In these studies, ARC tries to get information on jobs created, impacts on exports, and sales impacts. These indicators are used in ARC's annual performance reports.

ARC has participated in two major international benchmarking studies. In 1995-1996 it participated in the World Association of Industrial and Technological Research Organizations (WAITRO) study on best practices for the management of research and technology organizations; and in 1998 it commissioned a major benchmarking study to compare itself to thirteen leading R&D organizations—eight Canadian-based and five foreign-based. As a result of ARC's experience with benchmarking and cost-benefit analysis it has been able to develop and tabulate some relevant quantitative indicators of impacts, including jobs created and sustained, wealth generated, and exports.

IV What Have We Learned?

What is different about federal government SBDAs?—While in many ways SBDAs are just the same as any other government department, there are some principal characteristics that differentiate them.

SBDAs are knowledge-based organizations that require systems and mechanisms to create, store and communicate knowledge of a highly technical and specialized nature. Often this knowledge is frontier knowledge, requiring new approaches and methods to break new grounds along the R&D continuum from invention, to prototype, to commercialization.

SBDAs require a very high investment in qualified people, which involves sophisticated recruitment and retention methods and long-term commitments for developing and training expertise in specialized fields.

SBDAs require a very high investment in technology (equipment and facilities), which involves long-term commitments in funding for maintenance and renewal of infrastructures.

Because of the long-term commitments to ensure that qualified people and technology are available inside SBDAs, these organizations consequently have longer planning time frames than other government organizations. The requirement for credible information on real and potential results, and assessments of relevance and quality, are very critical for SBDAs to develop excellence in the S&T that they conduct.

The Return on Investment (ROI) is significantly harder to measure for SBDAs in comparison to other government organizations. The returns are often based on long-term impacts of the R&D work, and hence many socio-economic benefits are difficult to attribute to specific government program or project results, since they mature typically over several years. On the other hand, RSA work is sometimes quite focused and based on short-term results or is service oriented. In this case, measurement of excellence is more direct, and perhaps based more on the *accuracy* of the results of RSA work (e.g., weather forecasting, marine or air navigational data) from the point of view of the users, rather than on a measurement of *scientific merit* from the point of view of experts in the scientific community (although both are very important and are necessary conditions for achieving excellence).

A renewed focus on relevance—If there is a trend to be observed, in the mechanisms and measures of excellence that are present in government SBDAs in Canada, it is that relevance is now expected to be demonstrated in a very tangible way as part of the S&T management process. It is not always possible to do this in quantitative terms, but a case (a justification) for the research has to be made as part of the management and planning process. Ensuring relevance of S&T within a government SBDA is in part a matter of making appropriate decisions within a strategic and business planning framework that is linked to the mandate of the organization. Government SBDAs in Canada have become very adept at producing strategic and business plans over the past few years. All the organizations reviewed for this study have articulate plans that identify S&T priorities over short and long timeframes. These plans do appear to provide clear directions towards relevant S&T programs and projects. The successful planning processes, however, appear to be the ones that have clearly articulated linkages between strategic requirements of stakeholders and clients (internal and external to government) with their individual work programs. Those organizations able to convincingly build project priorities, based on real and perceived needs of stakeholders and clients, appear to have best practice planning processes in place.

Leadership—Generally, leadership strength in government SBDAs manifests itself in the use of best practices for strategic and business planning processes. These best practices appear to be those that emphasize project-oriented and results-based priority setting processes that engage the scientists and managers of S&T projects, and that respond to the demands of stakeholders and clients (within and without the research establishment). Broad strategic statements and directions of government and industry tend to be seen by the scientists and project managers as long-term frameworks developed by policymakers that may or may not know the intricacies of the S&T research challenges. The extent to which the scientists and S&T project managers feel that the strategic plans reflect the intricacies of their science is the extent to which they buy-into the broad objectives, and develop relevant projects that address these objectives.

