CANADA

Report of the
National Advisory Board
on Science and Technology

FEDERAL SCIENCE AND TECHNOLOGY EXPENDITURES COMMITTEE

Presented to the
Prime Minister of Canada

Revitalizing Science and Technology in the Government of Canada

The Report of the Committee on Federal Science and Technology Expenditures

CANADA

National Advisory Board on Science and Technology

Conseil consultatif national des sciences et de la technologie

November 2, 1990

The Right Honourable Brian Mulroney
Prime Minister of Canada
House of Commons
Room 309-S
Ottawa, Ontario
K1A OA6

Dear Prime Minister:

I am pleased to submit the final report of the Committee on Federal Science and Technology Expenditures which was unanimously endorsed by the general assembly of NABST at its May 27, 1990 meeting in Edmonton.

Our central conclusion is that departments' science and technology establishments are burdened with a system of operating and administrative policies that are seriously deficient in many respects. This makes it unnecessarily difficult for departmental intramural science and technology activities to meet the quality and productivity standards that should be expected of them.

We cannot overemphasize the negative consequences of these deficiencies. Intramural S&T activities inform crucial policies in almost every sector where the federal government is involved and produce unique, large and sophisticated public knowledge infrastructures which underlie both government and business decisions. The enterprise, which cost $1.6 billion in fiscal 1989-90, represents a substantial part (14%) of Canada's overall R&D effort.

The Committee believes that the situation can be corrected by adopting operating and administrative policies that conform to the best practices of leading organizations in the management of science and technology.

240 Sparks St., 8th Floor West
Ottawa, Canada K1A 0H5

The Committee focused on the **major dimensions** that are key to the successful performance of large R&D organizations:

1. **A Clear Mission** - essential to the vitality of any S&T establishment and to ensuring that precise goals can be set and performance measured against them;

2. **Organizational Structure** - a key element because quality and relevance depend on creating a visible and distinct organization that builds upon and leverages the scientific culture of its scientists and engineers while, at the same time, linking S&T establishments very tightly to the other parts of government. It is also required to facilitate productive relationships with universities, business and other scientific organizations;

3. **Personnel** - the most important resource upon which excellence depends;

4. **Management Processes** - crucial in creating and maintaining an environment conducive to S&T activities of high quality and relevance, particularly when resources are constrained and time-frames are shrinking.

The Committee concluded that fundamental changes are required in the organization and design of departments' intramural S&T activities and that a new management regime, one better suited to the unique nature of science and technology, needs to be established. More focused mandates, less bureaucratic and unproductive overhead, and improved management practices must be achieved. Our recommendations involve the adoption of a comprehensive management framework comprising the following **five design elements:**

1. **Institute Status:** Each department will transfer its science and technology establishments into a single science and technology institute (one per department) under the charge of a board of directors and under the direction of a chief executive officer. Establishments within an institute may retain their separate identity.

2. **Contractual Relationships** between the department and its science and technology institute. The department will enter into several contracts with its science and technology establishments for the scientific and technological services it requires to achieve its mandate and program objectives and that the institute can provide efficiently.

3. **A Revenue Dependency Funding Relationship:** Parliament appropriates funds to the department for its programs, which includes the sums the department requires to obtain the S&T support and services needed to accomplish its mandate; departmental program managers in turn contract with the establishments of the science and technology institute, which is thereby revenue-dependent for operating funds.

4. **A management structure** for the science and technology institute. The institute has the authority to manage its contracts with the department, including the revenues derived from them, to enter into contracts with other clients, to own intellectual property, enter into contracting and licensing agreements, set fees and retain the earnings generated by this activity, and to carry on activities in a manner consistent with the best management practices as they apply to its science and technology responsibilities.

5. **An evaluation regime** for the institute: The board of directors and chief executive officer have explicit authority and responsibility to ensure that scientific and technological activities and personnel are evaluated in ways that promote the highest standards of excellence, responsiveness and productivity, including the use of external onsite peer reviews and other internationally recognized methods and criteria of assessment. These assessments are to be monitored by a National Panel for Quality Evaluation.

The design elements are interrelated, **and all must be present** to produce the desired results and avoid unwanted behaviour.

The Committee wishes to draw your attention to two other recommendations. First, we strongly recommend that a mechanism be put in place by the government to allow scientists and engineers in the institutes to vote every three years for 100 of their colleagues selected on the basis of outstanding scientific achievements; those chosen would constitute a pool of experts from which 25% of the membership of peer review panels evaluating the S&T institutes and their establishments would be drawn.

Second, we are convinced of the need to establish a National Panel for Quality Evaluation under the auspices of the Office of the Controller General composed of scientists and science managers of substantial stature. Their role would be to ensure that evaluations conducted in the institutes are done in accordance with international standards.

The proposed new management regime would allow the federal government to implement the more progressive elements of its science and technology policy in a more effective way. For instance, the new framework would allow for a new impetus in the implementation of its contracting-out spolicy. In particular, by requiring the new S&T institutes to charge the full cost of providing science and technology services, they would be set on a more equal footing with respect to external providers of S&T services.

Our recommendations build on scientific values that are strongly held in departmental S&T establishments, harnessing them in a manner that ensures a much closer fit between their activities and the objectives and policies of the government, thereby, considerably reducing the mission drift that occurs under existing organizational arrangements.

Our recommendations do not call for additional expenditures, nor do they question the need for restraint in the present fiscal framework. Instead, our proposal offers a more robust structure to cope intelligently with restraint, and ensure that the focus will be placed on the management and quality of these S&T activities. This will increase value for money from these activities and open the door to more productive relationships with universities, industry and other scientific organizations across the country, as well as increase transfer of technology.

The members of the Committee are at your disposal to discuss further our findings and recommendations and to assist in their implementation.

Yours very truly,

Pierre Lortie

Pierre Lortie
Chairman
Committee on Federal Science
and Technology Expenditures

PL:mg

Members of the Federal Science and Technology Expenditures Committee

Mr. Pierre Lortie, Chairman
Chairman, Royal Commission on Electoral Reform and Party Financing

Dr. Pierre Bois
President of the Medical Research Council of Canada

Dr. Robert O. Fournier
Associate Vice-president of Dalhousie University

Mr. William G. Hutchison
Partner with the firm of Ernst and Young

Dr. Geraldine Kenney-Wallace
Chairman of the Science Council of Canada

Madame Paule Leduc
President of the Social Sciences and Humanities Research Council of Canada

Dr. A.W. May
President of Natural Sciences and Engineering Research Council of Canada

Mr. James A. McCambly
President of the Canadian Federation of Labour

Dr. Pierre O. Perron
President of the National Research Council

Dr. Norman E. Wagner
Chairman of the Board of Alberta Natural Gas Company Ltd.

Dr. Douglas T. Wright
President of the University of Waterloo

Executive Director

Mr. Neil Paget
Vice-president, Canada Consulting Cresap

Acknowledgements

The committee wishes to thank the numerous persons who have helped us in conducting our investigation of the manner in which science and technology activities are performed within departments. Several officials in central agencies and departments have provided us with detailed information and advice. Their opinions formed through considerable experience were invaluable. We also want to thank the Deputy Ministers of the three departments that actively participated in the studies for their availability and continuous support.

Many scientists and engineers have provided us with their evaluation of the current situation and suggestions for improving it through the survey and by participating in various meetings. Their input was essential and was highly valued. In this respect, we thank the executives of the National Research Council for their support and for allowing NRC scientists and engineers to participate in the survey.

The leading scientists and engineers who have participated in the peer review panels have performed a remarkable job. We were lucky to benefit from the support of the Natural Sciences and Engineering Research Council and the Medical Research Council, which efficiently managed the process and ensured that it was completed within a tight time-frame.

The Committee consulted many officials and executives in Canada and abroad. In all cases, they not only made the time to meet with us but contributed valuable insights and pertinent information. We must also mention our colleagues of the National Advisory Board on Science and Technology (NABST) who participated in progress reviews in the course of our study and provided us with useful comments and suggestions on the preliminary version of our report.

Our work was facilitated by the efficient and constructive support we received from officials of the NABST secretariat and of Industry Science and Technology Canada (ISTC). The continued commitment and support of Harry Rogers, Deputy Minister, ISTC, was a key ingredient in our ability to perform our mandate.

The Committee was also supported by several advisers. The bibliometrics analysis was conducted by Dr. Roger Miller of Université du Québec à Montréal and Secor Inc. Dr. Jon Younger of Novations was instrumental in guiding our access to the senior research and development executives in large industrial organizations. Dr. Peter Aucoin of Dalhousie University contributed considerable guidance to the Committee on the legislative implications of the recommendations and their relationship to current management and accountability policies of government. Miss Lucille Fowle of Canada Consulting Cresap conducted many of the interviews, and prepared and analyzed the survey and several progress reports. Her contribution to the final report was considerable. Special thanks to Miss Kathryn Randle for her professional editing of the final report.

The Committee benefited from the advice and great skills of Neil Paget of Canada Consulting Cresap, who co-ordinated the whole project and served as its executive director.

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List of Exhibits

Guide to Acronyms and Other Short Forms

Agr	Agriculture Canada
AECL	Atomic Energy of Canada Limited
AIST	Agency for Industrial Science and Technology (Japan)
BNR	Bell Northern Research
CANMET	Canada Centre for Mineral and Energy Technology
CIDA	Canadian International Development Agency
Com	Communications Canada
CPDL	Canadian Patents and Development Limited
EC	Environment Canada
EMR	Energy, Mines and Resources Canada
F&O	Fisheries and Oceans
GM	General Motors
GOCO	government-owned, contractor-operated laboratory
HWC	Health and Welfare Canada
ISTC	Industry, Science and Technology Canada
MITI	Ministry of International Trade and Industry (Japan)
MRC	Medical Research Council
NABST	National Advisory Board on Science and Technology
NCR	National Capital Region
ND	National Defence
NRC	National Research Council
NSERC	Natural Sciences and Engineering Research Council
OECD	Organization for Economic Co-operation and Development
PY	person-year
R&D	research and development
REM	research managers
RES	researchers
RSA	related scientific activities
SC	Statistics Canada
SSHRC	Social Sciences and Humanities Research Council
S&T	science and technology
TC	Transport Canada

1.0 INTRAMURAL SCIENCE AND TECHNOLOGY: A MAJOR NATIONAL ASSET

This report is about a major national asset. It is about a system that invests $1.6 billion annually in science and technology (S&T) and employs 18 000 people. This system, made up of the S&T activities conducted intramurally by federal government departments, accounts for about 14 percent of total research and development (R&D) activities performed in Canada. Expenditures on R&D performed within federal departments, which amount to approximately $1 billion annually, are higher than total expenditures for R&D performed by the five largest industrial performers combined, which in turn account for more than one quarter of all industrial R&D performed in Canada.

This is the magnitude of the intramural S&T activities of departments in the Government of Canada. Within the departments, the enthusiasm generated by the opportunity to enhance knowledge and apply it to promote public purposes on such a scale should be vibrant. It represents a substantial investment of national resources and should be a source of pride.

Regrettably, this is not the case. Many in Canada share the view that such government-performed S&T activities are not justifiable – that they should simply be transferred wholesale to the private sector or to universities. Serious questions are raised about the quality or, more precisely, the presumed lack of quality in these activities. And generally within S&T establishments, the morale of their highly qualified personnel is low and not improving.

1.1 The Committee's Mandate

Recognizing the seriousness of these concerns, the government assigned the task of reviewing federal intramural S&T activities to the Committee on Federal Science and Technology Expenditures, a committee of the National Advisory Board on Science and Technology (NABST), in the fall of 1988.

The government sought advice on a strategic direction for its "direct involvement in the conduct of science and technology activities . . . as well as the best means to achieve its objectives." The Committee's terms of reference (set out in Appendix A) called for a focus on the effectiveness of intramural S&T, taking into account the differences inherent in the federal system. Those differences include the varying nature of intramural R&D activities, international competitiveness in various sectors, and the government's objectives and capabilities.

Government S&T policy has been reviewed on several occasions in the past two decades. A major review of science policy was completed in 1970 by the Senate Committee on Science Policy, chaired by the Honourable Maurice Lamontagne. The Gendron report of 1972 examined some of the implementation issues arising from the Lamontagne review. In 1976, the Science Council of Canada urged intensified efforts to transfer the results of government research to industry. More recently, the specific issue of effectiveness in government S&T spending was addressed by the Task Force on Federal Policies and Programs for Technology Development (1984) and the Ministerial Task Force on Program Review (1985).

Government responded to the recommendations in each of these reports. Deliberate efforts were made to improve the system through reorganizations in co-ordinating agencies and changes in government policies. The adoption of the contracting-out policy and the renewed emphasis on this approach was a direct consequence of recommendations in these reports. Follow-up on the latter two reports also took the form of the Technology Centres Policy and to date, four centres have been established. Nevertheless, it is fair to affirm that despite changes in public policy needs, in the resources available and in research management practices generally, the government's system for managing intramural scientific activities has not kept pace with the best practices of leading organizations.

The assertion by the Task Force on Federal Policies and Programs for Technology Development that the traditions of excellence and innovation that have been the hallmark of Canada's federal laboratories "are being undermined by a growing atmosphere of irrelevance and an excessively bureaucratic management style," is as apt today as it was in 1984. Many scientists and policy makers ask whether the quality and relevance of intramural R&D activities can be retained, given outdated management machinery and a shrinking funding base. The result is apprehension about the ability of these establishments to maintain the quality and relevance of their work, and hence to fulfil the public purposes and support the crucial policy decisions for which they were established.

A thorough examination of the various studies conducted over the years reveals that their chief concern has been broad science policy – the macro picture – and that they have not examined the management systems in detail. In this context the Committee was struck by the prescience of the Glassco Commission, which stated that one of the three principal reasons for the failure of the federal science policy organization to function as intended "was the failure to distinguish between high policy as the embodiment of national aspirations in the whole field of science and operating and administrative policy concerned with the running of a massive governmental apparatus. Both of these require great skills, discriminating surveillance, and advice from non-government sources, but the approaches are quite different and no common procedures will satisfy both needs."

Given the focus of prior studies and the continuing attention given to "high policies," the committee concentrated its energies on the "operating and administrative policy" dimensions. Accordingly, this report does not deal with the institutional machinery of government, whose mandate may be to formulate a comprehensive science policy and ensure that it is pursued efficiently and to co-ordinate S&T activities performed or financed by government. Nor does this report attempt to define the relationships that exist or should exist among the missions of departmental S&T establishments and other public institutions such as the National Research Council (NRC) or Atomic Energy of Canada Ltd. (AECL). These questions are important but they were not the object of our investigation. The Committee felt that its mandate, and indeed the first priority, should be to ensure that the substantial investment made by Canadian taxpayers in departmental S&T yields value and a high standard of quality.

1.2 Intramural S&T: A Perspective

Expenditures on S&T activities in all federal departments and agencies reached $4.5 billion in 1988-89. The focus of this report is limited to S&T activities in government departments; but even when the S&T spending of agencies such as NRC, AECL and the granting councils is excluded, annual expenditures on these activities remain at about $2.3 billion – a substantial figure by any measure (see Exhibit 1.1). A substantial proportion of these funds is used to contract for S&T services from industry, universities and other government laboratories. After subtracting the S&T activities which are contracted-out, the amount spent on activities performed within the departments – intramural activities – amounted to $1.6 billion in 1988-89 (see Exhibit 1.2). It is also worthy of note that federal S&T establishments are distributed across the country, a characteristic that increases the complexity of the management process (see Exhibit 1.3).

Is the figure for intramural activities too high, as some observers have suggested? Comparisons of the proportion of R&D that is performed in the government sector in Canada with that of other OECD countries show that Canada is "in the pack" (see Exhibit 1.4). Against these international benchmarks, the current situation is in line with that of other industrialized countries. The enterprise is large, but so is the significance of the decisions informed by departments' S&T activities.

Not surprisingly, the issue of how to achieve value for money from government-performed R&D activities has become increasingly important in all industrial nations in recent years. Several solutions are offered; for example, privatization is sometimes suggested as a means of achieving this end. We do not doubt that in some instances this may indeed be what should be done. However, when the objectives and purposes of S&T activities conducted within departments are examined closely, this simple proposition loses much of its appeal. It brings to mind H.L. Mencken's adage: "For every human problem there exists a solution that is simple, neat...and wrong."

The Committee was concerned with issues of knowledge and innovation flows both within government and to the private sector and with technology transfer. It examined various mechanisms by which these processes are enhanced. These questions are discussed at length in Chapter 3.

The Committee worked towards recommendations that would have a substantial impact on the system and that would address core issues associated with carrying out these activities, not tinker at the margin. Comparisons with other industrialized countries indicate that modern governments perform, and most likely will continue to perform, extensive R&D activities. Canada is no exception. Achieving the maximum value for money from this huge S&T system is therefore the primary concern of this report.

1.3 The Committee's Approach to its Mandate

The Committee started from the recognition that by national and international standards, federal laboratories constitute a large research organization that consumes significant human and financial resources which must be managed effectively for at least two reasons:

Exhibit 1.1

Federal S&T Expenditures, 1988-89

Main Department	Total S&T[1] ($ Millions)	R&D Only[2] ($ Millions)	Person Years
Agr	415	369	4 982
EC	405	71	3 887
EMR	397	175	2 755
ISTC	311	277	199
ND	272	268	1 917
F&O	229	131	2 339
HWC	150	41	1 402
Com	77	74	383
TC	35	28	120
	2 291	1 434	17 984

Main Agencies

NRC	480	427	3 465
NSERC	365	314	159
MRC	189	176	54
AECL	107	95	2 442
CIDA	79	22	57
SSHRC	76	48	97
SC	282	10	4 225
	1 578	1 092	10 499
Other	648	297	4 548
TOTAL	4 517	2 823	33 031 [3]

Source: ISTC, Science & Technology Sector, *Strategic Overview of Science and Technology Activities in the Federal Government*, 1989.

1. S&T: Includes R&D and related scientific activities (activities that complement or extend R&D by contributing to the generation, dissemination and application of S&T knowledge, e.g., surveys, data collection, processing and dissemination of information).

2. R&D: Basic and applied research and experimental development.

3. Of these, 10 881 are in scientific categories. This is 14.3 percent of the federal public service.

Exhibit 1.2

Intramural S&T Activities of Departments, 1988-89

		Personnel Engaged in S&T Activities		
Main Department	**($ Millions)**	**R&D**	**RSA***	**Total S&T**
Agr	392.0	4 399	583	4 982
Com	49.6	330	53	383
EMR	281.8	795	1 960	2 755
EC	379.0	758	3 129	3 887
F&O	220.2	1 288	1 051	2 339
ND	141.8	1 812	105	1 917
HWC	109.8	270	1 132	1 402
Total	1 574.2	9 652	8 013	17 665

Source: ISTC, *Science & Technology Sector, Strategic Overview of Science and Technology Activities in the Federal Government,* 1989.

* Related Scientific Activities.

Exhibit 1.3

Intramural S&T Activities by Region, 1986-87

Region	S&T Activities ($ Millions)	R&D Activities ($ Millions)
Western Canada	431	277
Ontario (ex. NCR)	351	195
National Capital Region	1 258	529
Quebec (ex. NCR)	229	148
Atlantic Canada	209	132
	2 478	1 282

Source: ISTC, Science & Technology Sector, *Strategic Overview of Science and Technology Activities in the Federal Government,* 1989.

Exhibit 1.4

Government-Performed R&D as a Percentage of GDP, 1985

France	.58
United Kingdom	.46
Australia	.42
Netherlands	.39
United States	.35
Canada	.34
West Germany	.34
Italy	.26
Japan	.26
Norway	.23
Sweden	.13
Spain	.13

Source: Canada Consulting, based on OECD data.

- to ensure that, in a knowledge-driven economy, government has the scientific and technical information and advice it needs to support its policy and regulatory roles; and

- so that government can make its considerable investment in intramural S&T with confidence, knowing that the funds will be used effectively and produce value for money.

The past decade has been characterized by resource constraints in intramural S&T, and this trend will no doubt continue. As a result, the current environment is placing great pressure on government S&T facilities to respond to developments in increasingly complex fields of knowledge with static or shrinking resources and within time-frames that must increasingly be compressed. It is an environment that places a premium on astute choices about where to concentrate efforts and resources to achieve maximum effectiveness and value for the S&T investment. This in turn leads directly to the central issue of quality in the performance of intramural S&T activities.

Concern about the quality of intramural S&T is not an academic issue, nor is quality something that should be pursued for its own sake. The quality of the government's intramural S&T has the following practical implications for the well-being of all Canadians:

- Intramural S&T contributes to health, safety and security. Several hundred Canadians developed AIDS as a result of blood transfusions received before testing procedures were introduced to screen blood reliably for human retrovirus infection.

- Intramural S&T is critical for better decisions about resource management. A crisis in the east-coast fishery has resulted in economic hardship for thousands of Canadians and dozens of communities in the Atlantic provinces, in part because our current knowledge about the rate and size of growth in fish stocks leaves considerable room for error in predictions.

- Intramural S&T helps ensure that vital policy decisions are well-founded on complete and reliable information. When the first energy crisis struck in the 1970s, there was no comprehensive scientific resource appraisal available on which to base exploration decisions or policies on energy self-sufficiency. The policy decisions founded on this sketchy knowledge base affected the allocation of billions of dollars and had a major impact on the entire Canadian economy.

- Intramural S&T supports a sustainable approach to issues such as environmental protection. Acidic leachates from tons of base-metal mine tailings, accumulated over a 50-year period, pollute streams and rivers and kill fish; clean-up costs to resolve this unforeseen waste management problem will likely run to billions of dollars. Neither government treasuries nor the environment itself can continue to sustain such assaults. Increasingly, such issues require the application of S&T as a basis for decisions about development that meet today's needs without impairing the ability of future generations to meet their own needs.

The departmental S&T establishments perform roles that are critical to the efficient functioning of modern societies and reflect their complexity and the heterogeneity of situations. A large proportion of these activities are undertaken to support policy advice, develop testing methodologies and support industry in process and product approval. Other intramural S&T activities produce unique, large and sophisticated data bases, our public knowledge infrastructure, that inform both government and business decisions. And, a few establishments operate in formal or informal partnerships with industry to provide strategic technological advances for medium and long term time horizons or operate major facilities required by both government or industry. Finally, some establishments are simply service organizations which provide engineering support to private sector firms or other government departments and agencies.

By expanding knowledge, science becomes a tool for fulfilling government responsibilities and achieving government objectives; it provides information for timely and effective policy and regulatory decisions and establishes the public knowledge infrastructure which is critical to many business and economic development activities. As the quality of science improves, so does the reliability of information and the probability that the choices made are the best ones. It is incorrect to postulate that government is simply a funder of S&T. It is an important user, and the significance and impact of its regulatory and decision-making roles as well as the public goods nature of a substantial portion of its output mean that government S&T must be as good as that anywhere else – in industry, in universities and in private organizations.

1.3.1 Phase I: Organization and Management of S&T Activities

The Committee began by exploring how federal S&T activities are organized and managed, and by holding discussions with scientists, engineers and officials of departments and central agencies and R&D managers in the private sector. To capture the diversity of federal S&T efforts and ensure that its recommendations would be generally applicable, the Committee examined three departments that illustrate the range of intramural activities:

- Energy, Mines and Resources Canada (EMR), representing the mature, resource-based fields of R&D;

- Communications Canada (Com), representing more recently established R&D activity in an emerging, rapidly changing area of technology; and

- Health and Welfare Canada (HWC), a department whose mission to protect public health and safety is one of the most traditional of government regulatory functions.

These departments provided a diverse and representative insight into the way government policies are set and applied, and how they affect the management of S&T in departments. At the same time, recognizing that departments manage their S&T activities in the larger context of government-wide management structures and administrative systems, the Committee reviewed the role of central agencies in establishing the environment within which these activities are carried out. For example, because the effectiveness of expenditures is an important part of the Committee's mandate, it reviewed existing systems for evaluating the performance of federal S&T establishments, such as the program evaluation system supervised through the Office of the Comptroller General. Similarly, central agencies such as the Treasury Board Secretariat and the Public Service Commission exercise an important degree of control over personnel management systems. The Treasury Board Secretariat is also responsible for government-wide financial and administrative control systems. Other agencies have government-wide mandates related to the purchase of goods and services and the ownership and marketing of intellectual property – Supply and Services Canada and Canadian Patents and Development Limited (CPDL) respectively.

It soon became obvious from discussions with federal researchers and research managers, as well as from a review of structures and systems in place, that current arrangements pose significant obstacles to effective management of S&T activities. It was also clear, however, that attempting to adjust components of these systems would amount to tinkering at the margin. The Committee therefore decided to focus on identifying the specific challenges of managing S&T activities and creating the conditions that make effective management possible. Moreover, since the management regime is substantially determined by central agencies, the Committee was in a position to draw conclusions and recommendations that apply generally to the range of intramural departmental S&T activities.

1.3.2 Phase II: Culture, Values and Quality in Departmental S&T Establishments

The Committee's initial discussions with scientists, engineers and science managers pointed to systemic problems. It was told that departmental S&T activities are over-administered and poorly managed, with predictable consequences for morale and productivity. It heard about stifling central controls and administrative overload and that years of constraints on the use of human and financial resources have had debilitating effects on performance. It learned of first class equipment that is not being used because of a shortage of operating dollars. Some activities were said to be drifting away from their original purposes, pointing to a need for better alignment between federal program objectives and the research activities undertaken by departments.

There were concerns that the quality of intramural S&T establishments had deteriorated as a result of these developments, limiting their capacity to fulfil their national role and curtailing the ability of federal scientists and engineers to participate in the international networks that are now among the principal channels for keeping abreast of scientific and technical knowledge.

These preliminary discussions pointed to two avenues of investigation:

- First, the Committee sought a deeper understanding of the working environment and of the values and beliefs of scientists and engineers in federal S&T establishments.

To this end the Committee developed a survey in co-operation with researchers and research managers in Communications Canada, EMR, HWC and NRC. The survey – based in part on a similar survey conducted in government laboratories in Japan – was answered by about 1 000 federal scientists and engineers, including researchers at NRC. Through the Japanese survey and the participation of NRC, the Committee had results from both a national and an international control group to use as benchmarks in assessing the survey results. Quality, the weakness of management systems designed to monitor and drive quality on a consistent basis, and the pernicious effect of the micro-management regime emerged as concerns in the responses, as it had in the initial discussions.

- Second, the Committee wanted information on the quality of the science conducted in government laboratories.

The initial review showed that few of the evaluation systems in place address the question of quality directly, and none has quality as its central focus. For example, the survey indicated clearly that independent peer reviews with on-site visits, a preferred technique for monitoring research quality, were not consistently used by departments. When they were used, it was usually on an *ad hoc* basis and, more often than not, they were used as an indirect means of resolving management problems. This is a far cry from the on-site international peer review which should be the norm.

The Committee therefore initiated an international on-site peer review of six establishments, two in each of the three participating departments. The goal was to leave behind a review mechanism that had been tested. The Committee contracted the Natural Sciences and Engineering Research Council (NSERC) and the Medical Research Council (MRC) to manage the process. Peer review committees consisted of senior scientists from universities, industry and government in Canada and abroad. As was expected, leading scientists in their respective fields readily agreed to participate, many of them free of charge. The Committee is indebted to these outstanding individuals who did a remarkable job within a very short time (see Appendix B).

The report card from the international peer review process was mixed. In some domains the quality is clearly high; federal intramural science ranked with the best in the world. At the same time, there are several areas where the record is alarming. Missions are unclear or unrelated to government policy roles or objectives, quality is inadequate, and resources have been spread so thin that they no longer have any meaningful impact. The peer review reports testify to the fact that this evaluation method is appropriate for a government S&T establishment. Moreover, the on-site peer review process contributes to enhancing the performance of individual scientists and engineers, while giving senior management and policy makers valuable advice about the relevance of their current programs and projects, as well as the areas that should receive priority in future.

Parallel with the international peer reviews, the committee undertook a comprehensive bibliometric study of the same laboratories, which were matched against comparable labs in Canada and abroad. Important advances have been achieved in the science of bibliometrics. Conclusions arising from the work of the Research Policy and Science Studies Unit at the University of Leiden (the Netherlands) and of the Science Policy Research Unit at the University of Sussex (United Kingdom) are particularly relevant. The major advantage of bibliometrics is that it can provide a means of identifying, in a reliable, reproducible manner, the most successful and the least successful research activities.

Another impetus encouraged pursuit of the project. During Phase I of the study, it had been explained that quality in departments' R&D establishments was guaranteed by the personnel evaluation system, which was said to rely heavily on publications of individual scientists in determining promotions. Moreover, in the survey, scientists and engineers clearly affirmed that publications were and should be the primary and dominant factor in evaluating their performance. If everyone agrees that publications were and should be a major factor in evaluations, why should the best tools available not be used – that is, bibliometric techniques?

The approach followed has been to combine bibliometrics with organizational analysis to develop an analytical framework which is called an "input-activity-output-impact" approach. This was seen as essential to ensuring the relevance of the study since laboratories not only have differing inputs and outputs but also varying missions applied in a wide range of scientific disciplines. The assumption underlying the input-output model is that the impact of publications for each laboratory is a function of the level and types of inputs, the scope of activities and the range of outputs.

Each S&T establishment participating in the study was matched with several Canadian and international S&T establishments in similar fields of endeavour, or with equivalent mandates. Thirty-seven "outside" S&T establishments, in Canada and abroad, readily agreed to participate in the study and to provide – free of charge – the extensive data base required to carry out the organizational analysis as well as sophisticated bibliometrics. The high number of establishments participating in the study allowed development of an empirical taxonomy of clusters of establishments based on similarities in their inputs, activities, missions and output variables. Six clusters were identified. The results of the bibliometric analysis by cluster give additional weight to the conclusions that emerged from our other avenues of investigation.

The bibliometric study revealed that federal S&T establishments emphasize publication in scientific journals as a means of releasing knowledge more than the matched laboratories do. On a per-professional basis, the departmental scientists and engineers publish at a rate comparable to that of their colleagues in other establishments. However, with a few exceptions, the influence and impact of publications by scientists in federal departments were found to be lower than that of publications by their counterparts in other organizations.

The bibliometric analysis yielded results that were remarkably consistent with those obtained from international on-site peer reviews; the insights from the two processes were complementary. The unique contribution of bibliometric analysis stems from its ability to pinpoint the position of departments' S&T establishments relative to that of others in Canada and abroad working in the same fields or carrying out analogous mandates.

1.3.3 Phase III: Best Management Practices

As the Committee's investigation unfolded, the question then became how other large S&T organizations avoid the sense of malaise it was uncovering, rejuvenating themselves to remain vital enterprises producing quality work. The Committee therefore looked at the management practices of other large R&D organizations, particularly the most successful ones, to determine whether they had common characteristics. Were there shared elements that could be identified as today's best practices in the management of scientific and technological activities?

We examined the experience of research organizations in governments in the United States, France, the United Kingdom, West Germany and Japan, and visited several top R&D organizations owned by major companies in Canada and the United States to learn how corporations and governments manage their S&T activities. (Appendix C provides the names and titles of the persons consulted throughout the study.)

Their practices were compared with the current approach to managing federal S&T establishments in Canada. As will be shown in subsequent chapters, the most successful international R&D organizations have evolved towards a set of best management practices. These are considered necessary to ensure quality on a systematic basis, and their experience illustrates the fact that consistent and efficient technology transfer can be achieved only if these conditions persist. It became evident that the system that governs the management and operations of departmental S&T establishments seriously impedes the ability of senior management to adopt the best current practices for managing such establishments, hence the concerns about quality and value for money in intramural S&T.

1.4 The Need for Fundamental Change

The Committee's investigation and analysis led to an inescapable conclusion: marginal change will not solve the problems it discovered or ensure that intramural S&T activities continue to serve the public goals for which they were established. The time for marginal change is long past; superficial change will not achieve the desired results in terms of obtaining value for money in intramural S&T, sustaining quality in these activities and ensuring that they meet the needs of policy makers and Canadians, particularly in a context of prolonged resource scarcity. This report is therefore about fundamental and pervasive change.

The issue is how best to organize the government's internal S&T activities to produce work of the necessary quality and relevance in an environment of limited resources and shrinking time-frames. Restraint is reality. Further gains must come from more-focused mandates, less bureaucratic and unproductive overhead and improved management practices. Only by changing the basic management approach can Canada realize value from the substantial investment in intramural S&T. Only by adopting a management regime that meets the standard of today's best management practices can we ensure the necessary level of quality on a consistent basis. Only by embracing fundamental change can we ensure that intramural S&T are relevant to national needs and policy goals.

The Committee appreciates that by choosing not to identify specific S&T establishments in its report, but rather providing an overall assessment of the system, it paints the picture with a broad brush. Consequently, the descriptions of the existing management in intramural S&T establishments do not apply equally to all. In some cases, scientists, engineers or managers may feel unjustly characterized by some statements which do not apply to them. The Committee also recognizes that over the one and a half years since the inception of its investigation, progress has been achieved in some establishments.

The progress resulted, in most cases, from better mission definition arising from the involvement of scientists and engineers, management and strong advisory groups. Capable leadership from deputy ministers has resulted in streamlining of overhead, better business plans, which are used as proxies for contracts, and greater attention to the management of human resources. These initiatives are in the process of transforming certain establishments and boosting the morale of those involved. These examples illustrate that significant progress can be accomplished, but the fact remains that remarkable managers are exceptions and that all are striving in an environment that does little to encourage change and renewal.

The Committee is impressed with and applauds these individuals. Throughout the study, it wanted to ensure that its recommendations would lead to an environment where the results of such management efforts will be more pronounced because the environment is more supportive and appropriate for the situation.

1.5 Structure of the Report

The next chapter outlines a framework for successful management of large S&T organizations, a framework based on the best international practices in managing S&T and on discussions with scientists and executives in S&T establishments in Canada and abroad.

The following chapters deal with three major dimensions of that framework: the structure and linkages that make for effective management of S&T; the human resource management practices that ensure the productivity and vitality of the S&T environment; and the management processes that translate structure and resources into orderly activities. Chapter 6 recaps the Committee's findings to emphasize why fundamental change is needed and presents its recommendations.

Throughout its investigation, the Committee maintained a close working relationship with senior officials in the departments concerned and shared with them the results of findings as they emerged. The final report draws on the findings of the various studies the Committee commissioned and uses the evidence uncovered not as a report card on the establishments examined, but as a means of gaining insight and information on the management of S&T activities within departments across government. This department-specific information is collated in three separate reports that have been provided directly to the senior management of each department concerned. The objective was to provide the government with tools to manage better and to reap the full potential of the major national asset that is constituted by departments' S&T establishments.

2.0 BEST PRACTICES IN THE MANAGEMENT OF SCIENCE AND TECHNOLOGY ESTABLISHMENTS: A FRAMEWORK

If there is a single overarching lesson to be gleaned from this investigation of S&T management within government and outside it, in Canada and abroad, it is that effective management of these activities requires a high level of commitment to S&T as a priority and to continuous organizational learning and innovation.

How do large organizations achieve those aims? The review revealed a body of best practices that successful organizations use to translate commitments and priorities into concrete results through well-defined missions, appropriate organizational structures and linkages, effective human resource management, and rigorous management systems. Best practices emanate from a sound understanding of organization and management theory, grounded in a solid grasp of what works and what does not. It is theory based on practice and applied in the real world of organizational design and management regimes. An organization and management framework that embodies these practices is the subject of this chapter.

The need to make intelligent use of organizational and management sciences applies to all large entities. But no activities, whether in the public or the private sector, are as unique and challenging as the organization and management of S&T establishments. Nowhere else in today's complex organizations is the management of uncertainty more pronounced because investment in R&D is uncertain in outcome, and results are difficult to measure in conventional terms.

In addition, scientists and engineers bring to the organizations that employ them a distinctive culture based on strongly held scientific values. These values are derived to some extent from the organizations in which they work, but primarily from the broader scientific community. Well-managed research organizations respect and nurture these scientific values and build on them through the design of their planning, budgeting and evaluation systems, as well as their human resources policies and administrative procedures.

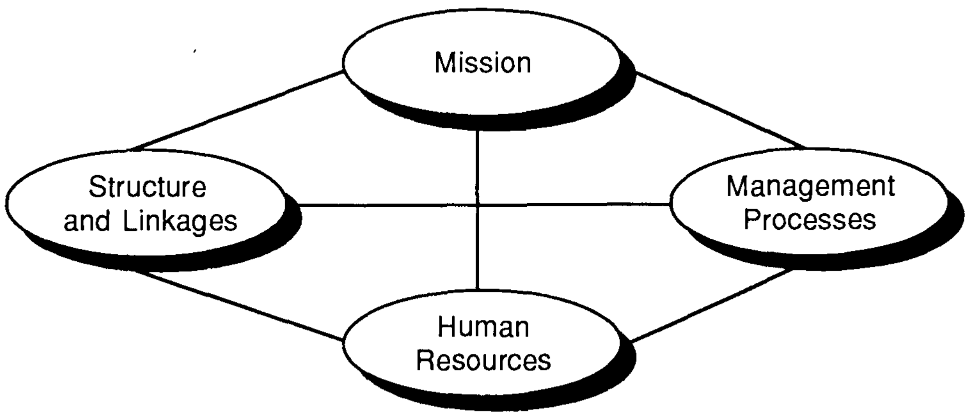
In approaching the question of S&T management in the federal government, the Committee carried out a survey to take stock of the culture and values of its scientists and engineers. The Committee found that scientific values are very strongly held by researchers; in contrast, government policies and procedures have been developed for a very different world. Given the gulf between what inspires and motivates scientists and engineers to excellence and what is enforced by the current management regime, it is not difficult to understand why concerns about quality, productivity and morale are prevalent.

These scientific values are common to all R&D organizations. Results of a similar survey of scientists in government laboratories in Japan revealed the same strongly held values expressed by Canadian scientists and engineers; despite major cultural differences, the scientific values were remarkably consistent. As the Committee expanded its scope and consulted with other governments and large industrial companies, it observed the prevalence of these same scientific values. S&T organizations with effective management systems have found ways to protect and harness scientific values, using them to move the organizations in the direction they want them to go. The structures, systems, policies and procedures of these research organizations are designed to engage their scientists' and engineers' values in the fulfillment of the organizations' objectives.

Given these strong similarities in scientific culture and values, the experience of comparable institutions must constitute a critical reference point for organizational design and management regimes. The Committee therefore examined the experience of some of the world's leading R&D organizations. That examination showed that the most successful organizations have evolved towards a set of structural arrangements and management approaches that is remarkably consistent – a common core of best practices for the design and management of R&D establishments. The components of that model, which were found repeatedly in the organizations studied, are shown in the accompanying diagram.

Exhibit 2.1

Best Practices Model



The balance of this chapter considers each of these distinct but related dimensions of the best practices model. The next three chapters look in greater detail at the experience of the federal government, comparing it with the practices of the world's leading S&T organizations with respect to organizational structure and linkage mechanisms, human resource management, and management processes.

2.1 A Clear Mission

The 1983 report of the White House Science Council (the Packard report) in the United States emphasized mission as a central factor in the performance of research establishments. The Packard panel found that:

> ...clearly defined missions consistent with the appropriate roles for federal laboratories are important to the vitality of any laboratory. Of the laboratories visited, those with well-defined missions clearly were better performers than those with poorly defined missions. Those laboratories with both well-defined missions and close interaction with the users of their research appeared to be the most effective of all.

International enquiries confirmed this finding, and the results of international peer reviews and bibliometric study yielded the same conclusion. S&T establishments cannot function effectively without clear, well-defined missions. This point cannot be overemphasized, which, as the evidence amply demonstrates, is a *sine qua non* for success.

This is not surprising. The establishments in question, whether in the public or the private sector, were created and are maintained as instruments for pursuing organizational mandates or goals. They are not in the business of developing knowledge or technology for its own sake. Their work may contain an important element of basic research, but these activities should be undertaken to advance a particular mission by transferring knowledge and supporting technology development or enhancement in other units of the organization.

Two principal lessons were derived from the most effective organizations. The first is that missions are not imposed on research establishments. Nor are they left to be defined by scientific and technical staff on their own. Rather, missions emerge from a rigorous and intense interactive process between the R&D organization and its parent organization. Moreover, establishing a mission is not a one-time effort, but a continuous process of reassessment and refocusing. The key issue is therefore how each R&D establishment is organized and linked to the various units of the parent organization to achieve the desired interaction.

The second lesson is that missions are formulated in such a way that precise goals can be set; R&D performance in turn can be measured against these goals. Situations may arise where attention to the original mission declines in priority, with the result that the establishment's activities become fragmented or some activities become unrelated to the main goal. If this occurs, the best organizations do not tolerate drift. Instead they reduce the size of their R&D establishment to meet real needs and reallocate their scientific resources to tackle new, well-articulated missions.

This report begins by examining structure – and, in particular, the organizational integrity of R&D organizations within larger entities – before going on to explore the linkages between such bodies and the other components of their parent organizations.

2.2 Structure and Linkages

Structure and linkage work together to create a distinct, visible R&D organization and, simultaneously, to tie it closely to the goals of the other units of the parent organization. It was found that leading R&D organizations consistently adopted this apparently paradoxical approach to separating out R&D in order to maximize linkage. The R&D organization is placed at a distance to allow scientific values to predominate, to ensure that management systems can be tailored appropriately to the scientific culture and to drive the R&D organization towards quality. The R&D organization is then linked back to the parent organization through strong contractual relationships to prevent mission drift, to ensure close links with the operating units, to facilitate information flow and systemic innovation and to strengthen the innovation process. Intense global competition based on compressing the time between the generation of new ideas and the production and sale of new products adds to the incentives to tighten linkages between the R&D organization and the other components of the parent organization.

2.2.1 Structuring for Distinctiveness and Visibility

Organizational distinctiveness in R&D organizations serves at least two purposes.

First, it allows the R&D organization to adopt rules and procedures designed specifically to take into account the unique characteristics and nature of its activities. This permits organizations to benefit from the distinctive culture of the scientific community. The culture endorses, among other values: a high degree of interaction among scientists based on knowledge and expertise, rather than position or rank; external peer review and assessment, rather than deference to internal organizational authority; and recognition based on intellectual performance as judged by one's peers, rather than recognition from organizational superiors. These values distinguish the scientific culture from the bureaucratic culture of many large public and private organizations.

This approach is at odds with the view of managers who seek to impose a standardized and homogeneous corporate value system on scientists and engineers. The latter view is on the wane; the futility, and indeed the perversity, of this approach are being acknowledged by the most effective S&T-based organizations on the international scene.

Second, distinctiveness allows for visibility. Visibility in turn serves several purposes. Scientists, whose culture invariably fosters extra-organizational identification, identify with their employing organizations, even in academic settings, only when the organization demonstrates its appreciation of the contribution they make. Organizations develop that pride and enthusiasm by acknowledging the value of the contribution of its scientists and engineers; the distinctiveness and visibility of the R&D organization is a concrete expression of that recognition. Healthy morale and *esprit de corps* are not founded solely on organizational design, but they flourish when employees identify with a visible organizational entity engaged in the practice of a valued profession. The Committee was constantly reminded of this fact when it saw how organizations had structured themselves to make their research establishments visible.

Visibility also enables R&D organizations to attract the best talent available. Scientists and engineers of high calibre want to be associated with a visible institution because it enhances their own ability to participate in the international scientific networks that are so central to remaining at the forefront of their disciplines.

Moreover, visibility allows an R&D organization to protect itself from the exigencies of short term pressures from related operating units within the parent organization. The Committee was particularly impressed by the extent to which chief executive officers in major corporations saw a need to safeguard the long term viability of their R&D organizations by structuring them as separate and visible entities. Quality research on strategic or enabling technologies demands a long term perspective and, in the view of these executives, the distinctive character of R&D organizations is best secured when they stand on their own and are not solely an appendage of line operations. This view is based not on theory, but on experience. Structures that fail to protect the long term viability of R&D organizations result inevitably in domination by short term forces, thereby rapidly eroding their scientific capabilities and competitiveness.

Distinctiveness and visibility work together to produce another valuable outcome: a continual drive for quality. Since the R&D organization is in a position to adopt methodologies and systems appropriate for judging quality, and because pride in the organization is a direct function of the reputation and scientific accomplishments of the group, R&D organizations are in an ideal position to build upon the scientific culture to promote excellence. This focus, in turn, reinforces identification with the organization and allows for better convergence with the needs of the parent organization.

A distinct organizational structure also ensures that scientific activities are not subsumed, let alone buried, under other organizational functions. The issue of quality and the management of quality control are thus brought to the forefront of the organization's planning, resource allocation and evaluation processes.

Organizations have learned that when R&D organizations are positioned down in the bowels of private or public bureaucracies, they are unlikely to be subject to the kind of quality evaluations their activities require. At best, they will be evaluated according to criteria based exclusively on the perceived needs of other functional or managerial units in the parent organization.

Distinctiveness and visibility therefore put the focus on the fundamental issue of quality. Quality is highlighted precisely because R&D activities are forced to stand on their own merits; they cannot be hidden within the interstices of the parent organization and its multiple undertakings.

2.2.2 Creating Linkages

Although best practices dictate structuring S&T organizations to operate as distinct and visible entities, they do not function in isolation from their parent organizations. In fact, they are tightly linked in a number of selective, yet critical respects. Effective organizations have devised flexible mechanisms to link their S&T activities to other units in ways that promote a healthy tension between R&D establishments and operating units.

The key to understanding the dynamics of these linkages is to appreciate the dual requirements of organizational integrity on the one hand and organizational linkage on the other. At first glance, this appears contradictory or paradoxical. Experience has demonstrated, however, that both requirements make sense in organizational design and work in management practice. The trick is to use linkages selectively without attempting across-the-board integration.

The goal is to ensure that R&D organizations have clear missions and pursue R&D activities of relevance to the parent organization. Achieving this requires that plans, priorities and budgets flow from a process of interaction on two levels: between the R&D organization and its parent organization on the one hand and between the establishments that make up the R&D organization and related operating units within the parent organization on the other.

Neither top-down corporate planning and decision making nor an incremental bottom-up approach can provide this interaction. The experience of corporations and governments alike demonstrates that comprehensive top-down decision making rarely, if ever, secures the necessary alignment between corporate mechanisms for direction, control and evaluation and the individual missions, programs, activities and assessments of R&D establishments. Conversely, bottom-up incremental approaches invite mission drift and goal displacement in R&D organizations.

Closer interaction at all levels of the organization is also demanded by the accelerating pace of the commercialization process. The time lapse between discovery and application, between prototype and production, is collapsing, forcing even closer working relationships between scientists and their counterparts in development, manufacturing and marketing.

The Committee's investigation disclosed an important measure of organizational learning about the value and use of linkage. Today's best practices evolved from this learning process; it is not simply a question of new ideas replacing old ideas, but of experience uncovering the best way to proceed.

Contract Linkages

Chief among the linkage mechanisms are explicit contractual relationships between the various components of the parent organization, including operating units, and the R&D organization and its component R&D establishments.

Contracts establish a client-contractor relationship; the organization and its operating units (the clients for research) enter into contracts with the R&D organization or its individual laboratories. Clients allocate resources to "buy" services from the R&D organization, which is thus revenue-dependent on the operating units. The integrity of the R&D organization is thus acknowledged, but the need to secure projects and funding ensures that it is not isolated from the goals of its users within the larger organization.

Such contracts, with their explicit acknowledgement of revenue dependency on the part of the R&D organization, are not imposed on either party. Rather, they are formed through negotiation among management, scientists and engineers at every level of the organization. This process ensures that the relationship between the R&D organization and the other components of the parent organization is pervasive and permeates all divisions: sales, marketing, production, client services, corporate planning, etc. Thus, contracts are not long term bulk arrangements, but rather represent the results of numerous negotiations between operating and R&D managers. This decentralized process provides the ongoing reference for performance, relevance and accountability.

Contract negotiation demands that managers in non-S&T parts of the parent organization develop a clear understanding of the R&D activities they need to serve their own operational missions, both short term and long term. For its part, the R&D organization must understand the needs of operational units and be prepared to "sell" its capabilities. As intellectual service organizations, these establishments are not engaged or financially supported to pursue research for its own sake.

The negotiation process promotes close interaction among different parts of an organization, each with particular interests to maintain and advance. This is acknowledged openly in a contractual relationship. The contract mechanism requires that the R&D organization interact productively at many levels of the organization. The interaction involves mutual adjustment achieved horizontally between equals; it is not a relationship between superior and subordinate in a vertical or hierarchical structure.

The contracting model also facilitates deliberate rather than arbitrary decision making during periods of downsizing. Rather than across-the-board cuts, the contracting model works effectively to force choices among competing S&T interests; priorities must be identified so that, when faced with financial restraint, program managers will reallocate funding to contracts of primary importance. The concern is that valuable long term research may be cut; therefore, other mechanisms are required to alleviate this problem.

Executive Linkages

Leading organizations make sure that the senior executive officer of the R&D organization is a full member of the parent organization's senior management team. Two purposes are served.

First, the research executive is not subordinate to the operational executives heading client groups. This is crucial to a serious approach by both parties to the negotiations and protects the integrity of the R&D organization. Second, the research executive is in a position to participate in the parent organization's strategic decision making and provide the S&T perspective in planning, budgeting and evaluation at the corporate level.

This practice is used precisely because two needs must be served simultaneously: the need for tight links between R&D management and operational management, and the need to ensure that business strategies embody the best technological knowledge and that R&D investments made by the parent organization will allow it to retain or enhance its leadership position in the future.

People Linkages

In the public and private sector organizations the Committee examined, the best-practice organizational structure is followed through with a great emphasis on personnel exchanges and active networking between the R&D organization, operational divisions and functional management units. These mechanisms have largely replaced traditional methods of organizational co-ordination. Effective organizations recognize that productive co-ordination among research, operations and marketing flows from people, not from complex (and especially bureaucratic) organizational structures.

In addition to using contractual and executive relationships as linkage mechanisms, leading organizations also emphasize less-permanent organizational designs, such as temporary multidisciplinary project teams, to promote concerted action by all organizational entities and increase their effectiveness. The existence of these temporary structures does not guarantee results. Rigorous management is required if the roles assigned to these structures are to be fulfilled. Interorganizational and interdisciplinary exchanges demand constant management attention if purposes like creativity, innovation and, especially, technology transfer are to be served. But it is people, not systems, that create, innovate and transfer technology. Individual and collective leadership is thus a necessary condition for success.

These mechanisms have allowed innovation and creativity to flourish, but the transfer of technology from research establishments to user organizations remains a central challenge. Organizations everywhere acknowledged that technology transfer is exceedingly difficult, even under the best of circumstances. There is no simple formula. At the same time, organizations recognize that excessively bureaucratic approaches pose almost insurmountable obstacles to technology transfer. We were reminded repeatedly that governments have traditionally had a poor record in this regard.

2.3 Human Resources

With the right mission, structure and linkages in place, human resources is the next element of the best practices framework. Effective research organizations give highest priority to their human resources and to developing the best means of recruiting, training and rejuvenating their pool of scientific personnel, appraising their performance, rewarding excellence and outstanding contributions, and offering opportunities for individual development and renewal.

2.3.1 Managing for Quality

Merit is the overriding concern of these organizations and the principle that governs recruitment, development, appraisal and promotion. It involves the design and implementation of incentives and rewards. It recognizes that the individual performances of an organization's scientific personnel are central to quality and results.

Leading R&D organizations use a variety of strategies to attract and maintain the finest talent. They sponsor university research to solidify their links with universities; they offer associate programs to employ doctoral students and post-doctoral personnel in their establishments; they monitor university activities to improve their ability to recruit outstanding students; they undertake joint projects with universities to keep abreast of the cutting edge of research which could eventually be applicable to their product or service.

These organizations are also committed to developing scientists and engineers within the organization. The careers of scientific personnel are managed carefully to ensure the right mix of experience in basic research, applied R&D, and research management. More experienced scientists coach and help develop new recruits. Planned attrition allows the entry of new personnel to promote constant rejuvenation of the pool of scientific staff.

Performance appraisal is a central part of the development process and is designed to match the nature of the activities performed in each establishment. Individual scientists and engineers are assessed regularly and rigorously. In the research laboratories, close attention is paid to researchers' publications, to the conferences in which they are invited to participate, to the honours they receive from their peers, and to the patents and other intellectual property for which they are responsible. Each of these measures has its basis in the judgement of the scientists' peers outside the organization. In the best organizations, the senior executives of the R&D organization take significant pride in knowing their scientists and engineers and paying close attention to how well each is performing in the broader scientific community. In the establishments which perform more technical functions, productivity criteria are developed and individuals measured against them. Moreover, in the process of negotiating their contracts with operating units, it is not uncommon for the operating units to indicate which scientists or engineers they want or do not want working on the project. This "market" selection process is a further impetus for rigorous appraisals.

The most effective organizations also offer tangible recognition of quality work. Some organizations provide substantial monetary rewards for significant patents. Awards ceremonies and other forms of public recognition are also common. And, many organizations offer opportunities for research freedom to those so honoured.

Reward systems are a form of evaluation that have the added benefit of giving a signal about organizational values and current priorities. An organization's awards program, particularly when it celebrates scientific achievement recognized by the international research community, is an important means of marrying scientists' and engineers' professional loyalties with those of their organization. The monetary value of such awards may vary widely, but the essential element is the importance attached to the award by the top management of the parent organization.

In all these ways, vibrant R&D organizations seek constantly to accommodate the dual requirements of stability on the one hand and continuous rejuvenation on the other. Personnel are shifted from project to project; funding priorities are changed; new ideas are championed and supported. The continuing challenge is to achieve the highest standards of excellence while changing the research agenda to respond to shifting demands. To meet the challenge, independent, on-site peer reviews are used to evaluate program quality, and external advice is used to monitor changing needs. Some projects are terminated, but personnel remain as long as their performance continues to contribute to these goals.

2.3.2 Managing for Vitality

It follows that managing people, rather than adhering rigidly to bureaucratic personnel administration systems, is an essential task for research managers. Managers must be able to manage individuals and groups of scientists and engineers, and not merely implement regulations and procedures governing categories of scientific personnel.

This is not to imply that the organizations investigated ignore personnel systems entirely. Indeed, it was found that their personnel systems are highly developed, but they are specific to the R&D organization and tailored to the circumstances and culture of science. Moreover, they are used rigorously to foster excellence and commitment, to deploy and redeploy personnel in the most effective manner, and to assess individual performance according to the highest standards of quality.

These organizations also integrate the management of financial and personnel resources for at least two reasons. First, they recognize that integration ensures the greatest possible degree of flexibility for managers to employ a range of staffing strategies. Second, integration is necessary to avoid incongruity between personnel resources and financial resources, as well as the perverse effects of financial controls on personnel management – a situation that often arises in traditional public sector organizations, particularly in terms of predetermined staff complements and the design of incentive and reward systems.

In addition, the organizations examined allow their R&D organizations management autonomy, which is essential for their continued vitality. This is perhaps the greatest challenge facing research managers. They must have the authority to deal with attracting new talent, redeploying experienced scientists, and promoting constant individual and collective rejuvenation and renewal. Furthermore, most organizations must meet these needs without the relatively easy response of growth in personnel complements. The managers spoken to acknowledged that these needs are easier to identify than to meet; but there were no doubts that the requisite managerial authority is essential to fulfilling them.

Finally, it is clear that decentralization and delegation of authority as practised by the organizations examined demand a management regime within which the R&D management function and R&D managers are considered crucial to overall organizational success. R&D management in these organizations is not merely an administrative undertaking, as it is in many highly bureaucratized systems. Nor is it synonymous with the task of chairing a university-based teaching and research department, where individual researchers act essentially on their own, even if they sometimes collaborate for selected purposes. R&D management is a crucial role in successful R&D organizations and one that demands the careful selection and development of some of the best scientific talent in the organization. Thus, best practices place significant emphasis on finding managers who not only understand research, the scientific missions of their organizations and their interaction with the larger objectives of the parent organization, but also understand R&D management.

2.4 Management Processes

R&D establishments in the organizations examined have flexibility to create the appropriate environment for R&D and to manage, as appropriate, to maintain that environment, even within the tight controls inherent in the linkage mechanisms described earlier in this chapter.

2.4.1 Flexibility

Flexibility entails giving research managers the authority, discretion and instruments they need to manage facilities and financial and human resources in ways that address the particular circumstances, culture and requirements of the research enterprise. This means that the R&D organization is not managed at the micro level by corporate authorities outside the research organization through standardized rules, regulations and procedures.

Managerial autonomy for R&D organizations reflects recognition by senior corporate management of the distinctive character of the research function and the distinctive culture of scientific personnel. It is also an acknowledgement of the challenge facing research managers in securing quality, assessing performance by external criteria, and fostering continuous innovation.

Control over the R&D organization is secured through linkages. But they are linkages among the parts of the organization. They are not controls by one part of the organization over the other, and they do not call for intervention by corporate functional managers in the daily management of the R&D organization.

Achieving the necessary flexibility in the public sector is a challenge. As a recent OECD report on the management of government laboratories makes clear, the needs of a traditional bureaucracy do not always coincide with those of a productive research environment (see Exhibit 2.2). As a result, there must be sensitivity on both sides and recognition of each other's needs.

Exhibit 2.2

Differing Needs of Bureaucracies and Good Research Environments

Government bureaucracy	Good research environment
• Stable job security; well-defined functional roles	• Mobile, flexible work force
• Not differentiated from rest of bureaucracy for simplicity and fairness	• Differentiated environment according to mission
• Clear audit trail; high degree of financial accountability	• Risk taking; administrative paperwork minimized
• Equitable employment practices	• Merit-based employment, championing the best
• Positive client service – everything available for the public good	• Protected intellectual property; selective, managed relationships with other sectors

Source: Adapted from *The Changing Role of Government Research Laboratories*, OECD, 1989.

2.4.2 Planning Processes

Effective planning in research organizations is based on several preconditions. Leading organizations are clear on their R&D missions and on the role of each establishment in achieving those missions. The nature of internal and external relationships is also well understood, as are funding methods and performance criteria.

At the same time, these preconditions are only a starting point. To be consistently responsive, planning processes must involve continuing reviews of missions, organizational vitality and clients' requirements.

Where research into underlying scientific principles or fundamental technologies is involved, time-frames as long as 10 years are typical, while more immediate goals take the form of project milestones. Applied R&D projects fit somewhat more readily into annual planning and budgeting processes, but they too are often derived from a multi-year perspective.

Planning systems are both laboratory-wide and project-specific. The best systems keep as close an eye on what is not happening as on what is currently under way, asking questions such as these: Are there areas where we are not yet allocating resources but that may become priorities in the next few years? What steps are we taking to move in that direction?

Effective planning systems begin even before the project proposal stage and bear strongly on which new projects receive funding and why. Well-managed laboratories evaluate proposals rigorously to ensure that objectives, success factors and evaluation measures are well-defined from the beginning. Peer review is used by organizations as part of the decision-making process to proceed on major research projects.

Thus, strategic planning in the organizations examined involves continuing and healthy tension between initiative and control, and between bottom-up and top-down decision making. As a consequence of the tension between initiative and control, planning is separated from the budgeting process, although time horizons for research budgeting are regularly lengthened from one year to three years or more.

The tension between bottom-up and top-down decisions also allows a balance between scientific freedom and focused activities. No mission-oriented laboratory can afford to allow scientists to pursue individual research projects entirely of their own design. But neither can any expect highly trained and creative scientists simply to execute projects defined by non-scientific managers or clients. An interactive process is required so that both scientist and client can contribute their particular perspective and expertise.

The degree of freedom accorded scientists varies widely within organizations. Those who have made outstanding contributions are often given wide latitude. Management lets them know through incentive and reward systems what type of research will be recognized by the organization. Beyond that, their work is largely self-directed. This is a privilege to be earned, however, and is far from the norm for scientists in mission-based facilities.

2.4.3 Evaluation Systems

Whether in the public or the private sector, leading R&D organizations pay close attention to the quality of their scientific activity. There is no single best method of evaluating quality; all use a range of mechanisms that draw on scientific and organizational measures of success. All the organizations examined, whether they concentrate on fundamental or applied science or development, use science-based evaluation measures in their criteria for success. The relevance of a project to internal or external clients' needs is not traded off against quality as measured in purely scientific terms. In fact, the very process of measuring quality, on a continuous and systematic basis, provides insight into relevance at the same time.