Convergence of "top-down" and "bottom-up" management processes—As we consider the strengths of the federal SBDAs in ensuring excellence, one of the features of the current systems that are in place for managing science and technology programs and projects is the combination of "top-down" mission-oriented management with "bottom-up" investigator-initiated research projects. Increasingly over the past five-years or so (in the post "program-review" era) this has become more of a norm within the SBDAs examined in this study. The combination of these two approaches has created a powerful research and development planning and prioritization environment that is seen as one of the strengths of the emerging environment of government S&T.

People management—A significant weakness consistently raised by scientists and managers within the SBDAs, is that the S&T groups and laboratories within government are constrained by having to play by the same rules of other government human resources systems. Scientists and science managers are subject to the same policies that apply across the government. For example, salary freezes a few years ago had a big effect on job attrition. The process of recruiting highly qualified personnel for S&T is much more strategic and long term in nature, and requires a significant investment of time and effort to recover from down periods as experienced during the past decade or so. It was suggested that the old job classification system for scientists was antiquated, and this did not help the recruiting/retention issue. Notwithstanding, it was also suggested that the new Universal Classification System (UCS) does not sufficiently take into account issues of recruitment and retention of scientists in a highly competitive science and technology job market (e.g., salaries, professional training, and flexible work guidelines).

Co-location/clusters—Co-location or clustering of government scientists with other users/clients (internal or external) is seen as a good practice for government-based S&T. For example, there are benefits to having the program and regulatory staff who deliver government program services (particularly RSA-related S&T activities) co-located with the scientists. One of the benefits, it was suggested by some of those interviewed in this study, is that this improves the planning process, keeping SBDAs focused on mandated priorities, and preventing "mission-drift". Another benefit of co-location (or clustering) is that by having scientists in close proximity with users/clients, a dynamic and purposeful work environment evolves that is more creative. It should be noted, however, that this kind of co-location (or clustering) is not possible in all cases in geographical terms. There are many exceptions (such as hydrographic services, building and construction R&D, aerospace).

Use of key indicators—The use of department-wide key indicators to complement program or project-specific indicators of excellence is an area in which SBDAs are currently evolving. Some of the key indicators being considered are in the following categories: expenditures on research and development; quantification of scientific activities; personnel working in science and technology; research output (e.g., publications, citations, patents); and selected economic indicators.

Key issues for ensuring excellence in SBDAs—There are of course many issues that were discussed on how to ensure excellence in SBDAs as presented in this report. However, the key issues that scientists and managers focused on, in the consultation process for this study, centre around the following themes: keeping the work current; the adequacy of S&T funding; making the place of work more desirable for researchers/scientists; and introducing more flexibility to allow researchers to participate in external research activities (e.g., joint projects with other scientists outside and inside government).

Use of peer review—Peer review is still an important and necessary review procedure for the assessment of ongoing government research programs, even for research programs that have a fairly applied (i.e., industry-oriented) mandate. Canadian government reviews of S&T policy, from the Lortie Review in the late 1980s to the S&T Policy Review of the mid-1990s have consistently found that peer review is an important and necessary practice for Canadian S&T departments and agencies. When possible, peer reviews are integrated with other complimentary reviews such as program evaluation. The advantage of integrating peer review with other reviews, such as program evaluation and audit, is that it places the issue of scientific achievement in the context of other issues such as program legitimacy, client relevance, and the adequacy of the management environment. This is necessary in all the departments that we studied because they are all mission-driven.

Use of international benchmarking—International benchmarking has become an increasingly used technique to measure and compare performance and results of scientific laboratories and science-based institutions. International benchmarking studies provide an opportunity to assess one country or region's leadership status in research and development against world standards of excellence. Though this approach has been *ad hoc* within federal SBDAs, it does seem to be gaining increased recognition and acceptance (e.g., at NRC).

Adopting principles for measuring excellence—In measuring excellence, the measurer should address relevant and significant questions. The method of measurement should be credible. Cost-justification should be taken into account when deciding on the method of measurement. The approach should not impinge on the actual delivery of the conduct and outcomes of the government S&T activities. More than one source of measurement increases credibility of the assessment (i.e., for credible assessment one needs multiple lines of evidence). Assessing the capacity and mechanisms available to SBDAs for achieving excellence is as important as measuring the results of S&T programs and projects.