Any organization, whether engaged in marketing, manufacturing or research, uses external benchmarks to judge performance. A marketing department measures comparative market share, conducts competitive analysis, and monitors the impact of its advertising campaign against that of competitors. A manufacturing division does comparative cost-analysis against other manufacturers and watches closely how competitors' products are manufactured. A research organization also requires objective, external benchmarks against which to measure performance if its contribution is to have any lasting value to its parent organization.

The predominant criteria for scientific evaluation continue to be publishing in refereed journals, participation in international conferences and applications for patents. This is how the scientific community judges its own members; organizations can therefore determine whether their scientific employees are in the mainstream of research and contributing strongly in their fields. Bibliometrics is being used increasingly for this purpose.

The other important method of evaluating scientific quality is independent, on-site peer review. Managers in public and private sector organizations recognize the need to compare the quality of their efforts with international benchmarks. They use external peer review teams, which visit their laboratories and comment on the quality and effectiveness of the R&D projects, to provide this independent and expert assessment. Peer review is also an important means of identifying new directions for research and of suggesting where an R&D organization's future priorities should lie.

Because of the confidential and critical nature of some R&D programs to corporate competitiveness, major corporate research establishments often draw on scientists inside the organization, but outside the research program under review. Despite the constraints imposed by confidentiality, the leading companies use the peer review mechanism extensively. Some use an external research advisory board or committee that reports to senior executives and the board of directors to conduct the on-site peer reviews.

2.4.4 Budgeting and Accountability

In the organizational structure described earlier in this chapter, R&D organizations are revenue-dependent, that is, they receive a major portion of their funding from internal or external clients who buy their services through contractual relationships. The challenge of this funding relationship is to balance long term stability with short term accountability.

The best organizations recognize that the contractual relationship with operating units is inherently biased towards more short term technology applications and problems. Exclusive reliance on that mechanism therefore runs the risk that insufficient resources will be committed to avenues of research that could significantly enhance the future competitiveness of the organization. Consequently, earmarked funding is provided directly by the parent organization to pursue these strategic avenues.

The budgeting process is a powerful lever used by organizations to give weight to planning and evaluation processes. For example, funding of research contracts must be related to the evaluation of results to ensure that the level of funding reflects the quality and relevance of the work being done. A budgeting process that simply allocates a lump sum based on last year's appropriation, regardless of planning priorities or evaluation results, renders those systems powerless.

Financial and personnel resources must be co-ordinated within a single budgeting process. Measures such as research dollars per scientist or technical staff per scientist are often used to maintain an appropriate balance of resources.

The budgeting process must also achieve a balance between flexibility and fiscal responsibility. The process of research and discovery is such that all funding requirements cannot be predicted in advance. Most research organizations set aside a special fund for new initiatives and special projects. Individual scientists or research units can apply for "genesis" funding to explore potentially important new areas under the direction of the head of the R&D organization. These funds are a potent instrument to encourage the best, most creative scientists to pursue promising new areas of research. In the final analysis, however, strong financial management prevails. The accelerating cost of research, combined with the uncertainty of outcomes, dictates close management of expenditures.

2.5 Conclusion

The best practices framework should not be construed as a description of any specific organization; rather, it is a compendium of the practices and direction pursued by leading organizations in the management of their R&D activities. The validity of the model is buttressed by the fact that the committee's investigation revealed a significant degree of commonality among leading R&D organizations, in both the public and the private sector, with respect to four major dimensions of research management: mission, structure and linkages, human resources, and management processes. Their approaches emerged from experimentation and learning, often to meet the challenge of ruthless competition.

These best practices are outlined here as a means of highlighting the most crucial findings. The best practices model gave a coherent framework within which to analyze what was learned about the organization and management of federal departmental S&T establishments and to compare those findings with the practices of the world's leading R&D organizations. The next three chapters report the detailed findings on three major dimensions of the best practices model – structure and linkages, human resources and management processes. Finally Chapter 6 summarizes the conclusions that emerged from the study and, using the best practices model as a guide, sets out the committee's recommendations.

3.0 STRUCTURE AND LINKAGE IN INTRAMURAL S&T: COMPARISONS WITH BEST PRACTICES

Structure and linkage are the components upon which effective organizations are built. Structure provides the framework for building distinctive, visible, and stable organizations. Linkage connects the R&D organization to the needs of its parent organization and facilitates the transfer of knowledge and innovation in support of the broader purposes of the parent organization. Governments and companies alike, in seeking to maximize returns from their investment in R&D, have introduced fundamental changes in structure. Companies, in particular, have paid considerable heed to the essential linkages between themselves and their R&D establishments.

R&D organizations must be distinctive entities. While they are part of larger organizations and do not exist as an end unto themselves, their organizational structure must provide them with distinctiveness and visibility within which the scientific culture can be harnessed and appropriate management systems and reward structures can be developed. An R&D organization's structure must recognize that scientists have a loyalty beyond their employing organizations – they are also members of international scientific fields or disciplines. Effective organizations recognize and foster both organizational and extra-organizational allegiances. This requires a structure that balances stability, relevance and accountability with the flexibility necessary to keep pace with scientific change and effect rapid transfer of knowledge and innovation. The Committee's inquiries indicated that private sector and, to a lesser extent, public sector organizations in other parts of the world have made substantial progress in dealing with these structural challenges.

3.1 Structuring for Organizational Distinctiveness and Visibility

Canada's federal departmental laboratories are integrated both structurally and through management processes with government departments. Far from being distinctive, the S&T functions of departments are fully integrated in departmental planning, budgeting and human resources systems. Yet, scientific values and culture within federal S&T establishments remain strong, leaving scientists and engineers caught between two worlds. As a result, S&T establishments devote considerable time and attention to attempting to retain and justify their unique culture and requirements. Excellence in conducting R&D requires that scientists work in a distinctive organization suited to that purpose, yet their position within a departmental organization creates a whole new, often conflicting, set of demands. Instead of working with these scientific values and levering them to achieve its broader goals, departmental management is too often critical of the scientific culture that engenders these values. Central agencies and departmental management systems are designed to minimize differences in approach. They run counter to the very different management regimes that outstanding S&T organizations require.

As a result, any distinctiveness that exists today is more in name than in fact. The trend has been one of increasing integration, driven by the belief that increased control over S&T units, in the form of departmental and central agency planning and evaluation systems, would yield greater accountability, greater compliance and, as a result, better performance.

Today, distinctiveness has been blurred, and the desired results of integration have not been achieved. Too often S&T objectives and programs are developed in isolation from long term strategies of senior departmental managers, while day-to-day activities and compliance with departmental systems are monitored in elaborate detail. The lesson is that the more S&T is integrated into the general operation of a department, the less the performance of the S&T organization can be recognized and encouraged. Its performance dwindles, with a concomitant impact on its ability to remain current and perform up to the appropriate standards.

Integration of S&T into departmental structures also deprives the scientists and engineers of an all-important consequence of distinctiveness: visibility. In the international R&D community, scientists are recognized almost as much by where they come from as who they are. The institutional name is often the basis for establishing and maintaining a scientific reputation and for attracting top talent. Some S&T establishments of the government have been able to retain some visibility through their names, such as the Canada Centre for Mineral and Energy Technology (CANMET) or the Geological Survey of Canada. Scientists and engineers identify far more with these organizations than they do with their departments. Newer establishments, such as the Communications Research Centres, are attempting to establish themselves as visible organizations. Yet increasingly, visibility in these establishments is in name only. Rather than fostering the sense of belonging to the institution, the structure in place works against this.

Making S&T distinct from the rest of the organization also allows for differentiation within the function itself. S&T spans a wide range of activities and purposes, and the most effective R&D organizations allow for distinctive structures and management processes, as appropriate, to reflect this diversity. For example, basic research requires planning and evaluation processes that are different from those for applied research or developmental work. Moreover, the use of flexible management structures is commonplace as these organizations work to shift technology towards its intended purposes. Rigid government structures create an inherent resistance to flexible management systems and approaches in S&T organizations.

When these distinctions become blurred, roles and functions become confused, and the ability of the organization to remain relevant in the long term may be jeopardized. As one of the Committee's peer review teams reported, without differentiating the environment to protect long term research, their scientific base will gradually erode:

> The laboratory is clearly pursuing its mandate, concentrating its resources on applications research; nearly every project is directed at some application or development. As a consequence, however, little basic research is being undertaken and there are only a few people remaining who carry the "corporate knowledge" of the basic science. In the [peer review team's] view, a laboratory of this size and prestige should support some basic research in key areas of interest.

3.1.1 The Corporate Experience

The current approach to structuring intramural S&T in federal departments is in stark contrast to practices in other organizations. Canada's leading research organization, Bell Northern Research (BNR), was established as a separate structural entity in 1970.

Other technology-intensive companies, almost without exception, have undergone significant reorganization of their R&D effort in the last two decades. These companies are using a variety of means to make their R&D organizations distinct and visible, either as separate departments with their own senior management, or even as totally separate organizations. The result is a shift away from a corporate cost-centred model and towards stand-alone R&D organizations functioning in a service relationship to the parent organization.

Corporations are also moving to distinct organizational structures because they recognize the unique need to sustain quality scientific work. One of the leading companies to establish a distinctive organization is 3M. At one time, there was a single R&D establishment; up to 40 percent of its R&D could consist of sponsored projects for 3M operating companies. Concerns that the long term research base was being undermined led to the differentiation of three types of laboratories: a corporate laboratory with no sponsored research activity, a sector laboratory with a controlled level of sponsored research, and divisional laboratories designed to be 100 percent service organizations for the operating companies. The major emphasis continues to be on applied research that serves 3M's needs directly; 80 percent of the total R&D budget is spent in the divisional laboratories.

Similar approaches are repeated in varying ways in all the leading companies visited. Long term research on enabling or strategic technologies is often positioned in a separate corporate laboratory. Applied R&D is structured within distinctive laboratories that interface with the operating units, and a variety of organizational arrangements are used to promote the rapid transfer of knowledge and innovation and foster tight linkages.

3.1.2 Other Governments' Experience

These changes are not limited to corporate R&D. Countries such as France and West Germany have structured their public sector research centres so that they are distinct and visible, and they nurture and protect the scientific culture and values that are essential to high quality R&D. Governments in the Scandinavian countries have also reorganized their research efforts around more-independent research establishments. For example, Norway's Scientific and Industrial Research Council had made all its laboratories independent institutes by 1986.

West Germany is an example of structuring to meet the distinctive purposes of government-funded R&D. Institutional roles are well-defined and differentiated to cover the spectrum of scientific disciplines, and structural distinctiveness is the norm.

The Max Planck Institutes are devoted primarily to basic research, with more than 90 percent of their funds provided by government. The 55 institutes concentrate on research areas that their universities cannot readily undertake, whether because the work is in interdisciplinary fields or requires specially equipped laboratories.

The West German system also includes 13 national research centres that carry out long term, applications-oriented, economically risky research requiring large interdisciplinary research teams and substantial funding. The results of this research are expected to be transferred to industry. The centres are funded 90 percent by the federal government and 10 percent by the Laender.

The Fraunhofer Society is a relatively new structural initiative within this framework. The society is a series of distinctive institutes that link university research and technology with industry needs. The institutes concentrate on applied research and product/ process development on a contract basis. Professors have joint appointments to a university and an institute, and graduate students can carry out course requirements while based in an institute.

In the United States, the GOCOs – government-owned, contractor-operated laboratories – provide another example of a distinctive institute model. These laboratories are established by federal government departments and are managed under contract by external agencies. Contractors range from state universities, such as the University of California, to private sector firms such as Martin Marietta.

The GOCO model achieves several objectives. GOCOs provide an environment in which scientific values are the norm, while at the same time aligning the laboratory's activities with a specific mission defined by the government. They also overcome the problem of dealing with government-wide policies and processes that are not appropriate to a research environment. For example, salary restraints in the United States public service over the last decade have made it increasingly difficult to attract scientists to government laboratories; salaries are no longer competitive with the private sector. Under the GOCO model, scientists are employees of the contractor and can be paid at market rates.

The GOCOs also illustrate how distinctiveness and visibility promote quality. GOCO laboratories such as Los Alamos National Laboratory, Lawrence Livermore National Laboratory, Argonne National Laboratory, Brookhaven National Laboratory or Lawrence Berkeley Laboratories rank among the top research organizations in the United States. They have attained their reputations based on scientific merit, and many people are not even aware that they are an integral and major part of a government department.

3.2 Creating Linkages

Directly or indirectly, research done in governments and industry alike must be justified in terms of its contribution to a broader, often non-scientific, purpose. It is therefore essential that strong linkages relate the S&T organization back to its parent organization. The major challenge is to avoid mission drift, in other words, to define the mission in clear terms. When S&T is fully integrated with the operating or program units, its mission is too often allowed to drift. In addition, the S&T establishments are obliged to act in ways not suited to their role or to the unique requirements of performing it at an appropriate level of quality. The essential structure for accountability and performance is not in place. Therefore, the S&T organization does not function at its full potential.

Internal linkages with policy and program units have become a concern. For example, the committee heard about cases where program managers contracted out for expertise that was later found to be resident in the department's own laboratories. In other cases, scientists were at a loss to find ways to sustain long term research programs that were not considered relevant by external users. The scientists believed that the research program was absolutely essential to the public good, yet because it had not been formally linked with overall organizational goals or built a constituency of users within the department, they were unable to convince the authorities that continuation of the program was warranted. In these cases, structural integration of R&D within departments is clearly not facilitating lines of communication and interaction between the department's S&T establishments and its policy and program units. As one peer review team reported:

> It is essential that there be a long term research strategy for the pursuit of good science and the effective management of resources. Although it is realized that effort may often be diverted from such a plan in order to deal with emergencies, the site-visit team was not satisfied that sufficient effort had been devoted to the development of research strategies. Equally, it is important to have a long term commitment of senior management to this research strategy, and not to require changes too frequently. While the goals and the research strategy will evolve, there should be a strong element of continuity.

Paradoxically, the separation of S&T into a distinct and visible organization actually facilitates such linkages.

3.2.1 Contract Linkages

A key element in establishing the necessary linkages is the creation of contractual relationships between the R&D organization and the various units of its parent.

In the federal government, and indeed in all governments, budgets are based on legislative appropriations. Budgets for departments are negotiated on an annual basis and, once decided, form the basis for the department's annual spending. The major criticism of this system is that it is not adequately responsive to changing conditions and does not offer a satisfactory way of linking performance with expenditures. Constant efforts are made to deal with these problems, but they have not been able to overcome these fundamental limitations of the appropriations process.

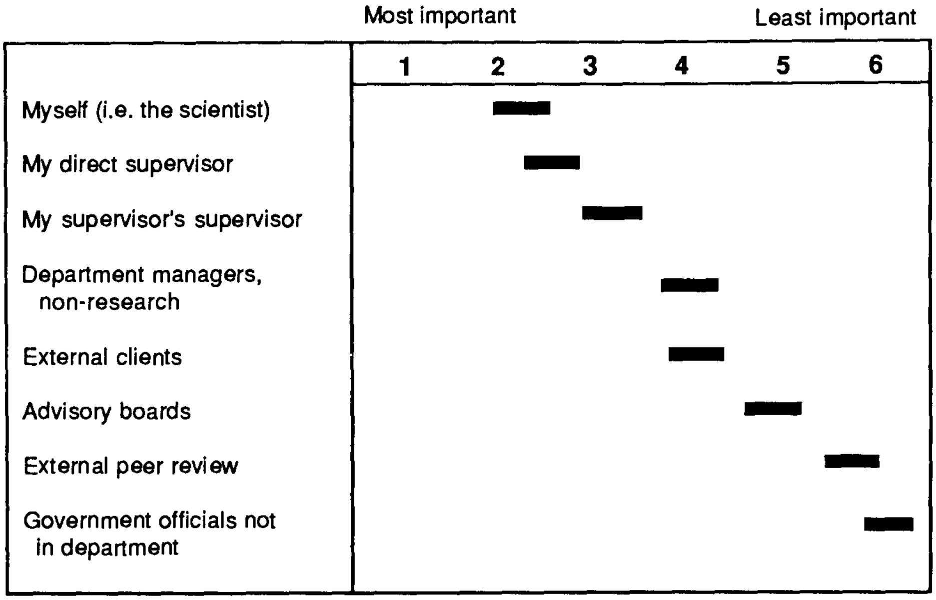
The Committee is particularly concerned about the appropriations process as a method of funding departmental S&T. By putting the emphasis on an annual process to establish a total spending level, many essential linkages are either not developed or are actively discouraged. This problem was observed by a peer review panel:

> It was difficult to glean from the presentation what work was expected to lead to a product goal and what was being done largely to expand the knowledge base. The individual pieces of work did not fit together, contributing to meet the needs of some large scheme. Alternatively, we were not offered the view of emerging needs or applications which would be met by the individual pieces.

This lack of correlation is evident in scientists' and engineers' responses to the Committee's survey, where they indicated that to a large degree, they initiate their own projects (see Exhibit 3.1).

Exhibit 3.1

Ranking of Influences on the Initiation of Research Projects



Source: NABST Survey on Research Management and Evaluation, conducted by Canada Consulting, 1989.

The appropriations approach to budgeting also impedes the process of shifting resources from one activity to another, or from a lower priority to a higher one. Often current activities will be funded as long as the budget continues to be spent. The comment by another peer review panel to the effect that "while excellence is demonstrated, it is felt that this field is no longer of national or international concern" is a case in point. But dropping a program to take on something new runs the risk that the new research area will not be approved for funding; a budget cut for the abandoned program will be the only result. Applying the appropriations system to a government research organization produces an internalized culture and does not put the drivers in place that sponsor and reward linkage of goals and mission, quality and productivity in scientific work, and effective diffusion of knowledge and innovation.

Private and public sector organizations are experimenting with a variety of contractual relationships between the R&D and non-R&D units of their organizations. Most agree that the most effective mechanism is to create a relationship in which the R&D establishments are revenue-dependent on their clients elsewhere in the parent organization. Budgets for R&D are allocated to the operating units rather than directly to the R&D establishments. In this way, users are forced to think carefully about what R&D services they wish to buy, and why, and R&D organizations are forced to be directed by and accountable to those footing the bill. In private sector terms, this means researchers must "sell" their services, understand their clients' needs and problems, and respond to market developments. In the public sector, the issue is ensuring that the S&T establishments support the mandate of the department.

For example, the United States Department of Energy laboratories are revenue-dependent. Their primary client is a major program of the parent department in the government. The department provides a base level of funding in the form of a few major, long term contracts. It also buys research from the laboratory in hundreds of short term contracts within an overall budget set at the beginning of the year. There is also small appropriation funding for exploratory R&D that is not contract-related.

Fundamental structural changes are under way in the S&T establishments in Great Britain, where R&D organizations are being set up as executive agencies. The first step is deciding whether the laboratory is required to serve government or will be shifted to private operations. If the laboratory is required, the mission is defined and the agency can obtain no more than 20 percent of its funding from work for industry. If it is not required to serve government, the laboratory is to be privatized. In most cases the decision is being made to maintain the R&D organizations as national laboratories. Giving them executive agency status is intended to provide them with distinctiveness and visibility. One important aim is to cut back on the petty and unnecessary micro-management that comes with being part of a government department. The other fundamental aim is to strengthen the contracting process that was already in place between program managers and research units within departments. However, with the new agencies, program managers in some areas will invite a competitive bidding process involving the agencies and the private sector.

In the private sector, contracting is the predominant form of funding for R&D organizations. Northern Telecom shifted from the appropriations method to a contracting approach many years ago, and executives who were in place at the time credit this change with significantly strengthening the research capability and relevance of the R&D organization. Today, almost all of BNR's research funding from Northern Telecom is project-specific. Contracts, called "strategic investment summaries," are negotiated twice a year between managers in divisions of BNR and Northern Telecom. These are complete plans, encompassing everything from research through to commercialization, and even projecting sales targets.

While using the contractual process as the vital link between the funder and the R&D organization, major private sector organizations also provide some appropriation-type funding to protect long term research. In a number of companies, certain laboratories are funded through an annual budget to ensure long term work on enabling or strategic technologies. In other cases, funding, often to the level of 10 percent of the research budget, is provided to ensure that basic research is encouraged within the R&D organization.

In 1985, Kodak reorganized its research activity, separating out a corporate laboratory for long term research and aligning the other laboratories to support specific business units and groups of units. "Under the new competitive pressures of our industry, a functional approach to the organization of R&D was just too slow," explained a Kodak executive. Development laboratories in each business unit carry out product development work themselves, and they contract for research from group research laboratories. The group research laboratories serve clusters of business units with both contract research and longer term research which is supported by the business group. At the corporate level, a corporate research laboratory carries out longer term research which is supported by the corporation and which, at the appropriate time, is transferred to a group research laboratory, or sometimes to a business-unit development group.

Although no money changes hands, the commitment of the laboratory to invest in taking the research to the next level of application constitutes the laboratory's financial commitment to what they have purchased. Approximately 50 percent of the budget of the group laboratories is financed by the business units in that group. Thus the research agenda of these laboratories is negotiated between its management and the operating unit managers. Kodak reports that both laboratories and operating units are still adjusting to the new client orientation. Striking the correct balance between meeting short term pressures of the operating units and maintaining a long term research base is a first priority of Kodak's senior vice-president and director of research and of the technology strategy committee, which is chaired by the chief executive officer of the corporation. Another continuing concern is promoting effective technology transfer among various laboratories and business units.

Martin Marietta is another company that has established a contractual relationship with its laboratories. The vice-president of research emphasizes the importance of scientists in the laboratories, realizing that their department is not a self-sufficient division in the business of doing research, but rather a service function supporting the business units of the company:

> We used to wait for the operating companies to come to us and draw upon our expertise, but they never did. We now see that we have to go out and sell our wares in the company.

3.2.2 Executive Linkages

The contractual relationship between the R&D organization and its parent does not place R&D in a position of simply carrying out whatever activities the operating units might request. Rather, contracts are negotiated between equal partners, each contributing a unique perspective and expertise. Heads of leading R&D organizations consulted by the committee warned that non-scientific users of R&D results cannot be expected to anticipate what R&D they require. Therefore, although they are the clients and funders, they cannot be in charge of setting the actual research agenda. Companies often avoid this problem by appointing the head of the R&D organization as chief science adviser to the company president. Heads of the various establishments within the R&D organization play a similar role in relation to the operating units they serve. In this way, the interests of both scientific integrity and client relevance are served.

In the private sector, all R&D activity generally comes together under the responsibility of a senior vice-president for R&D. Managers of the various establishments within the R&D organization reporting to the senior vice-president also often have a "dotted-line" reporting relationship to him or her and the manager of the operating unit that is the principal user of their R&D output.

As chief science adviser, the head of R&D in the leading companies is also a full-fledged member of the senior management team. The head of R&D is not there just to represent the interests of the R&D organization and research staff. He or she is made a member of the corporate executive team to ensure that strategic decisions made by the company take full account of and are informed by S&T implications.

In the public sector, heads of S&T establishments in some departments have relatively recently become members of the senior management team. However, as a whole, the public sector still lacks the vital integration of S&T in its senior policy and strategy processes.

The Committee found that in many departments, S&T activities were not a major area of preoccupation for senior executives. Therefore, technological considerations did not receive the level of attention to inform and influence the elaboration of strategic decisions as decisively as is attempted in leading R&D organizations. Some deputy ministers have acted to correct this situation, but the problem still exists.

The executive linkage is particularly important to ensure that long term research is protected and funded at levels commensurate with its significance to the parent organization. The contractual relationships with operating or program managers will always have an inherent short term bias; it is the responsibility of the senior management team to ensure that adequate resources are committed to counterbalance this natural tendency.

3.2.3 People Linkages

Leading organizations recognize that people create linkage, but that to do so they require organizational flexibility. Temporary, multidisciplinary team structures are often created to address specific issues. These might be teams of theorists and engineers, scientists and marketing managers, or even researchers trouble-shooting manufacturing problems. Scientists and/or research managers are also rotated on a regular basis to a different laboratory within the R&D organization to promote closer relations and interdisciplinary expertise. Scientists are encouraged to participate directly in the commercialization of their innovations, including manufacturing, marketing and customer service.

Transferring people from R&D into the rest of the organization is seen to be the most effective way to build linkages. Relationships are extended across organizational lines. Scientific understanding permeates the total organization and engenders broader support of S&T. Leading organizations work hard at managing the movement of scientists and engineers in their organizations. They all recognize that this approach offers the highest payoff for effectively transferring knowledge and innovation in their organizations.

There is little opportunity for this type of flexibility in the present federal government structure. A rigid classification and promotion system constrains the movement of scientists between laboratories and from laboratories to non-research roles in government.

IBM recognizes that informal relationships between scientists and engineers are insufficient to promote significant R&D projects that will make an impact on the business unit; the relationship has to be established formally. Based on the premise that an R&D organization will never really know and understand the needs of the client unless they work together, IBM created 17 technology laboratories, each with its own director and staffed with people from research, development and manufacturing divisions. The latter continues to be paid by the operating companies to which they report. The laboratories negotiate a single technology plan, goals are set, and progress is reviewed every six months. The laboratories are set up to provide a permanent vehicle for co-operative R&D activity.

General Motors also creates temporary structures as a means of relating its R&D organization to the rest of the company. Research managers are required to develop and reach agreements with division managers on commercializing a specific area of R&D under way in the laboratory. The operating division and the laboratory agree jointly to hire a recent graduate, usually at the master's level; this individual starts his or her career at GM with approximately two years in the R&D laboratories, moving later to a guaranteed position in the operating division to take the work started in the laboratory through the development and commercialization stages. Approximately 25 of these trainees have already been placed in the operating divisions of GM and have become important customers for the work of the R&D laboratories. "We treat them as our alumni," said a research manager, "and they promote the use of our capabilities throughout GM."

Northern Telecom and BNR work hard to ensure a continuous flow of scientific personnel, both within the research organization and to the industrial company. In this way, technology is transferred, the operating companies are staffed with people who understand technology, and the research organization has the opportunity to bring in new technical talent. As a result, the organization as a whole has a much fuller appreciation of the capabilities and potential of S&T to contribute to the achievement of corporate goals.

3.3 Technology Transfer

Putting to practical use the knowledge generated by the substantial investment in S&T made by governments and private organizations is a considerable challenge. The rigorous approaches adopted by the most successful private organizations to create meaningful linkages and facilitate the flow of knowledge and innovation across the organization attest to the difficulties inherent in the process.

The nature and purpose of a significant proportion of the S&T activities performed in departmental S&T establishments call for diffusion policies that are substantially different from those appropriate for private organizations. Many departments' S&T establishments are focused on the development of regulations and standards, are engaged in testing methodologies, products or physical conditions or are charged with the responsibility of constituting, maintaining and enhancing large and sophisticated data bases. These are unambiguous public functions. The primary motives for undertaking these S&T activities are regulatory, public policy formulation and the constitution of knowledge infrastructure. This in turn means that the scientific knowledge must be widely diffused as rapidly as possible, and not captured and retained by the funding organization.

Three conclusions can be drawn from the foregoing. First, since the S&T activities are performed in support of government policies and legislative mandates, tight links must exist between the scientists and engineers in the S&T establishments and the program managers in the departments to ensure that policies are continuously informed by new knowledge produced and that research programs are focused on the major areas of concern. These close relationship requirements are common to all S&T organizations.

Second, the wide diffusion requirement means that the knowledge must be released through the usual channels, such as publication in scientific journals and participation in scientific conferences and seminars. Thus, these means of releasing knowledge must be strongly encouraged. Interestingly, these diffusion mechanisms are also the best method of ensuring that the S&T establishments enjoy credibility with industry, which requires this knowledge: to improve its performance (and therefore regards it as important); to build the S&T establishments' reputations; and to facilitate the recruitment of the best talent – young or experienced – to the organization. Several peer review panels made comments on this point, urging that publications be emphasized by managers of S&T establishments. One even noted a serious backlog of current publishable material.

Third, scientists and engineers in these establishments may discover or develop new products or processes that warrant property rights protection and commercialization efforts. These are legitimate aims to pursue, and the management regime should facilitate the process.

Other department S&T establishments are essentially engineering service organizations. In many cases, they perform work for departments or the military. Here again, scientific publications and conferences should constitute important ways of releasing knowledge. Moreover, project reports and patents should be considered important scientific outputs of these establishments.

Some departmental S&T establishments perform contract research or engineering for private industry, or are said to perform work in support of the long term needs of industry. These activities bring to the fore not only the difficulties encountered by business in achieving effective technology transfer within its own organization, but additional ones resulting from the fact that the transfer must be done with external units.

It is worth noting that the predominant mode of industrial research in the private sector is the integrated R&D organization, that is, part of a business enterprise which engages in at least one other activity vertically related to R&D, such as manufacturing, marketing, distribution, sales and service. During the late nineteenth century and the first half of the twentieth century, this was not the case; practically all industrial R&D was conducted outside of the firm in stand-alone research organizations. Today, there remain very few stand-alone research organizations, in-house R&D having become the dominant mode for supporting corporate R&D. The evidence shows that in-house establishments use contract researchers as subcontractors for certain non-strategic activities while firms without in-house laboratories use contract research only for the simplest types of research projects.

This integration of R&D with production is driven by very strong economic considerations that are rooted in the very nature of R&D activities, such as the difficulties associated with specifying R&D services at the outset, as well as subsequent lock-in because of the extent of non-codified knowledge that is generated in any R&D project. Other factors are the advantages provided by cumulative learning and spillovers in R&D, and the fact that successful innovations must be responsive to user needs which, in turn, is predicated on close working relationships between R&D, production, marketing and sales.

These considerations highlight the challenge given to departmental S&T establishments that have a role to contract with and support industry for their business needs. Technology transfer should not be seen as a trivial affair. As one executive put it:

> To get real technology transfer you have to organize for it. You have to be prepared to spend a lot of time and money making it happen because it goes against the natural tendency of both scientist and client. Neither travels readily into the other's world. You will generally find that the scientists overestimate the value of their contribution to the client because they see only its scientific merit, not the impact on the client's business. On the other hand, management in the client company may not even be aware of the contact, let alone expect any results. For technology transfer to really happen, the client has to expect and count on the outcome of the research for success in the main course of its business.

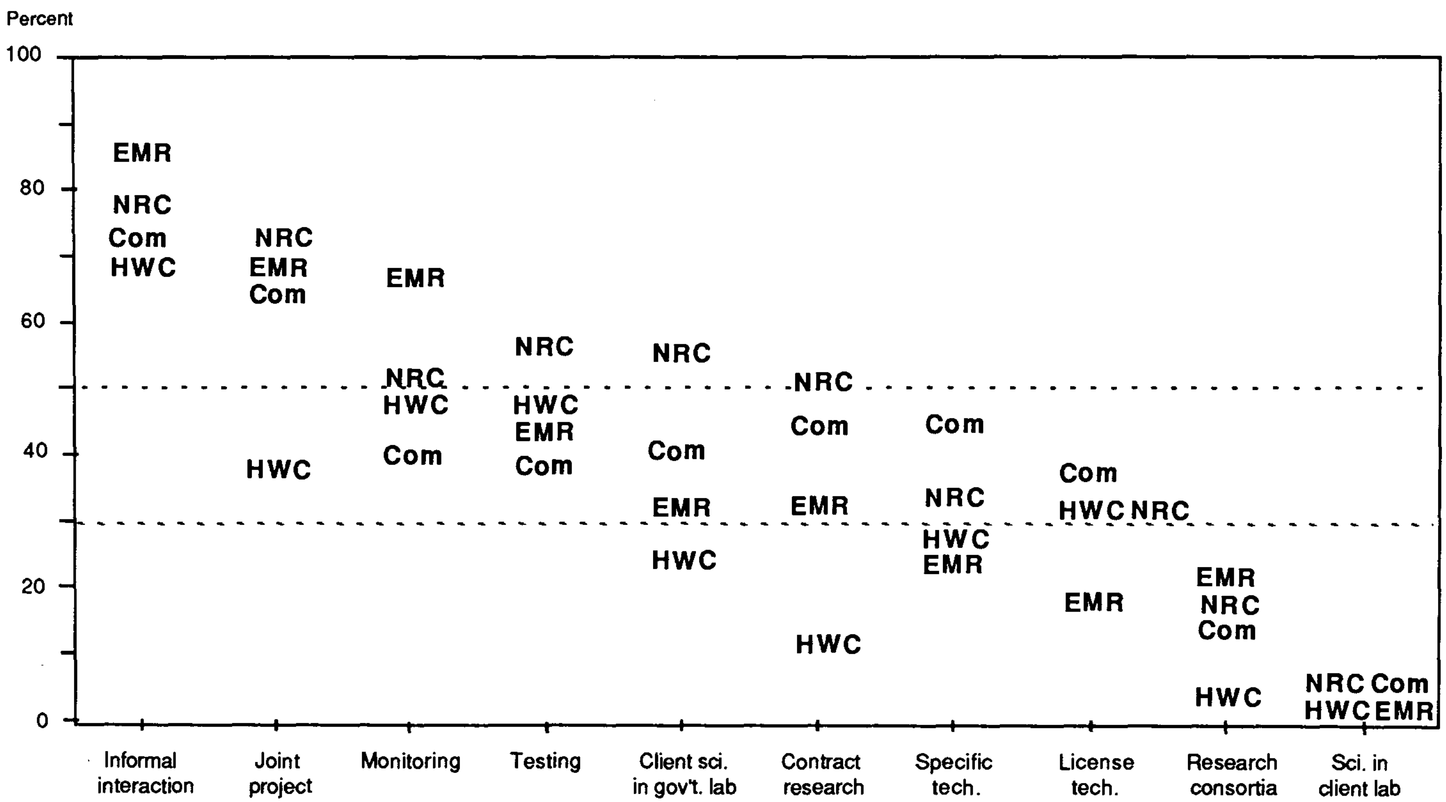
Leading research executives are careful to point out how difficult it is to achieve effective linkages. There are many signals that can be misread. For example, a couple of researchers working together across divisional lines within an organization is a start, and is held up as evidence of success. But, it is by no means a sufficient basis for meaningful linkage and effective technology transfer.

S&T policy initiatives in the federal government have focused on the need for relevance and greater external transfer of technology developed in government laboratories. Policies such as contracting out, extramural performance of R&D, and cost-recovery targets promote increased user involvement. While the intent of such policies is clear, the results are mixed. The Committee's survey revealed that the dominant means of technology transfer is through information exchange. More-active means, such as joint project teams or people transfers, which are prerequisites to effective transfers of technology, are used to a far more limited degree (see Exhibit 3.2). As one peer review team reported:

> There seems to be a general tendency to transfer partially developed technology because it is considered to contribute to a "Canadian capability," even where the world market for such technology is already saturated. Successful transfer has only taken place where there was a strong pull from the private sector partner. Many of the examples cited as technology transfer would be more appropriately described as being the provision of technical expertise or guidance, which helped a firm solve a problem, develop a product or a process, or remain competitive in a changing environment.
>
> The peer review team believes that technology transfer is most effectively carried out in situations which foster a co-operative working relationship, with an exchange of personnel both ways. There should either be a strong pull, evidenced by a major investment of both technical and financial resources on the industrial side, or a situation where the product or process to be transferred is fully mature with a minimum of risk involved.

Exhibit 3.2

How Scientists Interact with Users



Source: NABST Survey on Research Management and Evaluation, conducted by Canada Consulting, 1989.

Successful linkage also requires significant commitment of resources on major activities that are central to the organization's goals. Other, more limited forms of interaction are often used to prove the technology transfer case – as if the number of interactions were the real measure. Experience has shown that a high number of small contacts is not likely to provide the essential conditions for effective technology transfer. Unfortunately, a number of government laboratories have entered into a game of proving technology transfer by counting their interactions. Such an approach encourages the wrong kinds of linkages and provides no meaningful indication of what is really taking place. This was of particular concern to the peer review committees. The following peer review report excerpts are typical of the range of concerns:

> It was not clear that the laboratory's activity had in fact benefited Canadian industry or that the technology developed could be successfully transferred or licensed. There was no element of novelty which would impart potential competitive advantage to Canadian industry.
>
> There are far too many projects and too few staff to do justice to many of the high priority projects. The (establishment) is operating in an environment of declining resources. As management has attempted to continue to meet all its client obligations, it has maintained the number of projects, but has reduced the level of resources assigned to each. They have been unwilling (or have not been permitted) to take hard decisions reducing the number of projects.

Efforts have been made within the federal government to create distinctive structures for selected laboratories with an external focus through the recent Technology Centres Policy. The centres are required to develop business plans and support that involve an advisory board of representatives from the private sector. But the technology centres also remain part of the management regime that applies to departments. Thus, personnel controls persist, accounting-driven evaluations are the norm, and central agency contracting and licensing rules intercede.

The Technology Centres Policy also attempts to create a client relationship with the users of research results. From industry's perspective, the best scientists end up working on short term projects with industry because their expertise is marketable. However, concerns have been expressed that long term research is becoming the domain of scientists who cannot build relationships with companies, while the best scientists and engineers fear that they are not keeping abreast of advances or contributing to advances in their field. Unless these issues are addressed, technology centres run the risk of diminishing their distinctive research capabilities and thereby their ability to support industry in the long term.

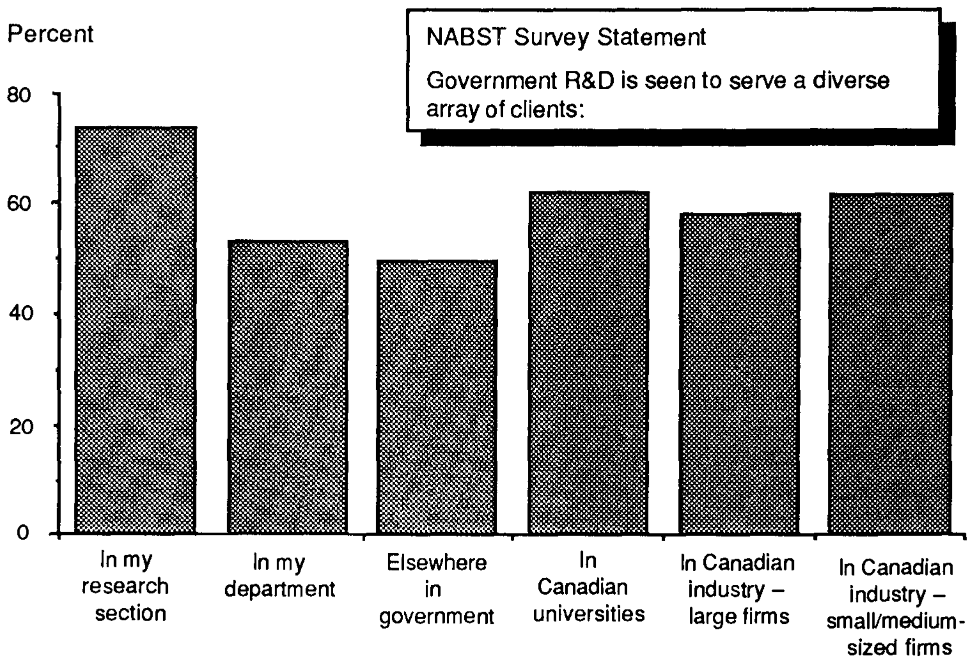
The Committee's survey indicates that such policies will have to overcome a history of entrenched scientific attitudes and an accompanying fierce independence in which self-directed research values predominate over the client focus. However it heard evidence that in some technology centres, the efforts of the last two years have, in fact, led to a change in the attitudes of scientists and the nature of their relationship with industry and universities. A peer review panel concurs: "The scientists have adapted well to government's policy shift for cost-sharing with industry and cost recovery for service work."

Government scientists see themselves serving a diverse array of clients (see Exhibit 3.3). This was of concern to the peer review committees visiting some of the laboratories. As one team reported:

> "The quality of research could be enhanced by decreasing the rather diverse range of client-directed projects. This would allow more focus, particularly in important areas, with a greater range of experimental approaches for characterizing the nature and potential relevance of a given problem, as well as considerably greater depth of understanding of the mechanisms and predictive aspects of the problem.

Exhibit 3.3

Clients of Government R&D

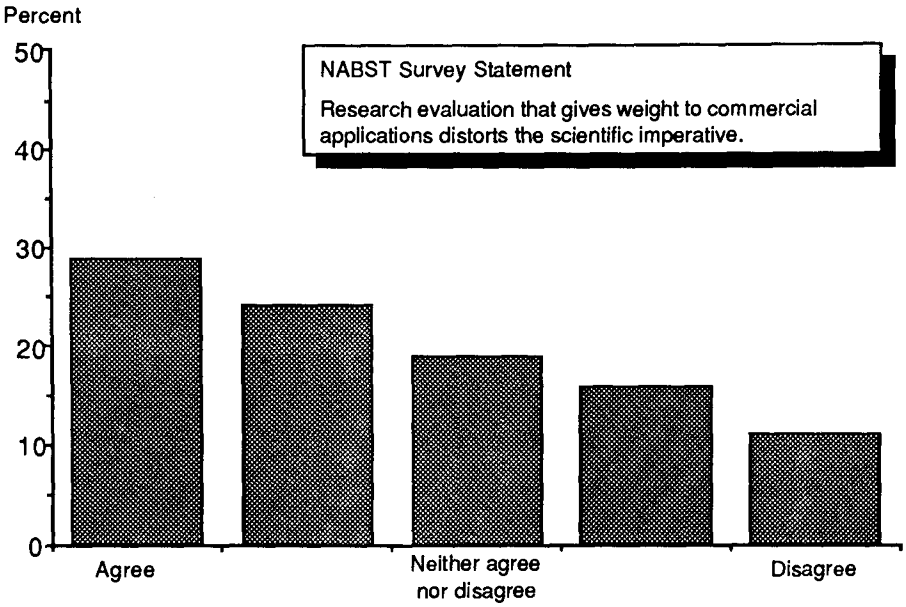


Source: NABST Survey on Research Management and Evaluation, conducted by Canada Consulting, 1989.

Another potential obstacle to effective technology transfer is that departmental scientists and engineers have made a decision to join the public service; very few feel they want to go out on their own and commercialize their research. Moreover, a large proportion of researchers feel that research evaluation that gives weight to commercial applications distorts the scientific imperative (see Exhibit 3.4).

Exhibit 3.4

Role of Commercial Applications in Research Evaluation



Source: NABST Survey on Research Management and Evaluation, conducted by Canada Consulting, 1989.

The limited nature of some technology transfer relationships is reflected by the belief expressed by one third of the scientists that research results are not fully utilized because the private sector capability to receive the technology is limited (see Exhibit 3.5). While this may be so, it suggests unfortunately that linkages are not strong enough to ensure that receptor capability problems can be overcome early or that research is not carried out where the transfer of technology is unlikely. While a strong challenge lies ahead in building effective linkages, the Committee's survey indicated that there is an inherent motivation to push towards this end. Scientists and engineers who have frequent interaction with their clients have a far stronger feeling that the results of their research are being utilized (see Exhibit 3.6).

The experience of technology centres also indicates that, with proper institutional and operating incentives, these traditional attitudes can evolve. A peer panel remarked that, contrary to the situation that prevailed some years ago and "because of the very nature of the technology centre concept and mandate, the scientists interact effectively with both industry and university communities, promoting effective transfer of technology and information." The technology centre concept does not apply to every departmental S&T establishment, but the lessons learned should not be lost.

Exhibit 3.5

Exploitation of Research Results

Percent

Reasons why results of research not fully utilized	Total survey	Researcher	Research Manager	Policy/ Evaluators
Private sector capability is limited	32	30	42 ←	14
Programs/support mechanisms to transfer the results are inadequate	17	14 →	25	17
Too little budget for utilizing the outcome	16	12 →	21	19
Little interaction amongst researchers within the department	14	18 ←	6	12
Few opportunities to contact people outside the department and understand their needs	12	15 ←	6	17
Public sector capability is limited	10	10	10	2
Other	14	17	10	12

Source: NABST Survey on Research Management and Evaluation, conducted by Canada Consulting, 1989.

Note: Columns may add up to more than 100 percent because respondents were asked to "check as many as apply."

Exhibit 3.6

Exploitation of Research Results and Interaction with Clients

Percent

Interaction with clients \ Utilization of results	Fully utilized	Partially utilized	Knowledge only so far	Not utilized
Only indirectly	6	4	7	22
Rarely	4	9	14	33
Sometimes	27	36	38	33
Frequently	59	49	36	11

Source: NABST Survey on Research Management and Evaluation, conducted by Canada Consulting, 1989.

3.4 Exploitation of Intellectual Property

The commercial exploitation of knowledge and innovations developed in government laboratories is seriously constrained by ownership restrictions and a laborious legal process. While encouraging client contact and technology transfer with one hand, the government is impeding its implementation with the other. S&T organizations in departments do not have full rights to enter into contracts, patent and license technology, set fees for services, or even retain a significant portion of the revenue generated by their services. Central agencies such as Supply and Services Canada and CPDL are involved at every turn.

CPDL, which is the federal government's mandated third-party legal and marketing agency, cuts into the midstream of the technology transfer process, effectively divorcing the S&T organization and, more importantly, the scientist responsible for the innovation from the patenting and commercializing process. Organizations exemplifying best practices in this area have found that the ownership of intellectual property and its management must rest with the organization that generated it. Moreover, significant monetary and other incentives are provided to the scientists and engineers to encourage them to seek patent protection and commercialization of their innovations. The commercialization process does not function well through the intervention of an external middleman because a large portion of the knowledge intrinsic to an innovation is non-codified and therefore cannot be transferred efficiently without the active involvement of the innovator.

The United States has taken major steps in this direction, enacting the *Federal Technology Transfer Act* in 1986 to provide incentives to federal government laboratories to transfer technology. The act gives laboratories the authority to enter into co-operative R&D agreements (CRADAs) on behalf of their departments and to negotiate licensing agreements directly. It is worthy of note that the act requires the central administration of the R&D organizations to delegate this authority to the director of each laboratory, a sharp contrast with the institutional framework that exists in Canada. Moreover, it permits laboratories to retain and use the full amount of funds earned from this collaborative work. Laboratories have the right to assign patent rights to a collaborator and, under some circumstances, even to waive the government's right to the intellectual property altogether. Government employees and former employees have the right to participate in the commercialization of government inventions.

The act also provides for substantial financial incentives. Agencies are *required* to set up cash award programs for scientists, engineers and technical personnel for new inventions, contributions to science, or activities promoting domestic technology transfer. In addition, individual inventors employed, or formerly employed, by the government personally receive a minimum of 15 percent of royalties earned from their inventions.

These incentives have had a powerful effect on the activity of scientists in United States government laboratories. In his July 1989 report to the president, the Secretary of Commerce indicated that the first two years of implementation of the act have already seen a marked increase in the number of co-operative agreements with industry and in the number of patented inventions by government laboratories.

Exhibit 3.7

Comparison of Research Budgets and Licence Fees ($ 000s)

	1986 Research budget	1986 Licence fees and royalties	Use CPDL
University of Waterloo	33 000	1 900	
Guelph University	48 000	417	
Queen's University	28 000	350	✔
National Research Council	260 000	50	✔
University of Ottawa	33 000	10	✔
University of Western Ontario	41 000	7	✔
McMaster University	47 000	1	✔

Source: The Office of Research in the universities.

But it is not necessary to rely exclusively on foreign experiences to demonstrate the dysfunctional impact of the current institutional arrangements that govern departmental S&T establishments. In Ontario, universities have the choice between adopting their own policies and technology commercialization organization or using CPDL. The leaders in earnings resulting from technology transfer, the Universities of Guelph and Waterloo, have adopted their own policies, whereas the other institutions in Exhibit 3.7 use CPDL.

CPDL earnings, including all government departments, NRC and other agencies, and 13 universities totalled $1.8 million in 1989.

3.5 Conclusion

Until now, government solutions to the challenge of managing research, increasing the flow of information and innovations, and increasing the commercialization of the knowledge produced in its S&T establishments have been process solutions rather than organizational solutions. The lesson from other organizations is that without the right structure and linkage mechanisms, new processes have little effect at best and, more often than not, have a dysfunctional impact. S&T activity thrives in an environment where scientific values and culture are recognized and levered to motivate and guide the organization. While it is not possible within large organizations to divorce the scientific cadre entirely from the processes of bureaucracy, it is possible to create some distance through new structures that still provide the tight linkages necessary to achieve a high degree of public accountability. To do so, it becomes imperative to eliminate the processes that both miss the mark and constitute an administrative overload on the management of S&T in government departments.

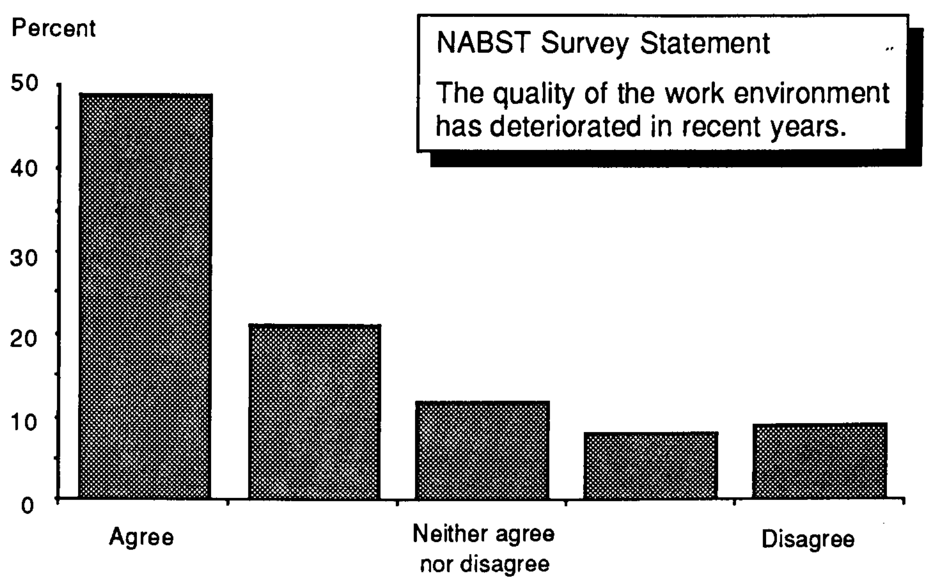
4.0 HUMAN RESOURCES IN INTRAMURAL S&T: COMPARISONS WITH BEST PRACTICES

Flexible and creative human resource management is essential in creating a vital and productive research establishment. To ensure a high level of quality in government S&T, quality people must be attracted, developed, rewarded and motivated. Good managers must be selected and trained. The system of human resource practices and policies must effectively meet the needs of individuals and of the institution. And the movement of scientists in and out of the organization must be balanced with the need for continuity in projects and lines of research. The status quo is never good enough; though it is often elusive, revitalization must be a constant goal.

The current human resource management regime was raised consistently as an issue of continuing and deep concern in federal intramural S&T. In the Committee survey, 50 percent of respondents agreed strongly that the quality of the research work environment has deteriorated in recent years (see Exhibit 4.1). The way scientists are recruited, the classification system, promotional opportunities and person-year controls, the aging problem, training for research managers, performance appraisal, recognition, and rewards all present challenges that can undermine the potency of any new S&T initiative government adopts.

Exhibit 4.1

Quality of the Work Environment



Source: NABST Survey on Research Management and Evaluation, conducted by Canada Consulting, 1989.

4.1 A Revitalized Scientific Work Force

It is well accepted among top research managers internationally that scientific effort must be managed around a variety of creative tensions. Some of these tensions relate to overall goal setting, laboratory management and the need to align organizational and individual goals. The most challenging tensions, however, seem to lie in establishing a human resource policy environment that recognizes the unique culture of the scientist. At the heart of these policies is the notion of revitalization: revitalizing the scientific work force overall and nurturing the continuous revitalization of individual initiative and contribution. The best-managed R&D organizations find the right balance between exposing scientists to stability and uncertainty, continuity and change, independence and interaction. All this is accomplished while maintaining commitment to the mission and continuity of contribution to organizational R&D goals.

The importance of revitalization in the public service scientific work force is well recognized by the S&T sectors of government. Several studies have spoken to the set of issues that government must address. Vigorous attempts to improve the management of human resources are under way in some departments. An interdepartmental committee on the management of S&T has taken human resource issues as a key priority.

The fact remains, however, that current policies for scientists and engineers are largely an extension of general government personnel policies, not a management system that meets the unique human resources needs of an S&T organization. While issues are being studied and some actions taken, the measures contemplated are too limited to address the situation adequately.

4.1.1 Demographic Profile of the Scientific Population

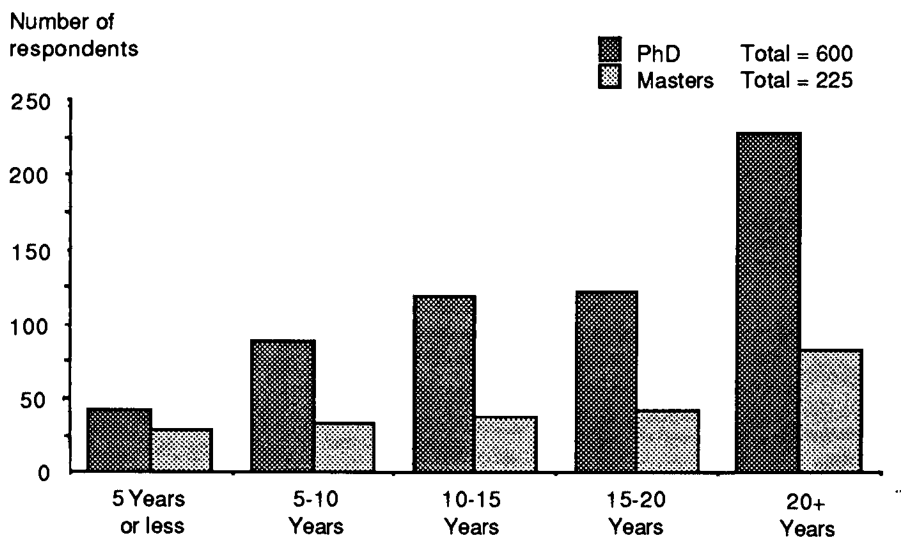
Although there is little evidence that the productivity or output of research scientists and engineers declines over time, it is accepted that the nature of the scientist's contribution, in fact, does change meaningfully and appropriately. While a scientist's individual contribution is likely to be greatest in the early years of a career, mid- or late-career scientists and engineers are more likely to be accomplished research leaders, mentors, team builders and networkers. There is general agreement, however, that the most creative technical period in scientists' and engineers' careers tends to end in their thirties or early forties, depending on the quality of the individuals and the environment in which they work. There are several explanations for this phenomenon. First is the tendency, over time, to specialize, rather than to seek broad new research areas. Second is networking; older scientists and engineers tend to affiliate more with others in their age and experience group than with junior scientists and engineers, who are closer to emerging paradigms. Third is the shift from individual contribution to a mentoring role, which tends to occur naturally as the scientist grows older and gains experience in the organization. Whatever the reason, it is clear that a steady flow of young new scientists and engineers is critical to the continuing revitalization of a scientific organization's technical excellence.

The federal public service, like government scientific establishments globally, is concerned about the increasing average age of its scientific and engineering professionals. The median age across government departments today is 48. Of equal concern is the fact that nearly one third of scientists and engineers in federal departments are eligible for retirement, half of them with full pension.

Average age levels vary across categories and by department. (Public service research positions are usually in the category called RES.) For example, the average age of an RES 1 in Com is 28, while in EMR and HWC it is 34. In the RES 2, 3 and 4 categories, the average ages are much closer to the median and range from 45 in RES 2 to 55 in RES 4. The majority of survey respondents had been in the public service more than 10 years, and more than one third received their PhD and master's degrees more than 20 years ago (see Exhibits 4.2, 4.3).

Exhibit 4.2

Number of Years Since Receiving Degree



Source: NABST Survey on Research Management and Evaluation, conducted by Canada Consulting, 1989.

Exhibit 4.3

Years of Employment in Government Laboratories

Years	Respondents	Percent	
1-5	162	18	
6-10	220	25	
11-15	196	22	57% over 10 years
16-20	132	15	
21-25	110	12	
26+	69	8	
	889	100	

Source: NABST Survey on Research Management and Evaluation, conducted by Canada Consulting, 1989.

R&D organizations employ a variety of strategies to ensure a continuous flow of new blood into their organizations. Top-performing organizations provide a variety of term appointments for master's, PhD and post-doctoral students. This ensures that young scientists and engineers are an active part of the R&D organizations while supporting the longer term interests of the laboratory in recruiting the very best talent. Good laboratories depend upon good people, and the recruiting process is given extremely serious attention. As one peer review team put it, commenting on a departmental laboratory:

> The committee identified a few problem areas. Some of these are related to the aging population of scientists, a problem which affects all laboratories, especially in the public sector. The older and mature scientists provide an essential backbone to the organization; the younger scientists provide drive and enthusiasm and are the world leaders of the future. Some increased emphasis on basic research and an expanded exchange program of scientists and engineers with other laboratories would help in maintaining an effective balance between the talents of younger and older scientists and help in recruitment.

4.1.2 The Classification System

The federal public service classification system for professionals in scientific and engineering positions has two major components: an incumbent-based system for researchers (the RES category) and a position-based system for professionals whose primary role is other than research. The former are almost entirely PhD-level scientists; the latter are a mix of BSc, MSc and PhD graduates in the natural sciences and engineering.

The RES category cuts across all disciplines and departments. The intention was to provide a vehicle for advancement that would (1) be based on merit or individual performance, (2) avoid the problem of having to compete for a new position in order to be promoted, and (3) reward scientists and engineers effectively for remaining at the bench rather than moving into managerial roles. In this respect, it is consistent with the technical ladder common across industry.

By contrast, a chemist, engineer or physical scientist in the non-RES category moves along a technical ladder that is discipline-specific and is expected to advance through the more traditional route of internal competition.

This two-track system of classification and reward is similar to systems in existence throughout industry. There, scientists and engineers generally rise fairly consistently on a merit basis in pay and stature. Most R&D organizations provide for several steps along the ladder. Typically, all new scientists and engineers begin on the technical ladder. Its rungs usually extend to the equivalent of laboratory director, although in organizations such as IBM and AT&T, the technical ladder may rise as far as vice-president equivalent for accomplished scientists who are recognized world leaders in their fields. Industry varies considerably in the specific positions assigned senior scientists and engineers, and in their responsibilities. For example, 3M has approximately 20 "corporate fellows." Exxon terms its most senior scientists and engineers chiefs and involves them closely in the identification of exploratory research areas.

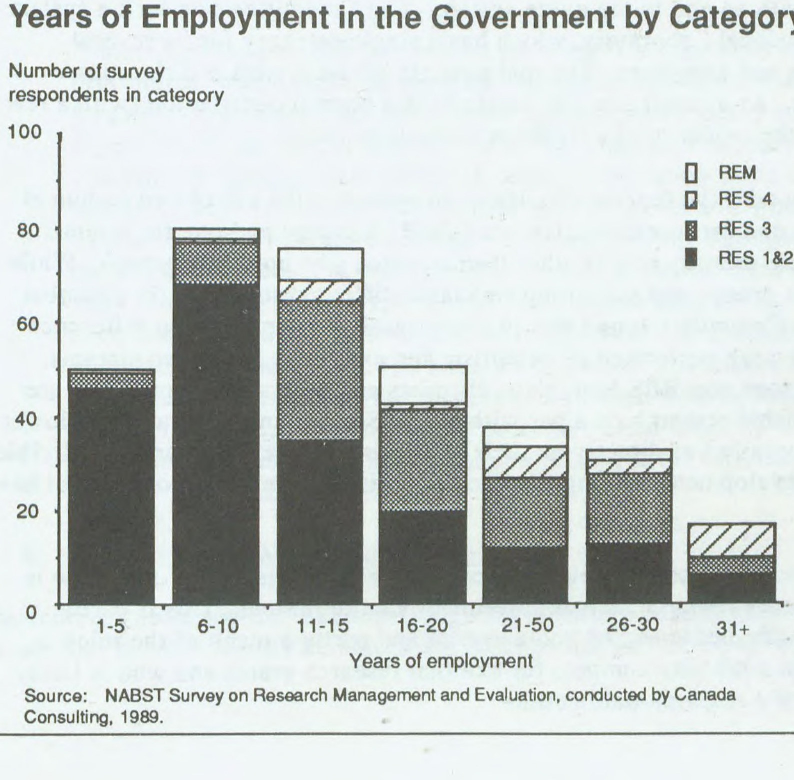
In theory, the classification system provides the means by which departments could effectively reward and advance individuals and assure a continuing stream of talent into the system. However, several factors operate to produce the opposite effect.