Amount of measurement activity—A study of the measurement activities of federal SBDAs was carried out in 1993.[60] That study focused primarily on the measurement of relevance and impacts, but it also dealt with the measurement of quality. In comparing the findings from the current study with the 1993 study, we found that, in general, the amount and quality of measurement activity within federal SBDAs has increased over the past seven years. Those departments that were the most active in 1993 are still the most active, but they have broadened the scope of their measurement activities and improved their methodologies—to include, for example, measurement of the indirect impacts of research. Those departments that were doing very little in 1993 have now embarked on the development of more systematized measurement policies—for example, through the development of guidelines on using performance measurement and the conduct of pilot projects.

60 *Methods for Assessing the Socio-Economic Impacts of Government S&T*, the ARA Consulting Group, May 1993. See, in particular, Appendix B, which summarizes the practices of six federal SBDAs.

Appendix A: List of Documents Reviewed

- *Allocating Federal Funds for Science and Technology*, Committee on Criteria for Federal Support of Research and Development (National Academy of Sciences, National Academy of Engineering, Institute of Medicine, National Research Council), National Academy Press (Washington, D.C., 1995).
- *An Indicator of Excellence in Canadian Science: Summary Report*, Preface by Martin B. Wilk (Chief Statistician of Canada), by James B. MacAulay, Statistics Canada, May 1984.
- *Building Excellence in Science and Technology (BEST): The Federal Role in Performing Science and Technology*, a report of the Council of Science and Technology Advisors, Ottawa, 1999.
- Chapter 22 of *Report of the Auditor General of Canada,* Ottawa, November 1999.
- *Compendium of Science and Technology Management Practices*, Natural Resources Canada, March 1997.
- *Development Resource Guide: R&D Management Positions*, National Water Research Institute, Environment Canada, 1998.
- *Driving Growth through Recruiting Excellence*, Best Practices, LLC, (www.benchmarkingreports.com), 2000.
- *Evaluation of Research: A Selection of Current Practices*, Organisation for Economic Co-operation and Development (OECD) (Paris: 1987).
- *Experiments in International Benchmarking of US Research Fields*, Committee on Science, Engineering, and Public Policy (COSEPUP), (National Academy of Sciences, National Academy of Engineering, Institute of Medicine, National Research Council), National Academy Press (Washington, D.C., 2000).
- *Food Directorate Renewal Initiative: Results of Strategy Planning Workshops*, Health Canada, November 9, 2000.
- *Objective-Based Fisheries Management: An Evolution of the Integrated Fisheries Management Planning Process*, DFO presentation deck, October 20, 2000.
- *Managers' Guide to S&T Impact Assessment*, Natural Resources Canada, 1997.
- *Methods for Assessing the Socio-Economic Impacts of Government S&T*, the ARA Consulting Group, May 1993. See, in particular, Appendix B, which summarizes the practices of six federal SBDAs.
- *NRC Advisory Policy, June 2000*, Secretary General of National Research Council.

- *Precautionary Approach to Fisheries Resource Conservation: Conceptual Framework*, prepared by Fisheries Research Branch, Science, Fisheries and Oceans, November 2000.
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Appendix B: List of People Consulted

Agriculture and Agri-Food Canada

- Brian Morrissey, Assistant Deputy Minister, Research Branch
- Bruce Mitchell, Director General, Research Planning and Coordination Directorate
- Ashley O'Sullivan, Director, Saskatoon Research Centre
- Edmund Mupondwa, Research Scientist, Economic and Market Research
- Bruce E. Coulman, Head, Forage Crops Section
- Neil Westcott, Section Head, Crop Utilization
- Kevin Falk, Research Scientist, Oilseed Breeding