One factor inhibiting the effectiveness of the classification system is the quota on RES categories 3 and 4. As industry has found, quotas have the effect of destroying the integrity of a merit-based technical ladder. This is particularly the case where turnover is low, as in the public service population. Even where it is not, the imposition of quotas in effect shifts the criteria for advancement at senior scientific levels from merit-based to incumbency-based. As a result, the career peak for scientists and engineers in the federal system is at age 40 to 45 with little opportunity for further advancement.

This situation has also significantly affected the performance appraisal system for research scientists. Promotion through RES 1 and the various levels of RES 2 is virtually automatic, with most of those hired in a given year arriving at the top of the RES 2 category at approximately the same time. Therefore, although the system appears merit-based on the surface, scientists are in fact promoted in lock step for the first 10 years of their careers. At this point, a major appraisal is conducted to determine whether they are promotable to RES 3. However, many scientists who have met the RES 3 criteria are now blocked in RES 2 along with their colleagues who have not been judged promotable. Among the survey respondents, there were almost as many scientists in the RES 2 category with more than 16 years of experience as there were RES 3 (see Exhibit 4.4). As one would expect, the motivation of these scientists is reduced by a system that, in the abstract, promises advancement based on merit but does not deliver in practice.

Exhibit 4.4

Years of Employment in the Government by Category



Source: NABST Survey on Research Management and Evaluation, conducted by Canada Consulting, 1989.

Industry has taken several steps to address these types of issues. Its experience, similar to that of the public service, is that quotas represent an expedient but ineffective bureaucratic solution to what is essentially a problem of good management. Very few industrial research organizations maintain a quota on scientific incumbency. Those that do experience the problems now facing the federal public service. The best public and private sector R&D organizations focus their efforts instead on ensuring the integrity of their classification structures at each level. Advancement at each level is scrupulously reviewed; those not able to demonstrate the competencies required for promotion within technical fields are counselled, given appropriate training, terminated, or moved into positions elsewhere in the organization where their skills can be put to better use.

By contrast, in the public service today, 70 percent of the RES 2 scientists are at the top of the RES 2 category. The primary motivation of scientists may not be formal position, but it is impossible for this situation not to affect their creativity and productivity. As one scientist put it:

> RES 2, 3 and 4 appraisal and promotions are driven not by ability or productivity, but by upper management perception of grade symmetry. Consequently, many RES 2s have not been promoted to level 3 despite having the necessary qualifications. This has a damning effect on scientific research.

The Committee found widespread concern about the presence and impact of this problem. Not surprisingly, support is growing for the addition of a new RES level, effectively creating a level 2A. This may have the effect of smoothing the curve at the top of the RES 2 category by spreading the group over another grade, but it is at best a stop-gap measure. It only shifts the problem forward into the future; it does not solve it. What is needed, the Committee believes, is rigorous management of the technical ladder combined with an end to the quota system. The Committee saw such a system at the Los Alamos National Laboratory, which has a single category for its several thousand scientists and engineers. The real strength of the system is a rigorous evaluation process. As a result, the pay levels have a normal distribution (with a few anomalies), again the evidence of a rigorous evaluation system.

Another deficiency with the federal classification system is the use of two technical ladders in tandem, one for research scientists (the RES group) and one for scientists and engineers whose primary role is other than research (the non-RES group). While these classification groups and sub-group standards differ substantially on a number of dimensions, the Committee found that in many cases, there may be no difference between the actual work performed by scientists and engineers in the two streams. Specifically, numerous non-RES biologists, chemists and others who have PhDs are conducting publishable research on a par with the RES community, yet are paid lower salaries, are not appraised as directly on their publishing productivity, and are eligible for management development training to which scientists in the RES group do not have access.

While a non-RES scientist can technically move into a RES category if he or she is publishing noteworthy research, actual movement is quite limited. This is partly because of the already-bottlenecked quota system and partly a result of the rules surrounding who in a lab may compete for external research grants and who is likely to receive credit for a research publication.

In many of the R&D organizations examined, both national and international, the Committee found systems in place where all scientists and engineers are in one category with considerably more levels and more sophisticated standards. This injects a greater measure of equity into the classification system and increases the likelihood that performance will be rewarded more fairly and explicitly.

4.1.3 The PY Problem

The application of person-year (PY) constraints is a government-wide phenomenon with particularly profound implications for the revitalization of the scientific work force. The burgeoning workload of the scientific sector, created in part by growing expectations about the contribution of science to government objectives, combined with PY reductions, has created a situation where departments tend to use the PYs available to hire experienced, rather than young, scientists and engineers. The clear trend is to hire not new PhDs, but scientists and engineers who have been out for several years, typically at the RES 2 level. This approach is in direct contrast to other scientific organizations which generally prefer to hire new graduates. From a departmental perspective, this approach ensures that each new or replaced PY position will be filled by a professional who should be able to contribute immediately, without going through the apprenticeship period usually expected of new scientists and engineers. In HWC, for example, only 10 percent of the RES population is RES 1, the entry level, while 57 percent is in the RES 2 group. From a government-wide perspective, the result is a diminished infusion of new blood into the scientific ranks and an exacerbation of the graying of the government's scientific work force. Given the age of the scientist at time of entry, it is fair to assume that mobility out of R&D establishments will be lower, thus compounding an already serious situation. This is a powerful limit on the ability of government intramural S&T to remain at the forefront and build a strong reputation within the scientific and business communities. Again, quoting from a peer review team:

> A more serious problem lies behind the current administrative procedures, which make an absolute separation between PY allocation (regardless of salary), operating costs (goods and services) and capital expenditures. It has become customary for managers to analyze the costs of a project almost entirely in terms of operating costs since the managers have relatively little control over PY costs and other overhead. Administrative constraints almost prevent managers from including these costs in their analysis. As an example, there are now situations where highly experienced professional staff are not adequately supported by technical staff who have other, equally valuable practical skills. The situation is endemic to almost all government laboratories, not just the establishment being reviewed here. In essence, the management procedures laid down by Treasury Board for the public service are inappropriate for the efficient management of scientific establishments.

4.1.4 Recruiting and Work Force Mobility

The federal public service, like most large organizations, needs personnel policies that ensure that fairness, equity and merit are an essential part of the hiring process.

While this process can be cumbersome and take a great deal of time to complete, the Committee found that a far more serious problem is the limited use of flexible approaches such as temporary and term assignments to attract young scientists and engineers into government. For example, under the current management regime, a department must free up a PY to engage a post-doctoral student. Again, the result is more hiring of older scientists, while the attraction of younger scientists and engineers into the laboratories is the exception.

The government has taken some steps to provide for the entry of younger researchers into departmental laboratories. It has created a special PY allotment of 175 recent PhD graduates for a three-year period. While this provides for some revitalization of the core scientific work force, it does not create any capacity for bringing in young scientists and engineers on temporary assignments. As a peer review report put it:

> The section heads are doing an excellent job of recruiting bright, well-trained young scientists who possess complementary expertise to existing permanent scientific staff. In this context it is important that the post-doctoral researcher component of these research programs be strengthened/enlarged.

In this respect, departmental laboratories operate on a system quite different from that of NRC, where 20 percent of the total scientific complement is made up of "research associates" who are, in most cases, post-doctoral fellows. NRC's council is not satisfied with this level of flexibility and is considering increasing this ratio. We found that many of the outstanding R&D organizations had programs similar to NRC's.

Another important factor in revitalizing a scientific work force – mobility of scientists and engineers to the outside – is limited for a number of reasons. First, scientists and engineers receiving government salaries may not be able to obtain competitive salaries in the private sector or academia unless they are accomplished research managers or significant top performers. As a result it is often the best and brightest that move on. The Committee's review of research scientists' salaries outside government suggests that, especially for mid-and late-career scientists, average salaries are slightly higher in the federal public service. Second, scientists who join the public service later in their careers need to work longer in order to receive full pension and so extend their careers accordingly. A third factor that limits mobility is that it is possible to become isolated, by choice or by circumstance, from the mainstream of research if a scientist's career does not involve regular competition for external research grants. As a result, scientists and engineers can get stuck in government with few or no options on the outside. The Committee has also found that, in many cases, public service scientists and engineers have a great deal of freedom to choose their own projects and work in an environment that places few demands on them for scientific quality and productivity. As one senior corporate scientific manager said, scientists and engineers tend to extend their careers in organizations where there is a great deal of freedom and no demanding requirements for research productivity.

For many scientists and engineers in federal departments, there is neither the requirement nor significant opportunity to move out of research roles over the course of a career. Researchers who attempt to build management or non-scientific skills face few rewards or incentives for doing so. Many scientists and engineers told of unsuccessful attempts to obtain management development training throughout their careers. All rewards and incentives are directed to remaining in the scientific stream. This is in contrast to industry practice, where continuing in a research role depends upon continued outstanding performance. In fact, for most researchers, the expectation is that they will move into other roles after a period in research. In industry, typically 20 percent or fewer of those entering research positions will remain in these roles throughout their careers. Research laboratories in such organizations as BNR, Martin Marietta and Kodak have career development systems that ensure flow by moving the majority of their scientists and engineers into applications, marketing and technical support roles. Exxon and other organizations make it a firm practice to ensure that most scientists and engineers are given a breadth of experience in roles other than research. This in turn creates opportunities for others to enter the organization, bringing new knowledge and capabilities.

The British government laboratory system takes a similar approach. The expectation is that scientists and engineers should, at mid-career, move into departmental positions. As in industry, this ensures a steady stream of new researchers. It has also proved a boon to other areas of the British civil service, which find scientists and engineers uniquely able in a variety of line, staff, and advisory roles. Significantly, the U.K. government was the only one to indicate to the Committee that it did not have an age problem in the scientific work force.

By failing to provide efficacious means for the movement of scientists and engineers into other roles, the government loses on several grounds. It retains a scientific establishment that is, ultimately, tired and frustrated. It pre-empts the opportunity for scientists and engineers to enjoy meaningful careers and make needed contributions in other sectors of government. And, it misses a key opportunity to ensure that, through the movement of scientists and engineers into policy and other management roles, there is good understanding of the relationship between science and other agencies on both sides of the transom. Industry has not missed this opportunity; most technology-intensive industries have a large proportion of scientists and engineers among their most senior management. Interestingly, one piece of information about the public service supports this argument. The Committee learned that between 1976 and 1978, a limited number of people from scientific ranks bid successfully for positions in other government sectors. These individuals now hold key positions in central agencies and at the senior executive level of several departments.

Graying is a problem that feeds itself. The lack of opportunity for new PhDs to enter government decreases the attractiveness of government as an employer for both new and seasoned scientists. At the same time, it dampens creativity in government science and reduces the effectiveness of its contribution to the policy-making and regulatory processes it is intended to support.

4.2 The Effective S&T Manager

Because research managers are the interface between the top-down and bottom-up forces in the S&T goal-setting and management process, the importance of effective top-level and first-line S&T management cannot be overstated. The Committee's findings are clear with respect to the importance industry accords the selection, development and reward of high quality managers of scientific and technical work. The experience of the federal government is generally quite different.

4.2.1 First-Line S&T Management

There is, to be sure, no standard basis on which individuals can be selected for supervisory and management responsibility. Nevertheless, the senior management of industrial R&D organizations devotes great effort to ensuring that those with managerial capabilities are identified and developed through both assignments and training. The principle focus of bodies such as Rohm & Haas's "technical development committee" is ensuring that their organization has the talent required to lead research and researchers.

The federal government situation departs sharply from this best practice. Several years ago, the research manager (or REM) classification was adjusted downward in relation to RES categories, with the aim of encouraging good scientists and engineers to continue in the research stream. The REM salary peaks below the RES 3 level and below that of other senior public service management job classifications. One consequence has been to weaken the integrity of the RES classification; many in the RES 3 category are in fact performing some version of the managerial role. Worse, the credibility of and respect for the REM position has declined to the point where, in many departments' S&T establishments, the research manager is too often viewed as a failed scientist. In other laboratories, the management role has been reduced to an essentially administrative function that is rotated among RESs.

The Committee's survey showed that managers are seen to play important roles in the selection, management and termination of research projects. In fact, next to the researcher, the direct supervisor was seen to be the strongest influence on project management. However, focus group meetings, written comments on the survey, and peer reviews showed concerns about the general quality of management in federal government laboratories today:

> Research managers here either don't exist or they are too bogged down in administration and bureaucracy to manage the research, i.e., foster, encourage, provide support, arrange collaborative efforts, protect us from bureaucracy.

In the absence of tangible incentives to perform the management function, it is not surprising that the REM role and classification are problematic. The result has been a general decline in government attention, at the sector and laboratory level, to effective selection and development of managerial capability. At the departmental and government-wide level, this has been worsened by the lack of effective mechanisms for the training and continuing development of managers of S&T activities. The problems of S&T management in government have become a vicious circle. The poorer the management that exists, the more bureaucratic measures and micro-management have been used to supplant the management function. The result is that fewer and fewer good people aspire to careers in S&T management.

4.2.2 Senior Managers of S&T Establishments

Beyond the issue of first-line S&T management is the larger question of ensuring the commitment of senior departmental management to technical excellence within S&T establishments. The interface role of the senior manager between what is essentially a service organization and the client body is integral to the effective flow of knowledge and innovation. The S&T manager must be both accountable for technical quality and mindful of client needs in the short and the long term.

Many problems identified by peer review panels have their roots in weaknesses of management.

> It is the opinion of the committee that, if many of the smaller, perhaps questionable projects were terminated, and the resources reallocated to a few well-focused areas chosen in the planning process described below, the new teams could be of sufficient size to make more significant contributions. They would have little difficulty reaching and maintaining a position at the forefront of their field. The committee also believes that such an approach would not seriously reduce the ability of [the establishment] to provide advice and expertise to its clients in technologies of importance for Canada.

The problem is double-edged. As discussed in the previous section, there are substantial barriers in the federal government to scientists and engineers moving into more-senior management positions. Consequently there are few entrants with strong scientific backgrounds in the director general, assistant deputy minister, and deputy minister streams. A companion problem arises from the fact that senior managers from non-technical backgrounds often lack the will or the opportunity to familiarize themselves with the culture and contribution of their scientific organizations. While this problem may be symptomatic of a larger societal confusion about the role and contribution of science in Canada, it can be addressed through specific programs that select and develop senior managers with the necessary breadth of perspective to lead organizations that combine technical and non-technical responsibilities.

4.3 Evaluating Scientists and Engineers on Quality

As a former senior vice-president of research for IBM put it: "In the more academic divisions of our R&D laboratories, the best test of whether our work is state-of-the-art is where we publish, where we're invited to publish, and at what conferences we're asked to speak. We measure quality by our ability to stay in the mainstream." In discussions with industry, publishing was seen to be important in all cases. Publication in influential refereed journals and invitations to speak at key conferences and symposia signal the status of the scientist within the scientific community and represent perhaps the most informed judgement of quality for individual scientists. Related indicators are participation in the scientific community as a reviewer or editor of key publications and patents granted.

Companies treat the overall publishing output as a measure of the health of the organization. One executive said he kept a private bibliography of the company's publishing and citation activity for his own evaluation purposes. In terms of evaluation criteria, the Committee's survey showed that the most important measure in the eyes of evaluators and scientists alike is publishing in refereed journals. Japanese government scientists and engineers shared the same view.

In response to this survey, scientists and engineers indicated that objective criteria such as solving a defined problem for a client or presenting at a conference deserved more weight than was generally given by evaluators. Interestingly, internal criteria such as publishing in departmental journals and meeting budgets and project deadlines were considered less important by scientists than they were by the evaluators (see Exhibits

4.5 and 4.6). The view of researchers and their managers again differed in this case, with scientists clearly emphasizing the importance of publishing and research managers giving almost equal weight to client satisfaction, publishing and maintaining the credibility of the laboratory in its field. Japanese scientists ranked patents second after publications as an indicator of quality, while the Canadian respondents ranked patents eleventh on a list of thirteen factors. This is explained in part by differences in patenting practices, e.g., the fact that it is possible to file very simple patent applications in Japan, which stay on the books for years, while in North America and Europe, one must have a final filing and examination quickly. However, equally important is the difference in attitude toward patenting among scientists in Japan.

Exhibit 4.5

Evaluation Criteria for Scientists

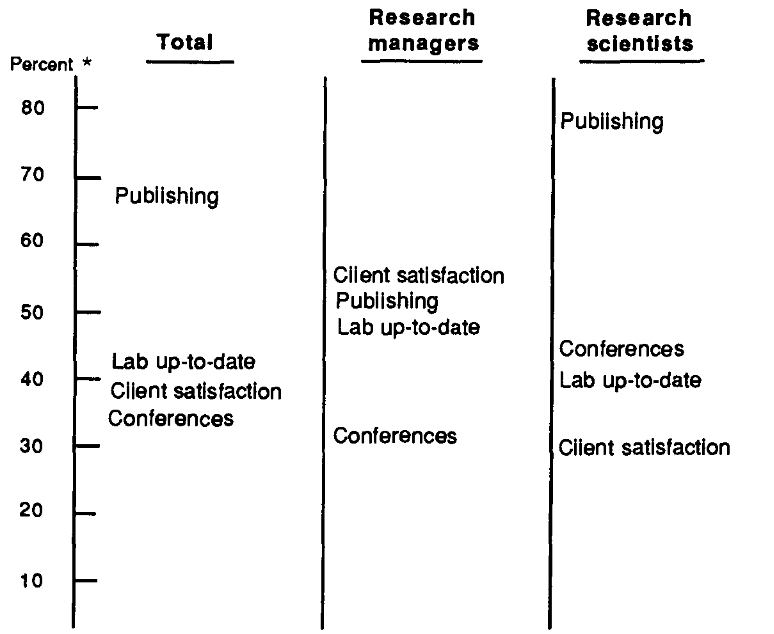
	Most important criterion in the view of the evaluators as perceived by the respondent		Most important criterion in the view of the respondent
Publishing in refereed journals	72	←→	67
Presenting at conferences	32	→	39
Client satisfaction	31	→	39
Maintaining lab's credibility in being up-to-date	23	→	41
Opinion of external peer review	14	→	20
Defined problem is solved	11	→	24
Publishing in departmental journals	23	←	16
Commercial demand for results	20	←	15
Opinion of advisory body	15	←	4
Meeting time-frame	14	←	7
Patenting	12	←	8
Reporting results internally	11	←	7
Meeting budgets	11	←	2

Source: NABST Survey on Research Management and Evaluation, conducted by Canada Consulting, 1989.

Most scientists consider the personnel appraisal system reasonably effective and more important than other forms of evaluation (see Exhibits 4.7, 4.8). The importance of individual appraisal again reflects the scientific values of researchers; their interest lies in their individual achievements as scientists. In fact the survey showed that evaluation of research and application of evaluation results happen primarily in the context of personal performance appraisal (see Exhibits 4.8, 4.9). In the absence of

Exhibit 4.6

Evaluation Criteria for Scientists as Identified by Research Managers and Scientists



Source: NABST Survey on Research Management and Evaluation, conducted by Canada Consulting, 1989.

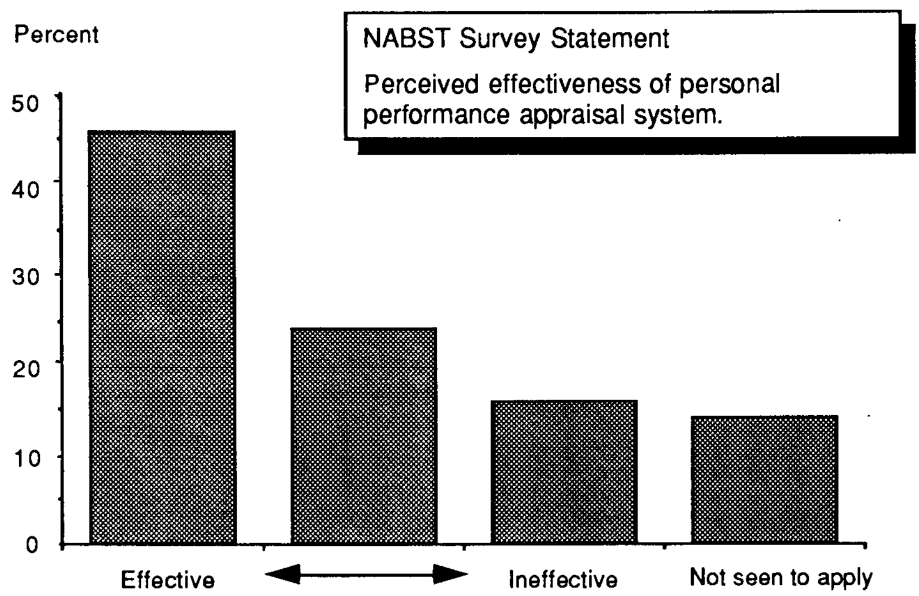
* Respondents were asked to select the three most important criteria in their opinion from a list of 13 possible criteria.

rigorous external evaluation, questions abound as to the efficiency of a system that relies so heavily on internal evaluations. Respondents were asked to rank, in order of priority, who is responsible for evaluation of completed research in their laboratory. The scientist and the scientist's direct supervisor were ranked most important, followed by six other categories (see Exhibit 4.10). Influences on the termination of research projects showed a similar internal orientation (see Exhibit 4.11).

For scientists in the RES category, for instance, the quota system for promotion renders much of the appraisal process ineffective. One scientist wrote: "Research scientist appraisals are a joke. Most scientists are deemed fully satisfactory yet the quota system for advancing beyond RES 2 blocks most." A further complication arises from the different bases used for evaluating RES and non-RES scientists, who may both be conducting research. While the RES scientist is evaluated on the basis of research output and quality, the non-RES scientist receives a standard departmental evaluation that includes non-technical development and even administrative contribution.

Exhibit 4.7

Effectiveness of Personal Performance Appraisal System



Source: NABST Survey on Research Management and Evaluation, conducted by Canada Consulting, 1989.

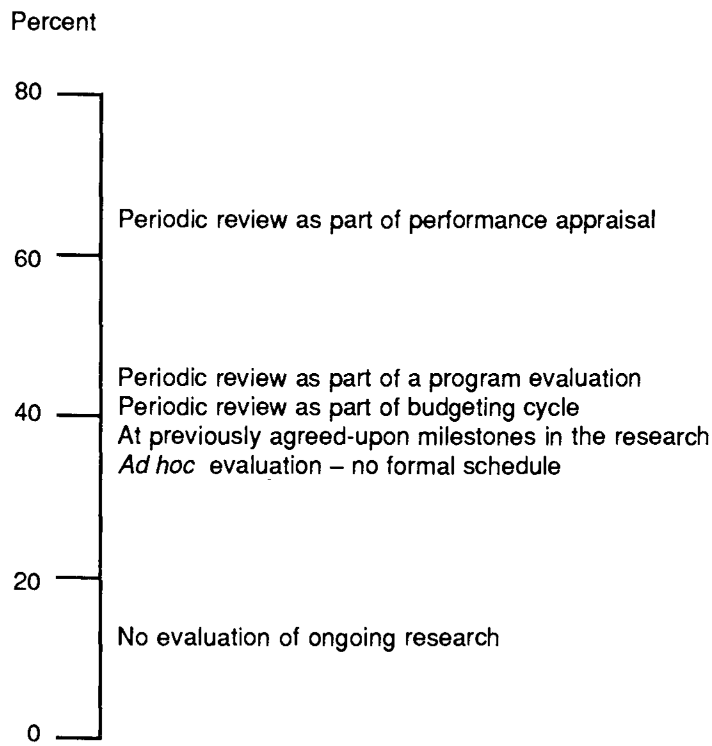
4.4 Performance Management Through Compensation

The Committee's analysis of compensation levels within and outside government shows that, on average, government researchers are compensated competitively relative to their private sector counterparts. This is especially true for mid- and late-career researchers, but less true for entry-level research scientists and research managers (the latter groups being those, not coincidentally, where government ranks are thinnest). Despite this comparability, however, private sector R&D organizations in Canada have much greater flexibility to attract top performers with higher than average salaries; in government, salary ranges are considerably narrower and ceilings considerably lower. The current salary structure suffers from instances of inversion of junior over senior salaries, compression, and spread between salaries for comparable jobs. Government salaries for scientists and engineers are also higher than academic salaries, particularly at the starting level, and in the past these jobs were seen as more rewarding and secure positions.

Outside of pay and promotion, government is understandably reluctant to provide financial recognition for the achievements of public servants, whatever the area of accomplishment, except for the most senior managers. This is certainly the case for scientists and engineers in the federal government. Nevertheless, it has been the experience of leading R&D organizations that instruments of tangible reward and recognition beyond base pay and benefits are useful in recognizing the accomplishments of outstanding scientists and engineers.

Exhibit 4.8

Prevalence of Various Research Assessment Practices

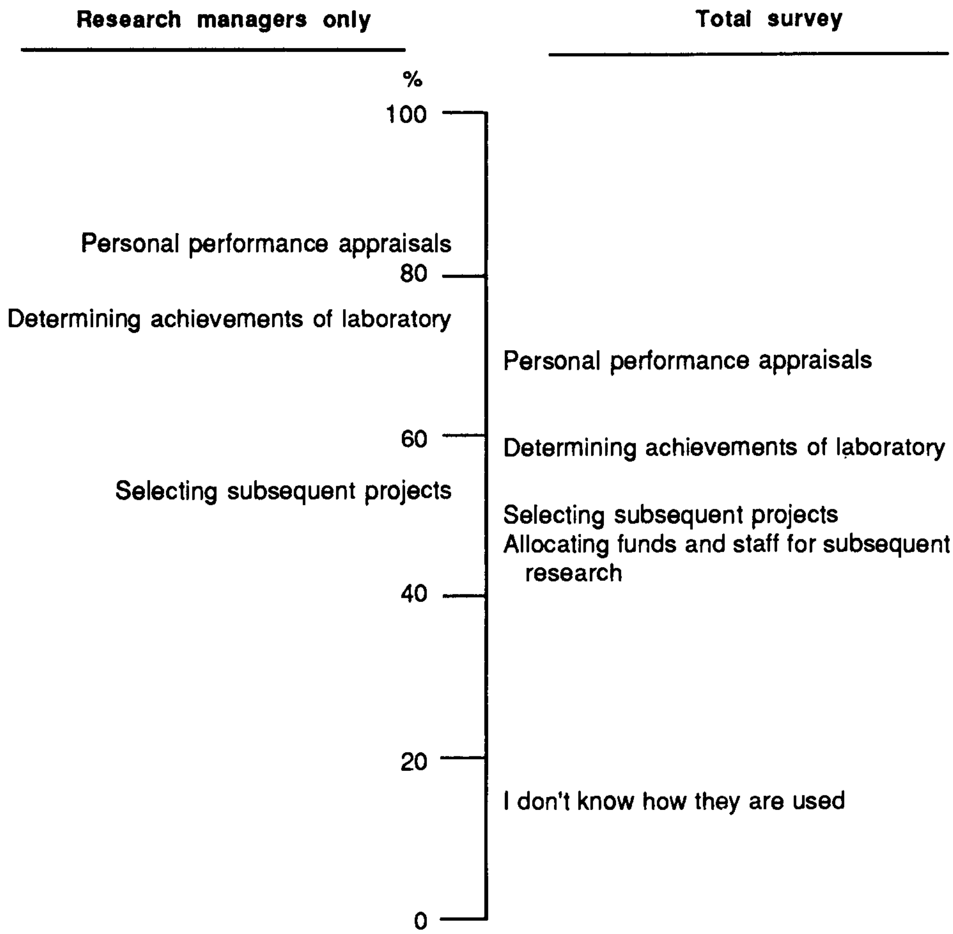


Source: NABST Survey on Research Management and Evaluation, conducted by Canada Consulting, 1989.

The act respecting inventions by public servants provides that the appropriate minister may authorize the payment of an award to the inventor whose ownership rights are vested in the government. Therefore, there are means of compensating scientists and engineers with a certain percentage of the revenues derived from technology developments that could be patented or licensed. There is substantial precedent for this in both the private and the public sector. Oak Ridge Laboratory, a United States Department of Energy GOCO, awards scientists 10 percent of the revenues derived from their patents up to maximum of $10 000. The new *Federal Technology Transfer Act* in the United States also makes provisions for financial rewards to scientists. Many leading private sector organizations make both patent and patent application awards. For example, IBM provides financial awards for scientists granted patents for their work. In France, Centre national de recherche scientifique (CNRS) researchers are allowed to consult one day a week and be paid by their clients.

Exhibit 4.9

Use of Research Evaluations



Source: NABST Survey on Research Management and Evaluation, conducted by Canada Consulting, 1989.

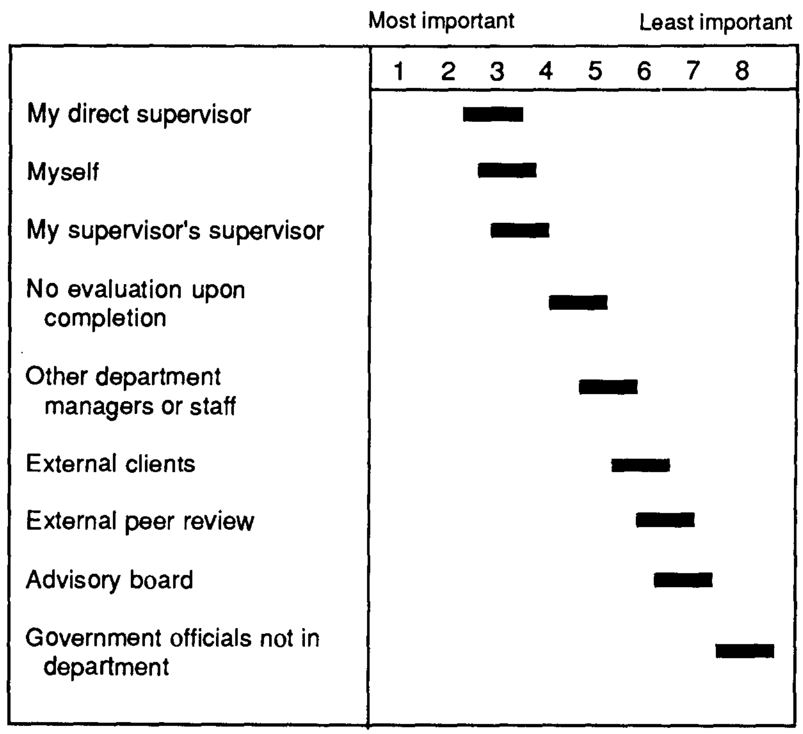
Private sector laboratories also place great emphasis on meaningful forms of non-monetary recognition. Appointment as an IBM fellow means, for example, that an IBM scientist or engineer has substantial freedom to define his or her own area of research; in addition, fellows have discretionary funds from which they can provide seed money to junior scientists. GE's Coolidge fellows are given a year's sabbatical. Carleton Award winners at 3M join a fraternity that is much prized within their corporate culture.

Exhibit 4.10

Ranking of Evaluation Methods

NABST Survey Statement

Typically, which of the following are responsible for evaluating research when a project is completed or a milestone achieved? Please rank in order of importance.



Source: NABST Survey on Research Management and Evaluation, conducted by Canada Consulting, 1989.

4.5 Promoting Scientific Interaction

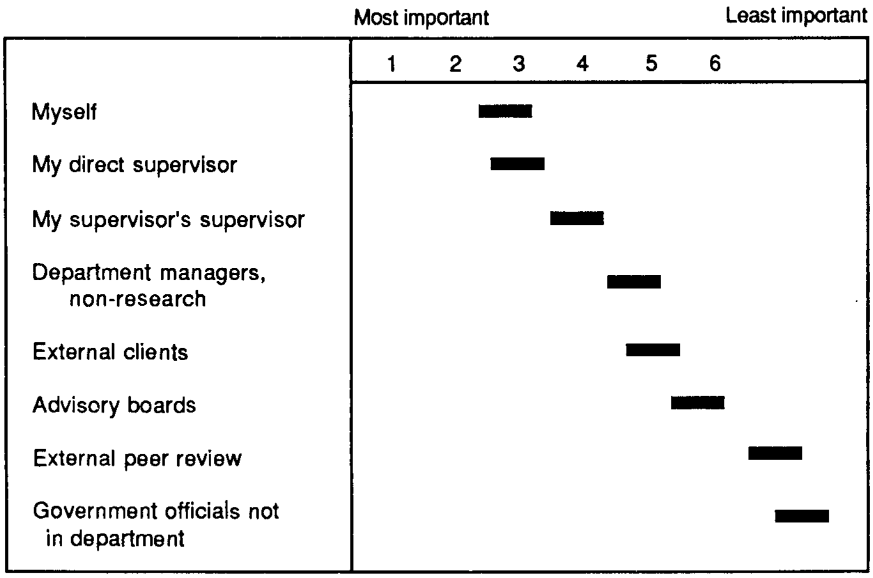
The Committee has already highlighted the importance of encouraging continuous interaction among scientists and engineers. The development of scientific knowledge and technology is increasingly a multidisciplinary enterprise. A number of discussions with senior research executives indicated that collegial relationships are a vital part of the rapid flow of knowledge and innovation, hence the need to facilitate such relationships and encourage the formal and informal exchange of ideas and methodologies. The peer review reports also underlined the importance of such interaction:

Exhibit 4.11

Ranking of Factors Determining the Termination of Projects

NABST Survey Statement

How important is each of the following in the decision to terminate a research project? Please rank from 1 to 6.



Source: NABST Survey on Research Management and Evaluation, conducted by Canada Consulting, 1989.

> The committee noted, during their two day visit, that some groups contained many young enthusiastic engineers. They impressed the committee by their obvious dedication and interest in what they were doing. However, the committee sensed less vitality in areas where projects had been running for many years. This is a common problem in a large laboratory and the committee has no magic solutions! It notes, however, that to assist in continuing education of personnel and to enhance their level of expertise, all directorates should encourage scientific exchanges with leading foreign laboratories. Currently, this exchange favours foreign visiting scientists. Canadian government staff should be encouraged to take sabbatical leaves or secondments to other laboratories in the private sector or in universities. Such exchanges are particularly important in a field which is progressing so rapidly.

An important requirement for the continued vitality of R&D organizations is active interaction with the university community, particularly through the use of student and post-doctoral programs. This was also emphasized in the peer review reports:

> The laboratory's facilities are currently the most advanced and equipped of their field in Canada, far superior than any in Canadian universities. In the past both universities in the Ottawa area (Carleton and Ottawa) have taken advantage of proximity to locate some of their MSc and PhD students in the laboratories, to conduct their thesis research using more advanced equipment. Such an interaction is beneficial to both students and the laboratory and should be encouraged. While the laboratory will have an access to a pool of young scientists to use, student training will also improve. The laboratory should take leadership in establishing joint research programs with other Canadian universities.

There are four primary means to promote the scientific community within the federal system and among federal scientists and engineers and their public and private sector counterparts. Ranging from informal to formal, these are (1) community building within government through, e.g., training and intramural conference and symposium attendance, (2) informal interaction with the larger public and private sector community, e.g., through planning, training, and symposium attendance, (3) joint activities, usually focused on shared projects or specific problem solving, (4) the formal (typically temporary) transfer of personnel, either across department or technology centre lines or between government and industry or academia.

These approaches vary in the degree of formality and the requirement for ongoing management attention.

4.5.1 Community Building within Government

Government tends to provide little organized opportunity for scientists and engineers from the range of departments, agencies, and technology centres to interact within and across disciplines on areas of mutual interest, other than to meet specific work requirements. Scientists in the Communications Research Centres meet often and work closely with their counterparts in National Defence, but to a much lesser extent with those at NRC, despite common or complementary objectives and work interests.

By contrast, leading industry and public sector laboratories make informal interaction among scientists a key management priority. They do so in the belief that such relationships promote the identification of mutual interests that spawns discovery and effective technology transfer. Kodak, for example, reports as many as 200 separate conferences, training sessions and seminars annually whose explicit purpose is to keep scientists and engineers interacting. Kodak management believes that important joint projects will be identified, information sharing will be encouraged, and good science will flow from this approach.

Perhaps the best job of organizing and encouraging peer interaction across organizational lines is done by 3M. They have established a technical network, managed on a rotating basis by laboratory heads. This network in turn sponsors several sub-networks or interest groups for scientists and engineers, and supports a variety of training and internal conferences. The network is allocated budget funds through a tax on research laboratory budgets administered through the office of the senior vice-president for R&D. It also elects people to represent the 3M scientific community on issues of professional interest, both technical and organizational. Its greatest value by far, however, lies in promoting relationships among scientists working in similar or related fields.

4.5.2 Interaction with Scientific Peers Outside Government

Conference and symposium attendance is one of the chief means for scientists and engineers to stay abreast of new developments. While journals and professional publications are an excellent resource, there is generally a two-year time lag between the emergence of new ideas and publication in a refereed journal. Conferences, on the other hand, allow "real-time" interaction and satisfy the need for urgency around the evolution of research. Moreover, the opportunity to present their findings provides both recognition to scientists and a measure of the quality of their research.

Most organizations, and certainly government organizations, resist travel as a discretionary expense because it can be subject to considerable abuse. The government has maintained a close watch on conference and training-related travel and taken great care to implement policies designed to ensure prudence and equity. Controls include Treasury Board approval of travel plan submissions at the beginning of the fiscal year and restrictions on conference attendance, particularly international conferences. As a result, few scientists and engineers surveyed by the Committee could agree with the statement that they have sufficient access to international conferences (see Exhibit 4.12).

While government tries to ensure that equity is served, leading scientists hold the view that earned invitations should be the primary criteria on determining conference attendance. In practice, most international travel is taken by the older scientists, engineers and S&T managers. Travel is seen as a fringe benefit rather than as essential for keeping scientists and engineers in the international mainstream of their disciplines. Restrictions also apply equally to those in mature and in quickly developing areas of science, thereby limiting the ability of government scientists and engineers to remain current in emerging fields of importance to Canada. The restrictions on conference attendance are also applied equally to scientists who have been invited to make presentations and to those who would simply be attending. Finally, restrictions on travel apply even where the explicit role of the research unit is the wide diffusion of scientific advances and technology transfer. In sum, travel policies may serve the prudence and equity interests of symbolic and actual expenditure restraint, but in some cases they undermine and weaken the government's scientific capability, at the significant cost of not being a fully active part of an S&T discipline. The outcome was captured by these comments by peer review panels: "Similar studies are being undertaken in offshore laboratories. The committee hopes that the group will become conversant with these developments." And, "The committee felt that the project goals did not reflect a full appreciation of the international state of the art."

4.5.3 Joint Projects

Joint programs, projects and undertakings are a third means of building a scientific community. In this area, the federal system has an interesting track record. Where joint projects have occurred, the results have been quite positive – for example, the combined efforts of Environment Canada, HWC and NRC in solving the problem of mussel toxicity off the east coast. More recently a new model of joint partnership with provincial S&T institutions has been implemented: the Geological Survey of Canada (affiliated with EMR) has recently opened the Centre géoscientifique du Québec where scientists from Institut national de la recherche scientifique – Géoressource and EMR scientists have been co-located and are involved in respective and co-operative projects. Although at the scientific level there is a belief that these undertakings are not as common as they should be, there is also evidence of an increasing trend in federal S&T establishments for joint partnerships with major Canadian S&T players.

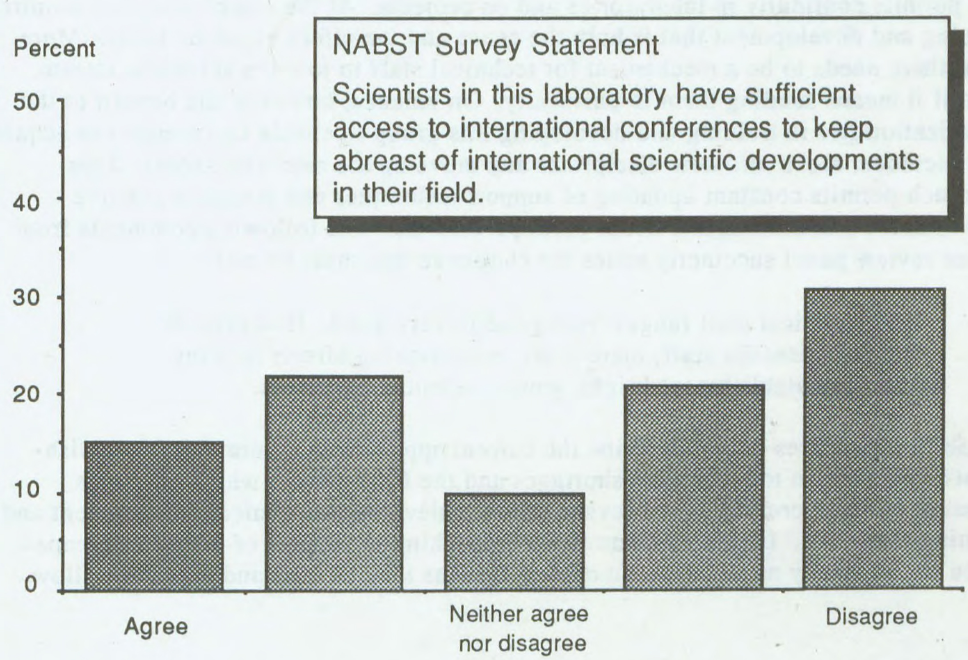
The Government of Canada does not have a forum where senior S&T managers can meet and discuss opportunities to rationalize certain S&T activities, concentrate resources in one establishment to build a critical mass of scientists and engineers in a given field, or simply create multidisciplinary teams to tackle major issues. This most likely arises from the fact that S&T establishments are closely integrated with the management system of the departments and that, as a result, S&T managers are inclined in any extra-departmental forum to defend their own territory. The dynamics in the Government of Canada differ a great deal in this respect from those of leading organizations.

4.5.4 Transfers

The transfer of personnel – both in and out – is the most daunting means of community building in some respects. In an environment of scarce resources, giving up a scientist to a transfer requires strong motivation and interest on the part of the organization. Hence, there are relatively few examples in the federal system. The Health Protection Branch of HWC has two or three scientific interchanges. CANMET reports five industry secondments to government and an equal number from government to industry, out of a total of approximately 500 scientists. This is the greatest number of transfers found, despite the strength of the imperative.

Exhibit 4.12

Access to International Conferences



Source: NABST Survey on Research Management and Evaluation, conducted by Canada Consulting, 1989.

Almost all the industrial R&D organizations studied use transfers and secondments extensively, particularly where the transfer of technology from basic research to application is involved. Kodak, for example, regularly moves individuals and groups from its corporate laboratory to its business-unit research and manufacturing facilities. IBM and Martin Marietta take a similar approach. This commitment results from the knowledge that technology transfers through people.

Government-to-government and government-to-industry transfers are also used effectively. The United States Department of Energy promotes movement between its various facilities on a temporary and permanent basis. In this way, relationships are cemented between organizations such as the Oak Ridge and Los Alamos National Laboratories. The Government of Japan makes particularly good use of temporary staff arrangements with industry, other government laboratories and the laboratories of other governments. As one example among many, Japanese government laboratories have formal relationships with a large and growing number of international companies operating in Japan, providing for continuing exchanges of scientists and engineers. In France, the CNRS can send scientists to work in industry for up to six months; after six months, they can continue in industry for up to a maximum of three years if the company assumes their salary costs.

4.6 Ensuring Strong Technical Support

Although not a focus of the Committee's work, the scientific technician in government laboratories has emerged as central to ensuring high quality, cost-effective S&T. This is a large and important group whose development and revitalization must be considered along with that of the professional groups. The dilemma in managing the technician work force lies in the fact that these individuals may form an important base that permits continuity in laboratories and on projects. At the same time, they require training and development that is both the cause and the effect of job mobility. Moreover, there needs to be a mechanism for technical staff to join the scientific stream, even if it means sending them to university. On balance, however, the benefit to the organization lies in training and developing this group to enable its members to acquire new methods, move into new disciplines and move up the seniority ladder. This approach permits constant updating of support techniques and creates a positive environment that attracts and keeps solid performers. The following comments from a peer review panel succinctly states the challenge that must be met:

> The technical staff ranges from good to very good. However, as for the scientific staff, there must be continuing efforts to bring into the establishment bright, young technical assistants.

These best practices do not describe the current approach in federal S&T establishments. In addition to technician shortages and the PY squeeze, which exerts its pressure most severely at lower levels, the time devoted to technical development and training is limited. Courses and on-the-job coaching in support of technical competence are generally arranged on an *ad hoc* basis as long as time and resources allow.

4.7 Conclusion

The Committee believes that departmental intramural S&T faces no undertaking more important than the revitalization of its human resource base. This can be done only by adopting a variety of changes – the rejuvenation of the scientific population, new practices to recognize and reward scientific contributions, attention to the role and development of managers of scientific work, and effective promotion of the community of scientists and engineers.

Revitalization depends on the continuous and rigorous evaluation of people. The best organizations pursue human resource practices that encourage and promote outstanding R&D performance. At the same time, scientific personnel are not viewed as permanent fixtures in the R&D establishment but as invaluable resources that can serve the broader needs of the organization in other functions. Rather than being left to chance, the movement and transfer of people within these organizations is planned carefully and executed vigorously.

5.0 MANAGEMENT PROCESSES IN INTRAMURAL S&T: COMPARISONS WITH BEST PRACTICES

Management systems in scientific and technical organizations, like those in organizations generally, set the course for the organization, ensure its financial viability, track performance, and work constantly towards invigorating the organization and maintaining its vitality. On the surface the tools appear similar, but in fact, their application in an R&D environment is very different. Recognizing the distinctions between these management systems is the key challenge in achieving effective management of S&T in government.

This is not to imply that management systems are passive or less important in R&D organizations. Indeed the opposite may be true. R&D management systems must be robust in serving their individual purposes. They need to be consistent with the larger purpose of creating an effective climate for R&D, and they must be in alignment with one another, rather than in conflict. It is also critical to recognize that the R&D organizations are not homogeneous and that an optimal match is required between the research mission of each unit within a complex organization and the management structure and system.

The committee's review of the management system for S&T in federal departments indicates that the government is doing many of the right things, but too often in the wrong way. It appears to be impossible to separate the management regime for S&T from general policies for budgeting, personnel and administration across government. Moreover, as new management system incursions are made into the S&T field, they are often layered on an already stifling and rigid system of checks and controls. The result is widespread concern across scientific organizations about the gridlock created by excessive micro-management. Unfortunately, change has too often meant only more micro-management, with loss of effectiveness the only result.

Scientists and engineers are generally frustrated by the increasing administrative burden. It affects the time they have to carry out their scientific responsibilities, it turns managers into bureaucrats, and it cuts at the energy and spirit of the organization. Many of the respondents to the Committee's survey commented along the lines of the following examples:

> Administration continues to increase at the expense of research. The intellectual climate necessary to nurture good research is missing – mainly due to an increasingly bureaucratic system that in reality is only concerned with budget, PYs, and the advancement of management. Individual scientists are cogs in the system. This system cannot attract or keep top scientists.

> Laboratory management/project management is very poor. Bureaucratic and administrative imperatives always take precedence. Morale is very low. Promotion to management seems to be reserved for those who have "never made a mistake."

Part of the administrative pressure the scientists and engineers feel is the basic load that comes with being in any large entity, particularly the public sector, where planning, budgeting and evaluation systems must meet the needs of a large and complex organization, as well as the ultimate test of public scrutiny. But another part stems from the S&T policy thrusts and assessment initiatives that have been put in place in recent years – advisory boards, client surveys, greater extramural performance and central agency planning and review instruments such as the *Decision Framework for Science and Technology.*

This chapter looks at the key management systems in the federal government: planning, budgeting and evaluation. It examines these systems in the context of how other organizations deal with similar challenges. It does not encompass issues related to performance appraisals of individuals; these human resources management issues were considered in Chapter 4.

Our evaluation of the quality of the R&D was carried out under normal international peer review processes, recognizing the need to match peers to the specific R&D function of the organization. These were pilot studies on a few S&T establishments to test the hypothesis that such peer evaluation is possible, credible and valuable. Similarly, in the bibliometric analysis, the government laboratories were matched with external laboratories pursuing a similar mission and function. Certain generic conclusions can be drawn from the pilot studies which are significant for all government S&T establishments. These conclusions are noted in the following sections.

5.1 Planning and Budgeting

There are many examples of the shift to a more planned or managed environment for S&T in the Canadian government. Like many countries, Canada has been undergoing the shift from bottom-up management of its government laboratories, where scientists determined their research programs more or less autonomously, to a combination of top-down and bottom-up planning tied to overall objectives. Federal policies in recent years have emphasized client relevance, cost recovery and staff reductions. This in turn has resulted in increased top-down direction and planning.

The purpose of planning is to set and communicate direction and provide the rationale for allocating resources. Planning in government, however, has too often had a control orientation that results in managing approaches and inputs rather than goals and outputs.

New policies and processes have often been introduced with little regard for the nature of the organizations in which they are to be implemented. As a result, in S&T establishments, they add another layer of management control but have little real impact on the behaviour of the scientific community. Such has been the case in federal government laboratories. Policies such as increased client relevance, for example, led to a need to involve clients in the planning process for S&T activities and in the evaluation of laboratories. In a few cases this has resulted in successful collaborations with the private sector. In other cases, however, the ability to provide evidence of client involvement has become a proxy for quality and relevance, regardless of whether the client relationship has actually had a positive impact on the output of the lab. Activity, and the measurement of activity, have taken priority over management of objectives and results.

The difficulties of introducing effective planning processes in the S&T sectors of government are multiple and far-reaching. First, growth in planning has arisen from two separate, and possibly even contradictory, forces. One is the overall downsizing of the public service, which has resulted in reviews of programs, planned cutbacks and tighter control of resources. At the same time, the current approach to planning in the scientific sectors of government also derives from the belief that more-effective management processes will result in higher quality and more relevant R&D activity. These two motivations have been understandably confused, with the result that planning has become an exercise in justifying one's existence, and each evaluation is suspected of gathering evidence for further cutbacks.

Planning in government S&T also suffers from the fact that in government, planning is planning, whether it is for research or social services or other government activities. The program evaluation system treats activity in S&T establishments in the same way it treats any other function, from issuing cheques to purchasing goods and services. Relatively minor additions to a program or reductions in activities may receive extensive scrutiny, while the overall mission of the establishment receives only cursory attention.

The annual budgeting and estimates process drives the broad planning activities of government departments. In the last few years, most departments have instituted planning processes that start at the section head level and feed into an overall proposal for the coming year. S&T sections contribute their input to the process and, in most cases, their budget is an A-base allocation determined in relation to their budget of the previous year. A few S&T establishments have sunset provisions or a budget percentage that must be earned from outside sources, but in most cases they simply receive a fixed budget allocation. S&T budgets have come under pressure over the last few years because of cutbacks in government spending and an attempt to shift intramural expenditures on R&D to the private sector and to universities. As a result, federal government laboratories have experienced across-the-board reductions in personnel and budgets for the last four years.

The peer review committees commented on instances where they found planning systems seriously inadequate:

> The processes by which the decision [to enter a field of research] was taken and its justification in terms of performance advantage was surprisingly sketchy for a program which will require a major commitment of resources to be world competitive.
>
> The management is effective in administering the shrinking financial resources as it attempts to maintain a quality R&D facility in transition. There is concern, however, about management's effectiveness in selecting projects, the criteria used to start, accelerate, and stop projects and how the new economic factors come into play. An important question is: how does the organization handle the temptation for "me-too" type of work? There must be a continuing formal review process for the selection of needs in advance of project commencement.

Two approaches are used to account for external revenue earned by S&T establishments. In the case of departments that are funded completely through appropriations from Parliament, anticipated cost-recovery revenue is added to the establishment's budget appropriation, while actual revenues earned go into the government's Consolidated Revenue Fund. In the case of NRC and other technology centres, external revenues are "vote-netted" from their appropriation, that is, the parliamentary appropriation is reduced by the amount of anticipated external revenue. A 20 percent "bonus" is added to the following year's budget, based on external revenues earned.

The Treasury Board approach to planning and budget differentiates between dollar allocations and PY allocations. It is possible, for example, that a laboratory might be required to reduce its PYs by 10 percent but receives an increase in its operating or capital budget at the same time. This decoupling of personnel resources from financial resources has resulted in some extraordinary imbalances in S&T establishments. The Committee learned of laboratories with more money than they have people to use it effectively; other laboratories have sufficient personnel but lack the budget to employ them productively. There were examples of equipment being bought from adequate capital budgets, but operating funds being too limited to buy the supplies needed to make the equipment work.

The Treasury Board planning process is geared to incremental additions of programs and activities on the one hand, and across-the-board cutbacks on the other. New initiatives are carefully reviewed by a Cabinet committee to ensure the most appropriate allocation of resources. Budget and staff cutback targets have been achieved through across-the-board belt tightening. While the across-the-board approach may be appropriate for Treasury Board purposes, its extension within departments, and in particular within S&T organizations, can have serious consequences. When it comes to research, the inevitable result of cutting everything by a uniform amount is that basic capabilities are eroded until the critical mass necessary for quality no longer exists. The peer reviews conducted for the Committee indicated clearly that this has been taking place in laboratories:

> The site-visit team is concerned about the small size of this section relative to the proposed breadth of research and its extensive involvement in regulatory issues and policy. In the team's opinion, it will be important that the group be given strong management support to pursue its research activities, especially in the new directions cited above.

The Committee found a number of management problems related to this planning system. While the resources available have been declining steadily over the past few years, laboratory management has tried to continue meeting its obligations to all clients. The resources available for each project must therefore decline. The Committee therefore found that in many establishments, the available resources have been spread too thin. There are too many projects and too few staff to do justice to the high priority areas. Again, quoting from the peer reviews:

> The committee is of the opinion that the top-down planning of the research program tends to be ignored in the immediate need to choose projects which optimize the use of scarce resources. As a result, there appeared to be a lack of co-ordination between directorates both in their choice of research projects and in the definition of the goals of those projects. The committee believes that a well-developed, establishment-wide long range plan with clearly focused short and intermediate term technical goals would result in fewer projects. This plan must recognize the critical mass required to make significant advances and the scale of effort deployed elsewhere in those areas. The projects would then be of higher quality with more depth of expertise. If such a plan were followed up by an annual technical review and accountability for achievement of short-term goals, the management of the establishment would have available a useful mechanism for arriving at the difficult decisions as to which projects should be terminated.

The reference-level approach to planning, in which current activity is protected while all new initiatives call for close scrutiny, leads to an environment where real change is resisted at all costs. After all, when the budget for existing programs is secure, why put it at risk by proposing to discontinue a program? Even if the purpose of doing so is to free money for a new program, there are no assurances that the reallocation of funds will be permitted by the authorities reviewing the budgetary proposals. As a result, although the scientific priorities of S&T establishments have changed, and activities have been reoriented to reflect, for example, emerging environmental concerns, from the point of view of the planning and budgeting process, S&T programs just carry on as before. In their reports, the peer review teams noted examples of this occurring in the laboratories reviewed:

> Work [on a particular technology] was started in the laboratory many years ago at a time when it could not be done elsewhere in Canada. The committee felt the reason for continuing to do these studies should be re-examined. If the laboratory [still has] unique expertise from which companies can profit, the service should be provided on a cost-recovery basis.

The deficiencies of this approach are compounded by the fact that once a budget has been approved, the department is not accountable for allocating its actual expenditures as described in the budget. The budget only sets the broad parameters of spending; more detailed allocation decisions are made internally. As one scientist put it:

> We have a planning meeting every year and set fairly specific tasks. But we also fill in our own appraisal forms at the end of the year on how we met our objectives. No one else actually checks. So we're really just feeding the information system. There are consequences of not filling out the forms, but there are no consequences of not meeting the plan.

In some departments, the planning process has very little to do in fact with the budgeting process. One department described an elaborate strategic planning process that involves all branch managers for several days – but it turned out that the session takes place after the estimates process has already been completed.

5.1.1 Best Practices Elsewhere

A government planning process that protects the status quo and resists new initiatives is in sharp contrast to the approach of leading S&T managers, who use planning as a means of shaking up the organization and keeping its activities abreast, if not ahead, of current needs. These managers recognize the need to impose new directions on scientists who, if left alone, would happily pursue their current study "to the fifth decimal point;" such managers find themselves hampered severely by a planning system that does not promote change. While there are outstanding examples of new directions taken by scientists and engineers in the federal government, these are generally individual initiatives adopted in an environment that does little to encourage change and renewal. While private sector R&D organizations shift priorities and work at cutting back activities with low potential to contribute to the organization's overall goals, they also protect their core technologies and ensure that essential and enabling capabilities are preserved.

The Japanese approach to planning, funding and evaluation in its government laboratories provides an interesting contrast to the appropriation method used in Canada. Japan's Agency for Industrial Science and Technology (AIST) within the Ministry of International Trade and Industry (MITI) is responsible for the management of 16 research institutes. There are three separate mechanisms by which these institutes receive funding, each with its own planning and evaluation system. All institutes receive ordinary R&D support to cover personnel costs and core funding. In addition, institutes contract for special R&D support to carry out research related to specific missions. For mission-driven research, most institutes have an internal competitive process for reviewing proposals, and then negotiate annually with AIST to establish a portfolio of projects to be carried out. Thus, projects are subject to review at the proposal stage. They are also evaluated during the project as part of accounting for the use of funds.

A third category of funding is designated R&D. This is a separate budget set aside for collaborative projects with industry and the academic community. Institutes and their external collaborators prepare joint proposals and present them to AIST for funding. In this case, there is a rigorous process of evaluation at the proposal stage and systematically throughout the project.

AIST uses these financing mechanisms as management tools. Recognizing that there are problems with organizational rigidity and aging in institute laboratories, AIST has been steadily reducing the ordinary R&D allocation to the point where it now constitutes about 50 percent of a laboratory's funding – down from more than 70 percent. Increasing emphasis is being put on the designated R&D category to promote stronger linkages with industry.

Research planning in all laboratories is a balancing act of contribution and risk. Leading research organizations tend to adopt a portfolio approach to planning that encompasses the various spheres of activity. In industry, the first of these is service to specific clients or constituencies. Service, involving a current year time-frame, typically constitutes 60 percent of an industrial R&D budget. Approximately 30 percent of total allocations are concerned with development or application activities, involving a time-frame of one to three years. Usually 10 percent or less of total research expenditures is geared to fundamental or exploratory work.

Most industrial R&D units see service activities as essential in maintaining credibility with client or customer groups, ensuring continuous dialogue on problems and the uses to which research will be put, and building the relationship necessary to effect good technology transfer – hence the need for a planning process that gives specific foundation to the identification of scientific and technological requirements.

In general, the planning processes of leading private sector R&D organizations reflect their structure. Planning tends to occur on two distinct fronts: enabling technologies, and technology or product development that supports specific business or operational units. For example, Martin Marietta, a major United States-based aerospace and defence contractor, begins its planning process with a review of technology trends and their implications. The process results in identification of technologies that are pivotal to the concerns of a specific business unit and those that are important on a pervasive basis across the organization.

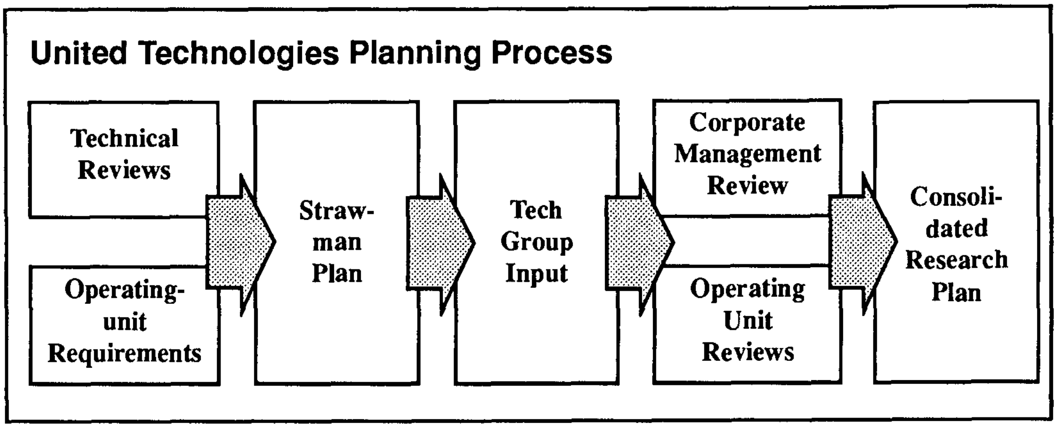
Eastman Kodak takes a similar view. They divide technology efforts into categories, depending on the maturity (or immaturity) of the undertaking along the *S* curve of technology development. In their view, corporate research should undertake technology investments that are likely to be pervasive in their contribution to Kodak; group laboratories should engage in applied research specific to business units in their group; and business-unit development groups should carry out the new-product development work based on these technologies as well as product and process improvements for existing products.