Department of Fisheries and Oceans

- John C. Davis, Assistant Deputy Minister, Science
- Brian Wilson, Director General, Program Planning and Coordination Directorate
- Howard Powles, Director, Fisheries Research Branch
- Joanne Hamel, Canadian Stock Assessment Secretariat
- Don Bowen, Marine Fish Division
- Allan Clark, A/Manager, Ocean Science Division
- Larry Marshall, Diadromics Division
- Don Gordon, Research Scientist, Ocean Science
- David Piper, Geographical Survey (works for NRCan)
- Dick McDougall, Director, Hydrographic Survey Atlantic
- Tony O'Connor, Director General, Canadian Hydrographic Service
- Jake Kean, Manager, Planning, Canadian Hydrographic Service
- Karen Davidson, Science Coordinator, Science

Environment Canada

- Marc-Denis Everell, Assistant Deputy Minister, Meteorological Services of Canada
- Ken Sato, Director General, Ecosystem Science
- Duncan Hardie, Director, Science Policy Branch
- John Carey, Executive Director, National Water Research Institute
- Rod Allan, Associate Executive Director, National Water Research Institute
- Mark McMaster, Research Scientist, National Water Research Institute
- Murray Charlton, Project Chief, National Water Research Institute

Health Canada

- Diane Gorman, Assistant Deputy Minister, Health Products and Food Branch
- Kata Kitaljivich, Senior Advisor, Science Advisory Board Executive Secretariat
- Laure Benzing-Purdie, Senior Research Coordinator, Health Canada
- Peter Fischer, Chief, Nutrition Research Division, Food Directorate

- G. Sarwar Gilani, Research Scientist, Nutrition Research Division, Food Directorate
- Kevin A Cockell, Research Scientist, Nutrition Research Division, Food Directorate
- Nimal Ratnayake, Research Scientist, Nutrition Research Division, Food Directorate
- Robert Pearce, Biologist, Nutrition Research Division, Food Directorate

National Research Council

- Lucie Lapointe, Secretary General and Director General, Corporate Services
- Rob James, Director, Planning and Assessment
- Ann Cooper, Planning and Assessment
- George Iwama, Director General, Institute for Marine Biosciences
- Laura Brown, Research Officer, Microbiology, Institute for Marine Biosciences
- Santosh Lall, Group Leader, Aquaculture Biotechnology
- Senior Research Officer, Fish Nutrition, Institute for Marine Biosciences
- Bob Boyd, Principal Research Officer, Institute for Marine Biosciences
- Denise LeBlanc, Group Leader, Biochemistry of Marine Toxins
- Dennis Salahub, Director General, Steacie Institute for Molecular Sciences

Natural Resources Canada

- Bryan Cook, Director General, Energy Technology Branch
- Robert Philp, Senior Advisor, Energy Technology Branch
- Yvan Hardy, Assistant Deputy Minister, Canadian Forest Service
- Allan Dolenko, Deputy Director, CANMET Energy Technology Centre
- Sylvain Coulombe, Deputy Director and Manager, Operations
- Rob Brandon, Project Manager, Community Energy Systems Group
- Rachelle Yazdani, Manager, Characterization Laboratory

Alberta Research Council

- Surinder Singh, ARC Planning Coordinator

Centre de recherche industrielles du Quebec

- Pierre Baril, CRIQ

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- Steven Armstrong, Director, Life Sciences
- Lucy Ellen Kanary, Director, Advanced Materials and Engineering

Appendix C: Approaches for Government Support of R&D

Approaches for Government Support of R&D

There are a number of ways by which the Canadian federal government supports R&D. **In-house R&D** is done by the federal government in its own laboratories and by its own researchers. With **contracts**, R&D is performed by an organization outside the department or agency that requested it. To aim for excellence, the required standards of performance are (or should be) specified in the contractual arrangement. **Contributions** are similar to contracts in that R&D is carried out outside the department or agency that is funding it. Contracts and contributions require agreements between the government and contractors or contribution recipients, respectively, specifying the terms and conditions under which funds will be paid. Payments are conditional on performance or achievement, and use of the funds provided is subject to audit. Day-to-day control over the R&D activities is entrusted to the contractor or contribution recipient, subject to stipulations in the agreement/contract.