The best R&D organizations also recognize that the planning process provides a unique opportunity for management to address multiple objectives simultaneously; as a result, they structure their planning processes to meet several ends:

- review prior year performance;
- review their technology delivery capability in the broadest sense – technically and organizationally;
- identify key technology trends, needs, and requirements, typically involving a 10-year forward view; and
- improve the effectiveness of the research management team.

Several examples are pertinent. Twice-yearly meetings of its technical council – the top 80 R&D executives – are held by 3M. Meetings usually incorporate both review and planning activities. Outside experts are often invited to speak on issues of general interest. For example, in 1987, these speakers included the chief scientist for the Strategic Defense Initiative, the Assistant Deputy Secretary of Commerce, who reviewed a national study of emerging technologies, and executives from a customer organization, who described the reorganization of their global R&D activities.

United Technologies takes a different approach. Its basic research centre begins its planning process with an explicit review of its technical standing in each of 13 strategic technology fields. The planning process combines these reviews with a knowledge of operating unit requirements to develop a "straw-man" plan that is forwarded for review, elaboration, and modification to the heads of the company's research laboratories. The draft plan is then brought forward for discussion with senior corporate management and with operating-unit heads.



Another innovative approach is offered by Exxon Corporation's plastics division, a $4-billion business operating in 43 countries. The basic research portfolio of this organization is managed through a dual track process. Approximately 10 percent of the budget is managed on behalf of senior management by the most senior scientists, essentially through a process of dialogue and collaboration with internal and external resources. But the bulk of spending is determined through an annual series of meetings that bring together senior business-unit and research managers to review progress and define key research programs.

Looking across the experience of the private sector, it is clear that planning is being used to achieve a number of purposes. Organizations are using planning to determine what businesses they are in and to ensure that this is reflected in subsequent resource allocation decisions. R&D units are an important part of these planning frameworks and work in consultation with the corporate level, business units and users to determine what and how R&D will contribute to corporate and business-unit goals. Planning in the leading research organizations is also being used to shift resources selectively and to stimulate revitalization. The process is selective, rather than across-the-board, and seeks constantly to build strength in strategic technologies rather than to be all things to all users.

5.2 Evaluation

S&T expenditures in the Government of Canada have been the subject of periodic but intense scrutiny for several decades. The magnitude of this spending makes it an obvious target for evaluation. As a result, many players and processes have been put in place to evaluate whether expenditures on S&T are effective, satisfy the needs of prospective clients and promote technology transfer.

The past decade has been a period of substantial change within the federal public service. Resource allocation has given way to expenditure reduction. Programs have been cut back and staffs have been reduced. At the same time, compliance and evaluation processes have become more entrenched and have been extended to encompass a greater and greater amount of government activity. The sense that prevails across government is that departments must get by with fewer resources but must also face increasing scrutiny of their resource allocation decisions and redouble their efforts to ensure compliance and effectiveness. At the same time, there is general concern that decision-making processes are no longer aligned with many of the control and evaluation systems. There is a strong sense in S&T establishments today that the evaluation structure has become overloaded and badly needs simplification. As one peer review team put it:

> It is clear that if a logical, appropriate scientific review process is to be implemented, it should be integrated and not added to current evaluation processes. In-house reviews, program evaluations, annual departmental overviews, OCG evaluations, etc., create an enormous drain upon existing resources.

From the perspective of the S&T organization, there are too many players in the evaluation process, their roles are unclear and accountability is blurred. Evaluations in S&T are driven by a number of interests. First, the research organization itself has an interest in knowing how well it is performing. Research managers rely mainly on their basic management systems to monitor their organizations. Second is the interest of the department in knowing how the S&T organization is performing, usually approached through program evaluations, client surveys and management audits. Third is the interest of the central agencies of government in knowing how well departments are performing in S&T. While central agencies such as Treasury Board, the Comptroller General and ISTC rely on evaluation information being generated by departments, this is seldom adequate. As a result, central agencies compound the evaluation workload with complex information requests and special studies. Fourth, there is the increasing interest of overseeing bodies. The Auditor General's role is fundamental to the parliamentary process, but his comprehensive auditing approach adds to the considerable evaluation burden without necessarily being suited to the particular circumstances of managing S&T. Add to this the scrutiny by review committees, task forces, and other special initiatives, and the sum is a heavy stream of information and evaluation studies that may or may not be useful in improving scientific quality and productivity.

Through its survey of federal scientists and engineers, the Committee sought to determine how much evaluation actually is going on and to assess its effectiveness and the extent to which it addresses the issue of quality. Scientists indicated that, in fact, there is considerable evaluation of research, extending from the proposal stage through to completion (see Exhibit 5.1). The emphasis is mainly on assessing research in progress and proposed work plans. In theory this parallels the Japanese approach, which places a great deal of emphasis on before-the-fact assessment to ensure that projects have clear goals. However, in practice in Canada the process is mainly internal to the establishment and is not subjected to rigorous assessments by independent review committees except where strong advisory boards have been established.

At issue is the cost and effectiveness of this evaluation approach. Central agency information requests to departments have become so numerous that they are now being co-ordinated across agencies. Review teams are seen as part of a steady stream of investigations whose purposes are not clear and whose members may or may not understand the scientific environment. Intensified evaluation efforts are seen by

Exhibit 5.1

Stages at which Research is Evaluated

NABST Survey Statement

For projects you are working on, please indicate the stages at which the research is evaluated.

	Total* (Percent)
Research topic and workplan are assessed	60
Clear milestones set beforehand	42
Assessment done while project is in progress	71
Assessment done upon completion of project	47
Follow-up assessment	15
None of the above	5
Don't know	4

Source: NABST Survey on Research Management and Evaluation, conducted by Canada Consulting, 1989.

* Percentage of respondents that indicated the statement applied to their situation.

scientists more as a means of satisfying the needs of central agencies for evaluation comprehensiveness and compliance than the needs of government to produce good quality science. Moreover, the external study process, whether conducted by NABST or other bodies, is not seen to be successful in achieving essential changes in the system. Of equal concern to the Committee is the fact the program evaluations that are used to evaluate S&T establishments place inordinate emphasis on tools and techniques, rather than on the judgement of knowledgeable people.

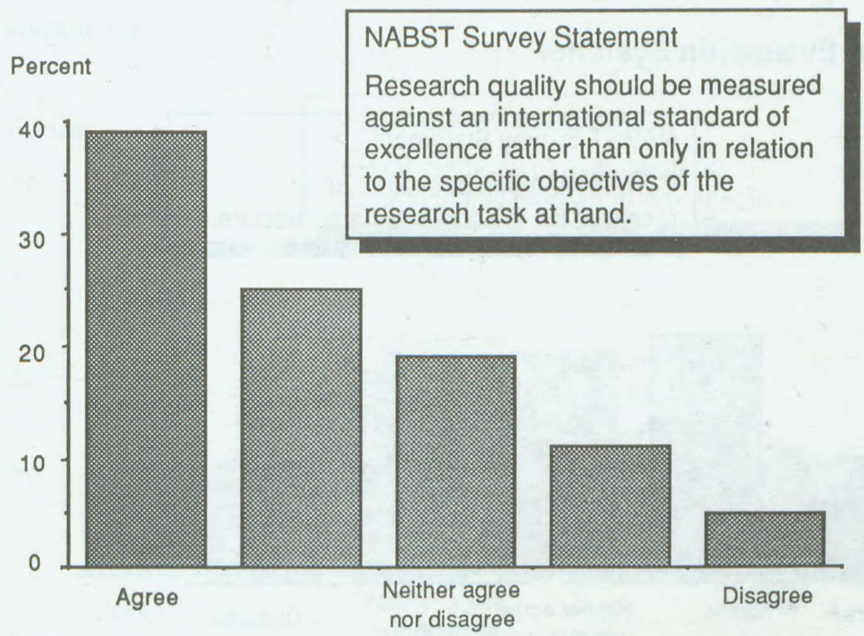
In summary, the current evaluation system as applied to federal S&T establishments constitutes a tremendous workload, detracts seriously from the work going on, and engenders a culture of suspicion while producing barely noticeable benefits for the quality and productivity of the system. The underlying feeling is that the real decisions are made outside the evaluative apparatus: "Why should we do all this studying and reviewing when the results may not be part of the real decision-making process?"

Central agencies have no driving interest in knowing about quality. First, the information on which to base judgements about quality is not there. While inferences may be gained through evaluations, central agency decision-making processes are either unable to factor in this information, or they treat it as a periodic insight. Second, there is no market for information on quality. The process of expenditure cuts has shifted more and more resource allocation responsibility to departments. Central agency processes establish targets, which in most cases represent real cuts in PYs and expenditures, while departments propose how to administer these cuts internally. Central agencies do not see the need for information on the quality of research in carrying out their planning and budgeting roles. But the question that arises is why such information is not considered vital at the department level.

S&T management processes deal with the question of quality in a variety of ways, but rarely do they bring to bear a comparative international perspective on intramural research. The Committee survey asked scientists and engineers whether they felt that "research quality should be measured against an international standard of excellence rather than only in relation to the specific objectives of the research task at hand." Eighty percent of respondents agreed, half of them indicating very strong agreement (see Exhibit 5.2). When asked whether current management and evaluation processes promote a high standard of quality, only 10 percent could agree strongly with the statement, while almost 20 percent disagreed strongly, and the rest were distributed fairly evenly in between (see Exhibit 5.3). The majority of respondents also agreed with the view that existing evaluation systems focus more on measuring activity than measuring quality (see Exhibit 5.4). Some went further, suggesting that evaluations tend to be conducted by the hit-team approach rather than as objective evaluations of S&T activities.

Exhibit 5.2

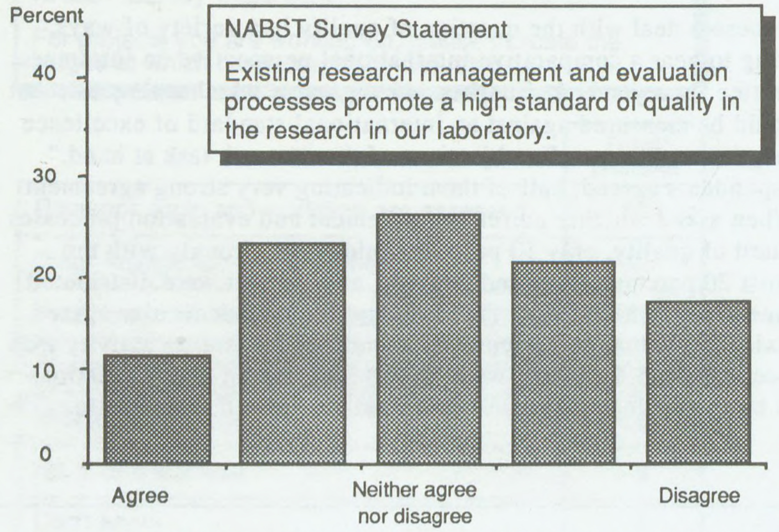
Measuring Research Quality



Source: NABST Survey on Research Management and Evaluation, conducted by Canada Consulting, 1989.

Exhibit 5.3

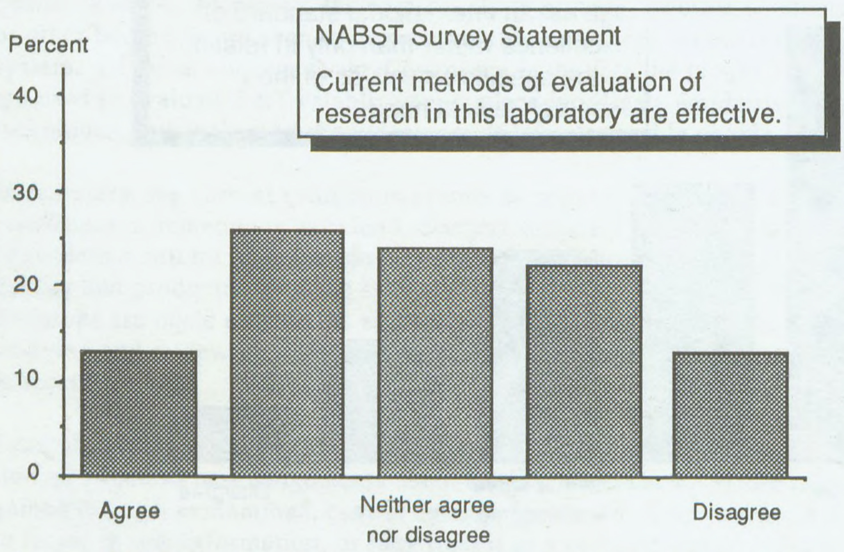
Rating of Existing Research Management and Evaluation Processes



Source: NABST Survey on Research Management and Evaluation, conducted by Canada Consulting, 1989.

Exhibit 5.4

Focus of Evaluation Systems



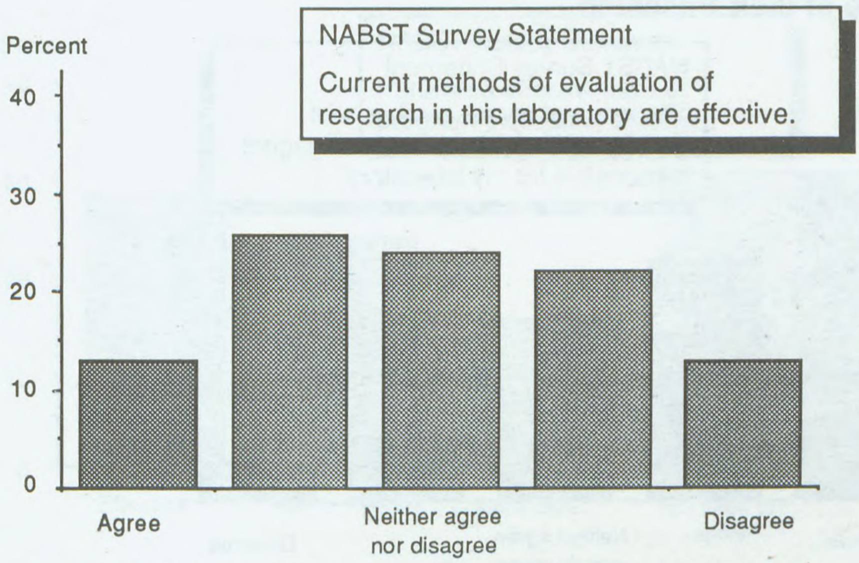
Source: NABST Survey on Research Management and Evaluation, conducted by Canada Consulting, 1989.

The program evaluation process set out in guidelines issued by the Comptroller General assumes that other processes, such as the performance appraisal process for members of the research category or research management processes, take care of evaluating research quality. In fact, as we have seen, these processes are neither systematic nor necessarily inclusive in their approach to the issue of quality. One recent evaluation by Communications Canada went beyond the guidelines of the Comptroller General and engaged external scientists to review a selection of research papers as a way of evaluating the position of the research relative to international standards. Other departments have undertaken reviews through external advisory bodies and, while research quality has been given some consideration, it has not been the central purpose of the reviews.

Only 10 percent of the Committee's survey respondents agreed strongly with the statement that "current methods of evaluation of research in this laboratory are effective" (see Exhibit 5.5). The most effective method was seen to be the laboratory's internal research project management and review process. A clear distinction was made between the sense of relationship between scientists and their research managers and between scientists and senior managers, further reinforcing the importance of internal systems as opposed to external, departmental or government-wide systems (see Exhibits 5.6, 5.7 and 5.8). The program evaluation system was seen to be effective by 30 percent of respondents, while other systems such as client surveys and financial audits barely rated a mention (see Exhibits 5.9, 5.10 and 5.11).

Exhibit 5.5

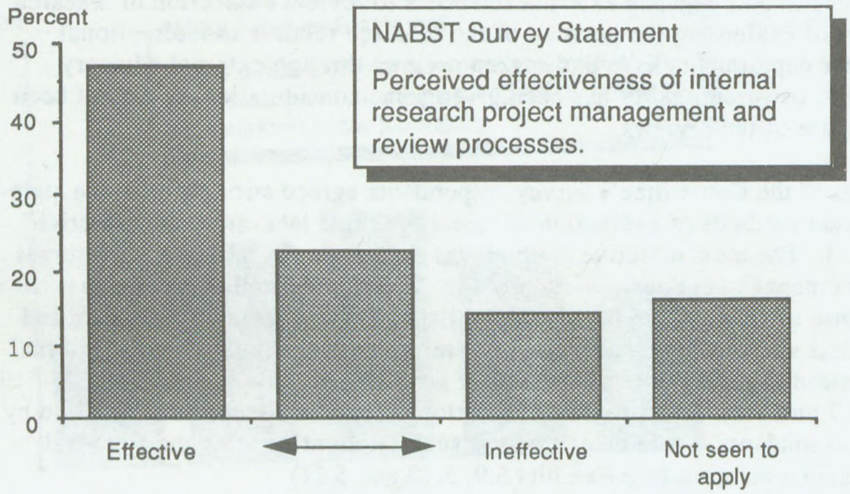
Effectiveness of Current Methods of Evaluating Laboratory Research



Source: NABST Survey on Research Management and Evaluation, conducted by Canada Consulting, 1989.

Exhibit 5.6

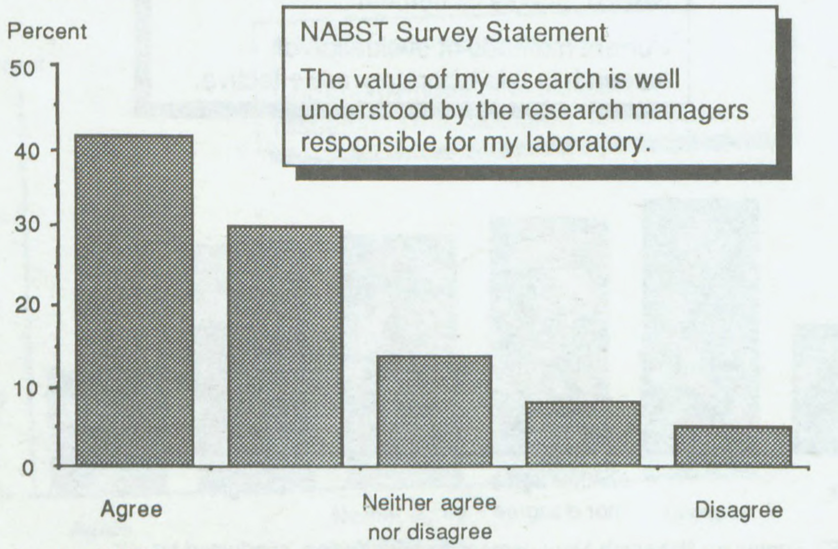
Perceived Effectiveness of Internal Research Project Management and Review Processes



Source: NABST Survey on Research Management and Evaluation, conducted by Canada Consulting, 1989.

Exhibit 5.7

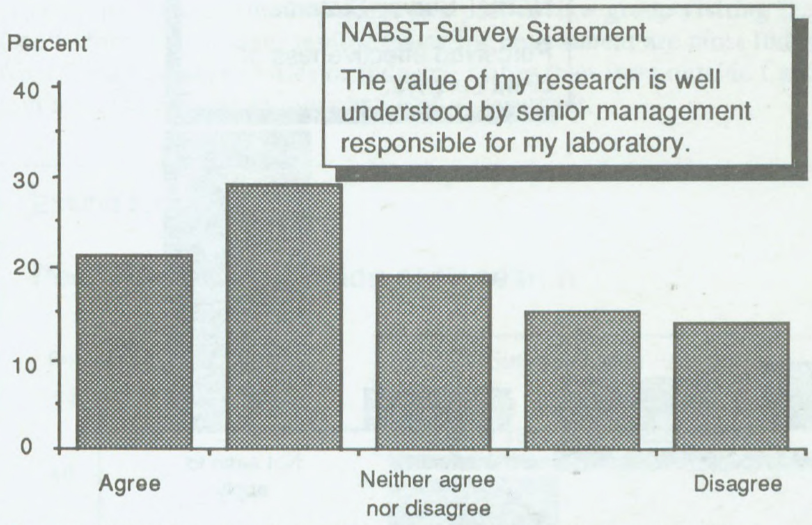
Scientists' Perception of Research Managers' Understanding of the Value of their Research



Source: NABST Survey on Research Management and Evaluation, conducted by Canada Consulting, 1989.

Exhibit 5.8

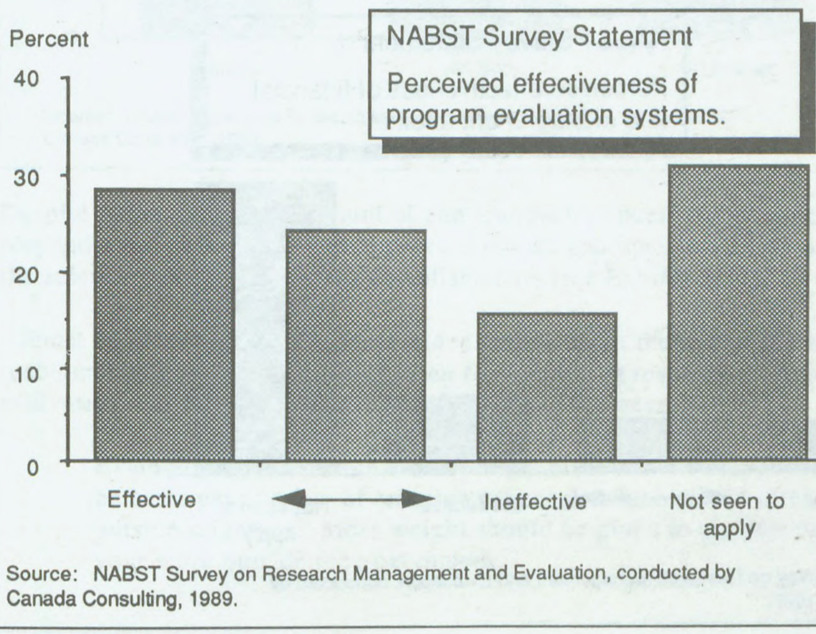
Scientists' Perception of Whether the Value of their Research is Well Understood by Senior Management



Source: NABST Survey on Research Management and Evaluation, conducted by Canada Consulting, 1989.

Exhibit 5.9

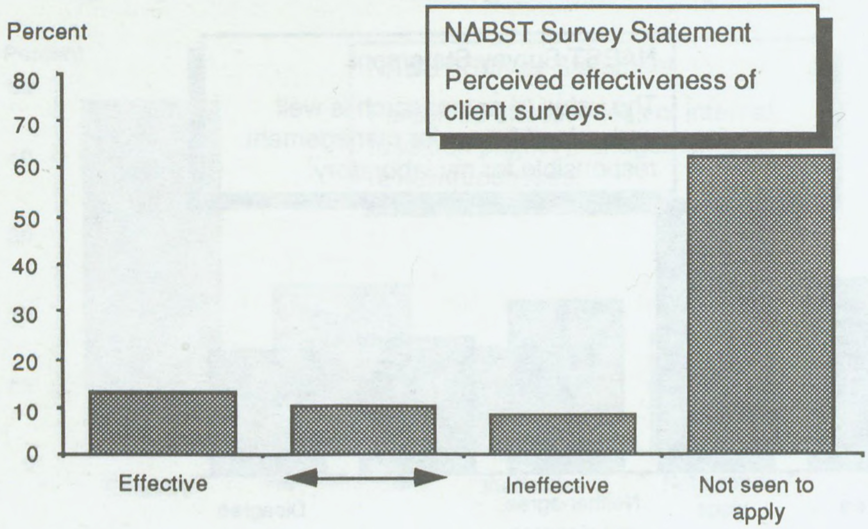
Effectiveness of Program Evaluation Systems



Source: NABST Survey on Research Management and Evaluation, conducted by Canada Consulting, 1989.

Exhibit 5.10

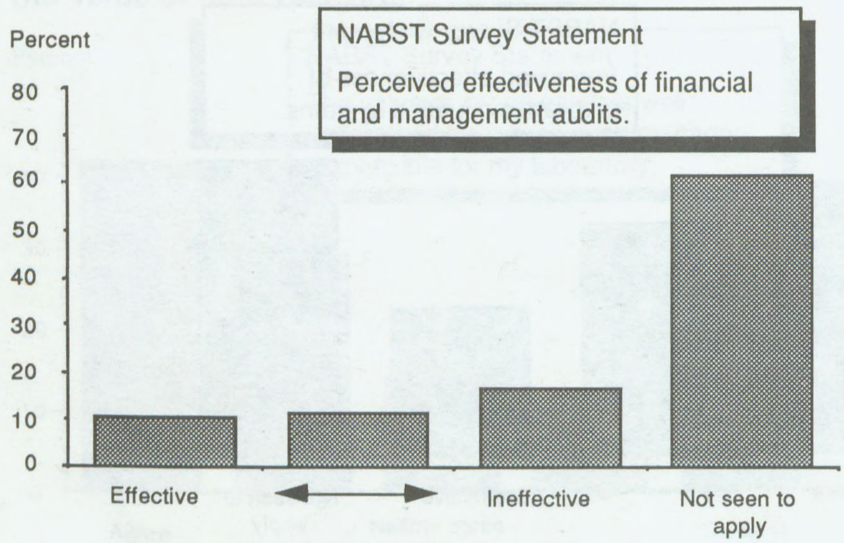
Effectiveness of Client Surveys



Source: NABST Survey on Research Management and Evaluation, conducted by Canada Consulting, 1989.

Exhibit 5.11

Effectiveness of Financial and Management Audits



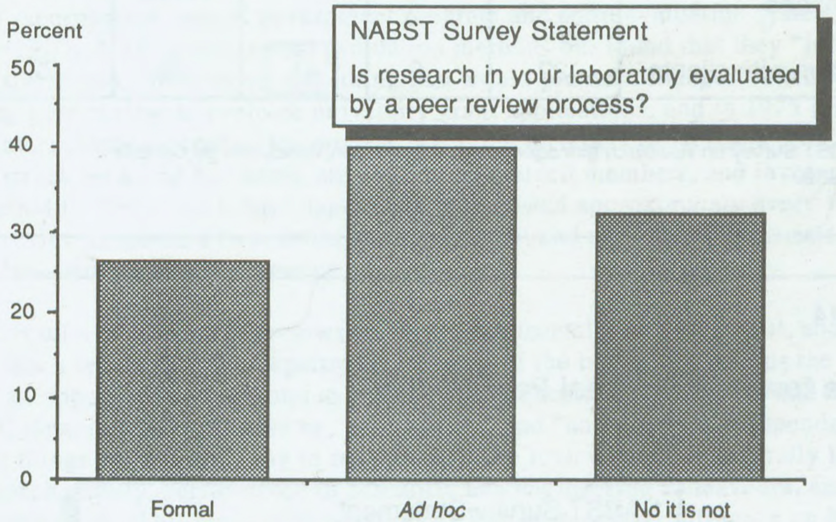
Source: NABST Survey on Research Management and Evaluation, conducted by Canada Consulting, 1989.

5.2.1 Peer Review Evaluation

Peer review has not been widely used and is more likely to take place on an *ad hoc* basis rather than as part of a formal evaluation system (see Exhibit 5.12). Implementation of peer review has varied widely, however. In some departments an external review of selected publications is considered to constitute peer review, while in others, client consultation is as important as a peer review group visiting the laboratory (see Exhibit 5.13). Peer review teams for government are most likely to be drawn from Canadian universities or industry, rather than from outside Canada or from among arm's-length experts in other areas of government.

Exhibit 5.12

Peer Review Evaluation of Research



Source: NABST Survey on Research Management and Evaluation, conducted by Canada Consulting, 1989.

Despite variations in the amount of and approach to peer review, most survey respondents considered external peer review an appropriate method of evaluating the scientific activities in their establishments (see Exhibit 5.14).

Almost 40 percent of respondents added comments at the end of the survey; the recommendation they made most often for improving research management and evaluation was to employ external peer review. For example:

> Evaluation of a research effort is very difficult. I believe there should be more peer review of research proposals which would often include outside scientists. More weight should be given to the acceptance of your work outside the government.

Exhibit 5.13

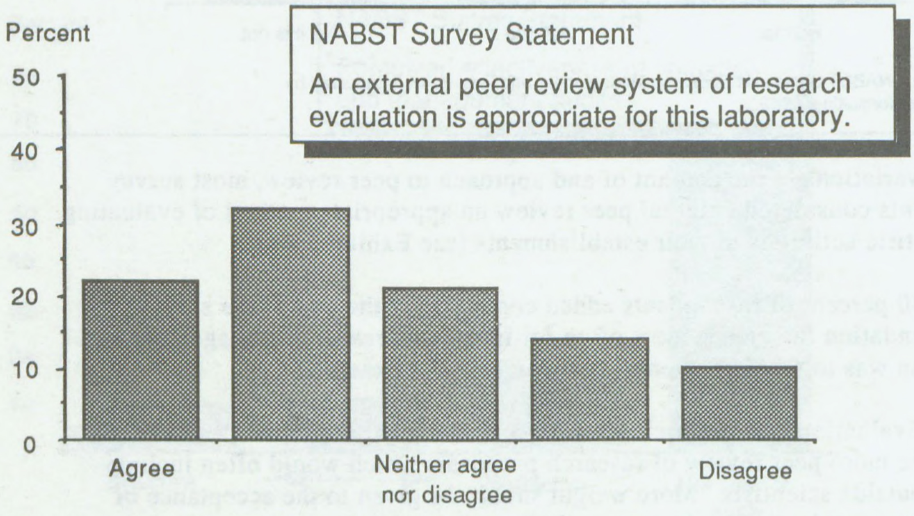
How the Peer Review Process is Conducted, by Department

	Percent				
	TOTAL	**HWC**	**Com**	**EMR**	**NRC**
Meeting with researchers at the laboratory	66	52	44	51	85
Through a review of publications	60	61	59	62	57
Consultation with clients	22	8	41	25	22

Source: NABST Survey on Research Management and Evaluation, conducted by Canada Consulting, 1989.