Grants are similar to contributions except that for grants there are usually no explicit constraints on the expected results to be achieved by the organization being funded. A grant is an unconditional payment to a recipient and government does not necessarily receive any direct services as a result. However, there are specific eligibility conditions that prospective grant recipients must meet. The funded organization must produce results that are compatible with the general objectives of the granting department or agency.

General incentives (such as tax incentives) are somewhat like grants in that they constitute an unconditional payment to a recipient, and government does not necessarily receive any related services from the recipient. However, for general incentives there are no specific eligibility conditions which recipients must meet, only general eligibility conditions (e.g., being a Canadian company doing R&D). **Procurement policies** regarding the acquisition of goods (e.g., scientific equipment), or of specialized technical services are also a means by which to support R&D in the private sector. A good example of the effects of procurement is the stimulus that massive defence procurement requirements have had over the private sector in the United States.

The Canadian federal and provincial governments provide opportunities to deliver R&D and RSA using all the approaches described above. This report, however, was focused on practices for measuring and ensuring excellence only of **in-house** government S&T.

Appendix D: List of Acronyms

ACRONYMS

AAFC	Agriculture and Agri-Food Canada
AOAC	Association of Official Analytical Chemists
ARC	Alberta Research Council
ARL	Army Research Laboratory
ADM	Assistant Deputy Minister
BEST	Building Excellence in Science and Technology
CARC	Canadian Agri-Food Research Council
CCEU	Cabinet Committee on Economic Union
CETC	Centre of Energy Technology Canada
CFIA	Canadian Food Inspection Agency
CFS	Canadian Forest Service
CHS	Canadian Hydrographic Services
CISTI	Canada Institute for Scientific and Technical Information
CMHC	Canada Mortgage and Housing Corporation
CNF	Canadian Nutrient File
COSEPUP	Committee on Science, Engineering, and Public Policy
CRIQ	Centre de recherche industrielles du Quebec
CS	Chief Scientist
CSAS	Canadian Stock Assessment Secretariat
CSTA	Council of Science and Technology Advisors
DFO	Department of Fisheries and Oceans
DM	Deputy Minister
DMC	Deputy Minister Committee
EC	Environment Canada
EDS	Endocrine Disruptor Substances
EPA	Environmental Protection Agency
EPF	Energy Priority Framework
ETF	Energy Technology Futures
GHG	Greenhouse Gas
GDP	Gross Domestic Product
GPRA	Government Performance and Results Act
HC	Health Canada
IAR	Institute for Aerospace Research
IFMP	Integrated Fisheries Management Plans
IMB	Institute for Marine Biosciences
IMS	Institute for Molecular Sciences
INMS	Institute for National Measurement Standards
IRC	Institute for Research in Construction
ISO	International Organization for Standardization
KPI	Key Performance Indicators
MII	Matching Investment Initiative
MSC	Meteorological Services of Canada
NABEST	NRCan Advisory Board on Energy S&T

NGO	Non-Government Organization
NIST	National Institute of Standards and Technology
NRC	National Research Council
NRCan	Natural Resources Canada
NRD	Nutrition Research Division
NWRI	National Water Research Institute
OAG	Office of Auditor General
OST	Observatoire des sciences et des technologies
PERD	Program on Energy Research and Development
PMP	Project Management Process
POL	Program Objective Level (plans)
R&D	Research and Development
RBAC	Research Branch Advisory Committee
ROI	Return on Investment
RSA	Related Scientific Activities
S&T	Science and Technology
SAB	Science Advisory Board
SAGE	Science Advice for Government Effectiveness
SBDA	Science-Based Departments and Agencies
SIMS	Steacie Institute of Molecular Science
SMS	Study Management System
SPSP	Scientific Priority Setting Process
SRC	Saskatoon Research Centre
STCD	S&T Companion Document
STFP	S&T Forward Plan
TAG	Technical Advisory Group
UCS	Universal Classification System