Exhibit 5.14

Attitudes towards External Peer Review



Source: NABST Survey on Research Management and Evaluation, conducted by Canada Consulting, 1989.

> Peer review is only effective if the reviewers are indeed competent and given sufficient resources (e.g. time) to do a good job – not a superficial evaluation based on information supplied by a manager or a small group with vested interests. The administration of this organization has kept on growing to the present 30 percent. Now it is doing all it can to manage R&D, with dubious results.
>
> In my opinion, research in those laboratories which are concerned with basic research would benefit from periodic external peer review, particularly of new research projects. External peer review and approval should be a necessary pre-requisite for commencing a new project. New projects could be submitted in any year, and then if approved by external review and internal management, these projects would be reviewed on a periodic basis, continued support being dependent upon continued external peer approval.

NRC has a unique review and evaluation process that involves external peer review but also incorporates federal government program and audit evaluation systems. Until the mid-1970s, NRC used internal evaluation methods but found that they "just reinforced the status quo. We needed something that would promote change." NRC was already using peer review to evaluate university grant applications, and in 1975 instituted an internal review committee process involving members of its council. Committees are struck on an *ad hoc* basis, are chaired by council members, and involve peers external to NRC. Each NRC laboratory is reviewed approximately every five years; the review involves a two- or three-day site visit and a review of materials provided by the laboratory and other sources.

The results of NRC peer reviews are presented formally to the council, and the findings are taken seriously. The department manager of the laboratory attends the meeting and has an opportunity to respond to criticisms and questions. Scientists and managers at NRC describe these reviews as "hard-hitting" and "an important independent view that says things we wouldn't say to ourselves." The review process generally looks at research quality, performance of scientific and engineering endeavours, and external relationships. This evaluation process has had an important influence on NRC decision making. Programs have been changed, weaknesses addressed and strengths recognized and built upon.

The Committee faced the quality issue right at the beginning as it set out to carry out its terms of reference. For some people external to the Committee, the prevalent view was to focus on relevance as the central issue to be considered. The Committee did not dismiss the importance of the relevance of the S&T effort, but firmly believed that quality is key and that without quality, the issues of relevance could not be adequately considered. The Committee also believed that the very process of reviewing the quality of R&D would shed light on its relevance. Moreover, the Committee felt that the issue of relevance was not applicable only to R&D projects but had to be addressed in the context of the S&T establishments themselves.

The absence of a consistent system of external peer review across the departmental laboratories led the Committee to conduct several selected international peer reviews to test their applicability. As described in Chapter 1, two research units in each of the three departments selected for the Committee's investigation were reviewed, and the services of two of the granting councils (NSERC and MRC) were engaged to co-ordinate the review process. These organizations routinely co-ordinate and manage peer reviews of research proposals from universities and other organizations; thus they are well qualified to oversee the process. In selecting peers to participate in this pilot project, emphasis was given to choosing experts from the private sector and from outside Canada who could bring industrial and international perspectives to the review. (See Appendix B for a list of peer reviewers.) During 1989, peer review teams were formed and reviews were carried out in six laboratories at Com, HWC, and EMR.

The peer review reports indeed identified instances of mission drift and viewed these as indications of declining relevance in the S&T establishments under review. The reports of the review teams, while focusing on quality, simultaneously provided important insights into relevance.

In general, the report card was mixed. There were noteworthy examples of international leadership and excellence in some of the laboratories, which provided reassurance that government science can indeed be carried out in a way that meets the high standards of international scrutiny:

> The quality of the research in this programme is first class, and nobody in the international community does it better. Collaboration with American, Russian and Scandinavian scientists is significant.

In other cases, the peer review team had serious concerns about the quality and contribution of the laboratory under review:

> Knowledge about [a particular technology] is considered to be a vital part of the branch's mandate, but it was not clear how the programme will contribute to that goal. There is little work that can be classified as "research," for most of the activity appears to be test work, involving low technology and low risk, with limited scientific input. The programme contributes little to basic knowledge or process development that would benefit Canadian industry. The programme is below average on both a national and international scale, and is not even up to industrial standards.

Several reports noted that research was spread across too many areas of activity and that the scale essential to achieve the critical mass that outstanding quality can demand was lacking. Other reviews found too much emphasis on short term user needs in laboratories, while investment in long term research capability was not being addressed adequately:

> Management has a winner with this group, although it appears to be somewhat shortsighted in the selection of future research program directions.

Reviews noted that some S&T establishments had stuck to certain fields and failed to move towards more recent technological trajectories, a problem that is also related to the lack of mobility and graying of the scientific complement. The following comment is revealing:

> While excellence is demonstrated in [a field], it is felt that this field is no longer of national or international concern. ... Overall, the lack of interest and scientific and technical leadership in [an emerging technology] is remarkable, and there is urgent need to train personnel to work in this area.

Taken together, these observations by international experts provided useful insights into research quality and the comparative strength of these federal research organizations. Without information of the kind derived from international peer review, the Committee is at a loss to see how resource allocation decisions can be made or how plans to strengthen research efforts can be formulated.

5.2.2 Bibliometric Indicators

Simultaneously with the peer review process, the Committee conducted a second pilot study, the bibliometric analysis. The purpose of this study was twofold: first, to determine whether bibliometric indicators provide a valid and useful measure of productivity and quality in federal government laboratories and, second, to evaluate performance in a sample of federal government laboratories against a comparison group of selected, closely matched laboratories. Another objective was to determine whether bibliometric indicators could constitute a relatively inexpensive but reliable indicator of quality. The pilot process helped the Committee understand the relative merits of alternative methods of evaluation and at the same time to gain further insights into the quality of R&D performed in the government.

The Committee originally intended to compare 6 federal establishments with 12 matched Canadian and foreign laboratories it chose in consultation with the directors of the government S&T establishments. However, the range of activity in each of the establishments selected required that comparisons be made at the laboratory level, resulting in a list of 36 external laboratories to which 17 matching government laboratories were compared. In order to conduct as valid a comparative process as possible, a range of variables, such as size of laboratory and its mandate, was factored into the equation.

Bibliometric indicators measure two dimensions of R&D activity: productivity, as measured by the number of publications per professional, and quality, measured by the number of citations per publication (weighted by the influence of the journal of the citation). In conducting the bibliometric study, the Committee was aware of the higher value of these indicators for research, as compared to development activity, and of the occasional ambiguity in the reason for the citation (agreement or disagreement with the work).

5.2.3 An Input-Activity-Output-Impact Model

The use of bibliometric indicators for the evaluation of the laboratories' research output raises a number of methodological questions. Our approach has been to combine bibliometrics with organizational analysis to develop a framework that we have called an input-activity-output-impact model. This was a necessary condition for the relevance of the study, since laboratories not only have differing inputs and outputs but also varying primary missions, contexts and scientific fields.

Our input-activity-output model views the impact of publications for each laboratory to be a function of: (1) the level and types of inputs, (2) the scope of activities, (3) the range of outputs. The goal was to make sure that the proper variables and outputs were taken into account. For this reason, the model was discussed in detail with the directors of research in each of the participating federal laboratories.

Most S&T establishments can be broken into three or four laboratories, each operating according to distinct disciplines, scientific fields or missions. Our approach was to identify the research laboratories that formed the core operating units of each S&T establishment. Each of the five participating federal establishments was thus divided into its constituent research laboratories, yielding 17 laboratories. In turn, each laboratory director was asked to identify two or three closely matching and comparable industry, public or university laboratories in its field in Canada or anywhere in the world, bringing our final sample to 53 research laboratories.

A questionnaire was designed to cover the variables included in inputs, activities and outputs. Following a structured interview, questionnaires were completed by directors of the laboratories. The questionnaire consisted of an organizational analysis as well as the publications and patents lists of all participating laboratories.

Each laboratory director was asked to submit a list of publications and patents for the period from 1983 to 1988. Publication impact was based on the measurement of citations during the period of 1984 to 1989 for papers published during the period of 1983 to 1988. Citation searches were made under contract by the Institute for Scientific Information in Philadelphia, Pennsylvania.

5.2.4 Comparative Bibliometric Results

Assured of a broad similarity between federal laboratories and their matched laboratories, we compared the level of publication and the bibliometric impact of scientific publications. (Impact is defined as the actual citation influence of the publication.) It should be noted that only short term impact has been taken into account, since we could only deal with relatively short periods of time for citations.

For each research laboratory, we calculated a series of bibliometric indicators, primarily based on: (1) number of cited papers, (2) number of citations, self-citations and in-house citations, (3) number of highly cited papers, and (4) total influence weight.

Bibliometric results for the five federal S&T establishments with their comparable matches reveal that of the five groups of laboratories in three departments:

- On average, for three out of five groups of federal laboratories, the absolute number of cited papers and the absolute number of citations are inferior to those of their matched laboratories. Most federal laboratories, however, are smaller than their matched laboratories in terms of the number of professionals.

- On average, the number of citations per cited paper, which is one of the indicators of scientific impact, is inferior for three out of five groups of federal laboratories as compared to their matched laboratories.

- On average, the number of net citations per cited paper is statistically inferior for four out of five groups of federal laboratories as compared to their matched laboratories. Net citations exclude self-citations. The rate of self-citation is relatively high for federal laboratories.

- On average, for four out of five groups of federal laboratories, the average influence weights are statistically lower than those of their matched laboratories indicating that, on average, matched laboratories publish more in high-influence journals.

- On average, the absolute number of highly cited papers is higher for four out of five groups of matched laboratories.

- As for highly cited papers per professional, on average, three out of five groups of federal laboratories score better than their matches for 10 citations and more, but less than 25. As for very highly cited papers (25 citations and more), matched laboratories take the lead.

Two groups of federal laboratories have lower numbers of cited papers and citations per cited paper than their matched laboratories, and one group has both a higher number of cited papers and a higher number of citations per cited paper. Other groups of federal laboratories are dispersed throughout the range.

Thus, when various bibliometric indicators are taken into account, and when size is used as a correcting factor, in two out of five cases, federal laboratories globally perform better than their matched laboratories. In two cases, however, bibliometric indicators point to lower global scientific impact. For one group of federal laboratories, no clear results emerge from the bibliometric analysis, as some indices point to better performance for federal laboratories while others favour the matched laboratories. In seeking explanations for the examples of poor performance of federal S&T establishments, the consultants noted:

> The most disturbing observation, however, is that many federal laboratories [in a particular field] are not having the scientific publication outputs and impacts that most matched laboratories in Western Europe and the U.S. have. Finding the causes of such situations is beyond our mandate. However, we believe that explanations could be found in factors such as (i) clarity of mission and primary task; (ii) relative size, scale effects and funding; and (iii) stimulating demands from industry and government clients.

This observation, like many of the conclusions from the bibliometric study, was remarkably congruent with the findings from the peer review process. While each method of evaluation provided unique insights into the performance of the laboratories, the overall productivity and quality level as measured by bibliometric indicators was borne out and strengthened by the comments of the peer review teams who visited the laboratories.

In terms of the value of bibliometric analysis to the management of S&T in the federal government, the findings can be summarized in this way: Bibliometric indicators are complementary but not substitute means for the evaluation of research laboratories.

Bibliometric indicators, provided they are accompanied by valid organizational data to categorize the actual mission and the primary task, do provide good and very direct comparative information on the scientific impact of laboratories.

5.2.5 Best Practices Elsewhere

The Committee found that other jurisdictions consider external evaluation of quality an essential element of their evaluation and decision-making processes. France has had a system for research evaluation in place for 40 years. The National Committee of Research is made up of about 50 people, two thirds elected from the national research community and one third appointed by the Minister of Research. The national committee administers a peer review process that leads to a review of each government laboratory every four years. Within this cycle, the national committee meets twice a year – once to review the performance of people conducting research and once to review the laboratories and the overall strategy.

The French government has also established an independent body, appointed by the President, to extend the evaluation process to the structures that underpin the research system in France. The national committee will examine institutions, programs and procedures with a view to appraising their appropriateness for future needs. The assumption underlying the national committee's role is that structures often lock a system in place, creating the potential for future obstacles to change, linkage and flexibility. By examining them rigorously, it may be possible to make fundamental decisions that will result in greater yields from the government investment in S&T in future.

West Germany uses a variety of approaches to evaluate government-funded research. The Max Planck Institutes, which are devoted primarily to basic research, depend to a great extent on the choice of a director; once this critical decision is made, the institute is given the funding and autonomy necessary to pursue its mandate until the director leaves or retires. Peer reviews of the institutes are carried out by the Max Planck Society and are used in annual discussions with the institutes.

Germany's National Research Institutes have been evaluated using visiting committees. The committees use the peer review approach and report on two fronts. For instance, a detailed general survey recommending far-reaching structural changes was reported publicly. The review of the academic staff was reported on a confidential basis.

Traditionally, the Japanese approach to research management has centred largely around close integration of planning, management, monitoring and evaluation of research. Where industry and government are both involved, the consensus approach to decision making is typically employed to determine the strategic, industrial and technological objectives of a project before it is undertaken. Applied and developmental work is done in a more closely managed environment, where goals are set and measurable results assessed. Here, evaluation generally takes the form of objective measures of productivity and achievement, and depends on systematic peer reviews. This approach also applies to research funded by industry and carried out by government research establishments. Post-research evaluation tends to focus solely on measuring technical achievement.

Japanese government laboratories are encouraged to undertake joint projects with industry. There, mid-term assessments by independent review committees are used systemically. Japanese companies that are co-financing R&D projects executed in government establishments indicate satisfaction with how government agencies evaluate their collaborative research program, even though members of peer review committees are normally drawn exclusively from universities.

Federal government research organizations in the United States apply a variety of evaluation approaches. Noteworthy is the fact that peer review is gaining wider use within government. The Department of Energy requires peer review in all of its major laboratories. The Department of Agriculture is also instituting a formal peer review process to evaluate the quality of the research in its laboratories. Finally, patents granted have now been made part of the evaluation criteria for United States National Laboratories.

Leading technology-intensive corporations in the United States employ a variety of methods of evaluation of their research activity. All employ a combination of measures that include, as a minimum, publishing output and some form of technical audit.

Technical audits are of two kinds: internally based and externally refereed. A most extensive and sophisticated approach to internally based audits is the technical review process at 3M. Once every two years, the technical performance of each of 3M's 80 laboratories is reviewed comprehensively by a team of laboratory managers and scientists from other laboratories. Review teams are supported by members of 3M's department of research planning, a 20-person organization that provides background data to review teams on market and competitive factors. The company believes that its approach to evaluation meets two objectives: assures the technical integrity of individual laboratories and reinforces a culture of quality throughout the research system.

United Technologies takes an equally rigorous approach to evaluation, but relies mainly on external reviewers. Its technology advisory committee is charged with reviewing research performance in 13 technology areas that the organization judges to be strategically important to its competitive position.

General Motors has a science advisory committee that reports directly to the executive committee of its board of directors rather than to the vice-president of research. The advisory group, made up of leading academics, conducts peer review visits of GM laboratories. Its role is to provide an external perspective on the quality and relevance of laboratory activity. Senior research management generally takes the committee's advice and treats it as one of several important inputs to the management of the laboratory.

Martin Marietta conducts an internal peer review of six of its laboratories each year. Internal research customers and technical staff dedicated to evaluation activity conduct the reviews jointly.

Patenting was seen as an important evaluation criterion in the private sector, both as a measure of quality or relevance and to give scientists and engineers an incentive to patent. For example, Kodak expects to see several applications patents developed for every fundamental patent coming out of its corporate laboratory. Recognition and financial awards are also used to encourage patenting activity.

5.3 Conclusion

The successful management of an S&T establishment depends on planning, budgeting and evaluation systems that work effectively together; each on its own has only limited effect. Further, if they are to be seen as genuinely relevant to the activities of scientists, these systems must be firmly based in the values and culture of scientific organizations. At the same time, they must be linked back to corporate planning, budgeting and evaluation systems in the parent organization. Achieving this differentiation while maintaining accountability is a central challenge for the management of these unique organizations.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 The Need for Change

The principal finding of this report is that the management regime in Canada's federal S&T establishments does not measure up to the best practices of the world's leading organizations. Canadians are not receiving the best value for money spent on these activities. Quality and productivity can be improved, and the achievement of essential public purposes can be enhanced. Doing so will require considerable and fundamental change. The shortcomings and deficiencies the Committee found are primarily the result of the organizational designs, structures and systems in place. Thus, the solutions must be systemic.

6.1.1 Missions

Although much attention has been given to S&T policies in Canada over the past two decades, the fundamental missions of departmental S&T establishments remain subject to uncertainty in several respects. While some have a clear idea of what they are about, many do not. Across government departments generally, there is a need to clarify the role of these establishments as investments and instruments to assist in accomplishing departmental mandates.

The missions of departmental S&T establishments must derive first and foremost from the mandate, policies and priorities of their departments. There are too many cases where missions are not clearly defined or aligned with the specific needs of departmental programs.

By contrast, the best practices of leading R&D organizations around the world, as well as peer reviews of departmental laboratories, demonstrate a consistent correlation between the clarity of an establishment's mission and the quality of its S&T activities. These establishments have missions that are sufficiently clear and specific to guide the setting of goals against which their performance can be evaluated. In leading organizations, missions are not imposed on the S&T establishments, nor are they defined by the scientists on their own. They emerge from a rigorous interactive process, a continuous process of reassessment and refocusing.

This report's recommendations are designed with these requirements clearly in mind. It is essential that federal S&T establishments have well-defined missions consistent with their roles and ones that enable them to develop meaningful goals.

6.1.2 Structure

At present, departmental S&T establishments are integrated within departmental management structures. Although some have a certain degree of visibility, they are not distinct because they do not have separate management authority, responsibility or accountability. They are parts of departments and subject to all the same departmental and central agency rules and procedures pertaining to departmental administration. This has four critical consequences.

First, there is insufficient emphasis on quality. It is not a major consideration in overall governmental or departmental planning, budgeting or evaluation nor is it a central issue in making public policy decisions or expenditure allocations. It is assumed that other processes, such as program evaluation and performance appraisal, capture the quality issue, but the Committee found that this is not the case.

The government's program evaluation process does not ignore quality by design, but there is little evidence that it confronts the quality issue adequately or that it regards quality as a central factor in effective S&T. In fact, program evaluators presume that performance appraisals fulfil this quality assurance role. It was found, however, that performance appraisals address quality only at very infrequent intervals in a scientist's or engineer's career. Moreover, there is no adequate accountability system in this regard. In summary, because S&T establishments use the same planning, budgeting and program evaluation systems that apply within departments, what little visibility they possess does nothing to secure an overriding concern for and action on the critical issue of quality.

Second, current management arrangements do not inspire scientists to excellence. A widely held view among government scientists is that their contributions to the missions of departments are not valued highly by other departmental units or by senior managers. As a matter of fact, in some cases, individual scientists simply decide themselves what projects they will undertake. This demonstrates the degree to which their work can drift away from the needs of their departments and the effect of not having missions clearly defined.

Given the character of scientific endeavor, this is not surprising. The nature of much of the work scientists do gives them a low political profile unless there is a crisis. This is also the case elsewhere, including the private sector. But in the best practices model, governments and private sector organizations have managed to make their R&D establishments distinct and visible, at least within the context of the larger organization and its senior management. This characteristic serves to create a sense of legitimacy and value for the contributions of the R&D establishment. It also increases the involvement of its leaders in the parent organization's planning and priority setting. Finally, it facilitates linkages with the external world of S&T.

Third, the present management system is not protective of the distinctive contribution that S&T establishments make to their organizations, particularly in regard to long term research and technological capacities. In the world's best organizations, R&D establishments are considered investments in the future. Although restraint is a fact of life everywhere, these investments are protected from across-the-board budgetary cuts insofar as their critical elements are concerned. Priorities are set within the budgetary process to ensure that the required capabilities survive whatever cuts are necessary and ensure that the establishment is not permanently crippled by indiscriminate actions.

Particularly crucial in this respect is the lack of sufficient expertise in research and technology issues on the part of senior departmental managers. The invariable result is that restraint is applied in ways that cut in the wrong places; elements critical to an establishment's functioning and to maintaining and promoting quality too often are not distinguished from less critical elements. In many cases, the reallocation is not done, cuts are made indiscriminately, and the reduced level of activity is not likely to have any meaningful impact.

Finally, current arrangements do little to build on the distinctive culture of science and the value system of scientists. Attempts have been made to place some scientific and engineering personnel in separate categories for purposes of classification and personnel management, but they have not been adequate to achieve the desired result. Performance appraisal systems have not been sufficiently rigorous or comprehensive. And, as noted in Chapter 4, not only are there quotas for some categories, but the actual promotion process is one where scientists are promoted in lock step for the first ten years of their career and essentially blocked thereafter. The standards of the wider scientific community have not been applied to the extent found in leading R&D organizations elsewhere.

Fundamental change is needed in all these areas. Federal S&T establishments must be organized to ensure distinctiveness and visibility, which in turn allows for the creation of the appropriate environment for scientific and technological excellence and quality consistent with the highest standards of assessment.

6.1.3 Linkage Mechanisms

Government planning and budgeting systems have changed significantly in the past three decades. But, they have yet to incorporate a means of establishing the contractual mechanisms between departments and their S&T establishments that characterize the leading R&D organizations.

In some departments, the use of a Memorandum of Understanding between the deputy minister and the assistant deputy ministers responsible for S&T establishments have been observed. These agreements specify objectives to be met in the coming year. They, in turn, have led to more focused planning efforts in the S&T establishments concerned. The positive impact of these quasi-contractual procedures is an indication of the large potential benefits stemming from rigorous contractual relationships in which the S&T establishments are revenue-dependent.

The current planning and budgeting system gives significant attention to new program proposals, but much less scrutiny to programs already in place. The system's implicit incentives force R&D managers to protect what is in place by ensuring that programs survive evaluation and expenditure review. New initiatives must compete for scarce new resources. As a rule, rationalization, reassessment and revitalization do not figure prominently in this approach to planning and budgeting. For this to be accomplished effectively, it must be done at the level of the S&T establishment by those knowledgeable about the priorities and trade-offs involved.

The deficiencies of the annual appropriations process have led the best R&D organizations to the contractual/revenue-dependency approach outlined in Chapter 2. The practices of the federal government have a long way to go to meet the standards of these organizations. Without this approach, there will continue to be insufficient attention to clarity of mission, to quality, to results, to organizational renewal, to productivity and to the effective transfer of knowledge and innovation to the operating units of departments.

Because most S&T establishments are integrated within their departments, the S&T investment is invariably considered just one of a range of budgetary demands within the department. Too often, accountability is diffused because responsibility for S&T within departments is pushed down the management hierarchy, not as a matter of good design or management, but because of a lack of interest on the part of senior management. The multi-layer, hierarchical structure also impedes the decision-making process, since decisions pertaining to laboratory management are often mired in several levels of communication and paperwork.

Thus, integration of S&T activities within departments has taken the place of carefully designed, explicit and transparent links that force precise mission and project definitions and a better understanding on both sides of needs and constraints. In theory integration may seem the ideal approach, but the results in practice – including excessive rigidity and procedures inappropriate to an S&T environment – are far from ideal. The efficient flow of knowledge and innovation is but one of the objectives undermined as a result.

6.1.4 Human Resources

The shortcomings in human resource management in federal S&T establishments stem largely from inflexible, centrally imposed staffing, classification and promotion systems. Although these deficiencies are not unique to S&T establishments, the imperatives of a meritocracy (which characterizes the best R&D organizations elsewhere) are not easily accommodated by existing government policies and systems.

In part, today's shortcomings result from the domination of human resource development by financial control systems. Instead of being used to develop the system's most valuable resource, personnel systems are used as a means of bureaucratic control.

This is most evident in the way PY controls, essentially a financial control device, drive the entire system. In these circumstances, considerations such as quality are secondary, and S&T establishments do not have the flexibility they need to set up suitable promotion and incentive systems. Similarly, the effective use of instruments such as national and international conferences, which are crucial to scientific innovation, information exchange and technology transfer, has been undermined by the failure of central agencies and senior departmental managers to appreciate these instruments. Travel to conferences, for example, is viewed as a perk or reward, and not as a critical and necessary means of pursuing an S&T establishment's mission and specific goals.

Given the complexity of the management environment for S&T, the Committee does not suggest that a simple formula will solve these problems. The challenge for all S&T organizations is to manage their human resources in ways that secure quality, enhance productivity, and promote rejuvenation. But international experience demonstrates clearly that this challenge cannot be met in a rigid bureaucratic environment.

6.1.5 Management Processes

Integration of S&T establishments within departments also means that their financial and personnel management is subject to departmental, central agency and common services department regulations and procedures.

The government has recently introduced changes in this approach. Despite the changes, however, an essentially bureaucratic structure remains. This may be necessary for some government operations, but it contrasts sharply with the management regimes of leading R&D organizations, even those operated by other governments. These organizations recognize that effective management cannot be achieved within a management system that emphasizes extensive centralized or corporate micro-management controls. Instead, they give managers the authority and flexibility they need to achieve the required results, given the human and financial resources at their disposal.

By contrast, managers in federal S&T organizations have insufficient autonomy in managing their financial and personnel resources, being constrained by departmental management systems and central agency rules such as financial and PY controls and quota schemes for certain categories of personnel. These systems provide little incentive for efficiency or effectiveness, let alone vital goals such as organizational rejuvenation.

In addition to the systemic deficiencies just discussed, a major shortcoming relates to the intramural capacity for technology transfer. Although successive governments have made the commercialization of technology a high priority of science policy, the actual record is poor. Few government scientists consider pursuing patents for their work to be a priority. A major impediment in this regard is the management structure in place for technology transfer. The mandatory requirement to use CPDL for the patenting process has long been recognized as deficient in several crucial respects. The urgency of the issue for the Government of Canada is such that it must be addressed immediately.

R&D organizations, particularly those in the private sector, which can harbour no illusions about results, recognize how difficult it is to manage technology transfer, and they organize and provide incentives accordingly. A few Canadian universities have adopted policies that conform to the peculiar dynamics of commercializing new scientific information and have achieved a good track record. To the extent that the primary motives for undertaking departmental S&T activities are regulation, public policy formulation and the constitution of sophisticated data banks and knowledge infrastructures, it follows that the scientific knowledge produced should be widely and rapidly diffused. To this end, publication in scientific journals and participation in scientific conferences and seminars must be strongly encouraged by management and through the use of appropriate incentives. Moreover, incentive programs, monetary and otherwise, must be implemented to motivate scientists and engineers to seek patents. Other governments, including that of the United States, have made major changes in this regard, including vesting authority for technology transfer and patents with S&T establishments and putting the appropriate incentive systems in place.

6.2 A Model for Change

Given the Committee's assessment of existing arrangements for managing departmental S&T establishments, and in light of best practices elsewhere, it has been concluded that fundamental change is required in the organization and design of the federal government's intramural S&T activities. The organizational model recommended can be applied to all significant departmental research organizations, so that each parent department will have a single S&T organization that includes all of its S&T establishments. The result will be one S&T institute per science-based department.

This proposal is not intended to be a panacea, neatly resolving all the issues facing S&T organizations within the departments. Rather, it is a fundamental step towards best practices and towards restoring the values and environment in which quality R&D can thrive. The recommendations outlined here would replace many of the existing management processes and control systems with management processes and control systems tailored to the particular requirements of S&T organizations. The success of the new model will depend ultimately, however, on the people responsible for its implementation: the scientists, engineers and research managers themselves. Even the best management model cannot substitute for the quality of people and their commitment to change.

The model, which the committee calls a S&T institute, would be constituted on the following organizational and management principles:

- *Institute status*: Each department will transfer its S&T establishments into a single S&T institute under the charge of a board of directors and under the direction of a chief executive officer.

- *Contractual relationships between the department and its S&T institute:* The department enters into a multitude of contracts with the institute's S&T establishments for the scientific and technological services the department requires to achieve its mandate and program objectives and that the institute can provide.

- *A revenue-dependency funding relationship:* Parliament appropriates funds to the department for its programs, including the sums required for it to obtain the S&T support and services needed to accomplish its mandate; departmental program managers in turn contract with the establishments of the S&T institute, which is thereby revenue-dependent for operating funds.

- *A management structure for the S&T institute:* The institute has the authority to manage its contracts with the department, including the revenues derived from them, to enter into contracts with other clients, to own intellectual property, to enter into contracting and licensing agreements, to set fees and retain the earnings generated by these activities, and to carry on activities in a manner consistent with the best management practices as they apply to its S&T responsibilities.

- *An evaluation regime for the institute:* The board of directors and chief executive officer have explicit authority and responsibility to ensure that scientific and technological activities and personnel are evaluated in ways that promote the highest standards of excellence, responsiveness and productivity, including the use of external on-site peer reviews and other internationally recognized methods and criteria of assessment. These assessments are to be monitored by a national panel for quality evaluation.

6.3 Design Elements

These five design elements constitute parts of a comprehensive management system. Here we outline the rationale for each of these elements. It must be recognized that they are interrelated and that all are required. The absence of one or more elements is likely to produce undesirable results.

6.3.1 Institute Status

Best management practices require organizational distinctiveness and visibility for R&D establishments. Experience demonstrates that distinctive status is a requisite condition for levering scientific values and driving quality and accountability for performance.

The Committee recognizes the paradox in this arrangement. But like many paradoxes, the presumed contradiction of the principles of good organizational design is more apparent than real. Leading R&D organizations have found, through experimentation, experience and organizational learning, that the separation of R&D establishments from their operational divisions enhances, rather than decreases, the pursuit of organizational and corporate objectives, on the condition, however, that appropriate and tight linkage mechanisms, as outlined below, are present. It does so because S&T must be measured against external benchmarks while tight linkage mechanisms ensure that the distinct R&D establishments not only avoid mission drift, but also concentrate more rigorously on their missions in pursuit of the objectives of the parent organization. They give considerable attention to quality and quality evaluation because they must justify their existence and sell their services primarily on the basis of scientific and technological merit.

At the same time, leading organizations recognize that having a separate but appropriately linked R&D organization actually enhances the inputs from the S&T organization to the planning and decision-making processes of the parent organization. This means that S&T are placed at the forefront of policy and priority exercises. For organizations that must use S&T to fulfil their mandates, this is an essential requirement.

Institute status is best achieved if the S&T activities now undertaken within departments are placed under the charge of a board of directors appointed by the governor in council and under the direction of a chief executive officer, with the title of president of the institute.

The composition of the board will be critical to the institute's success. Particularly at the outset, the board will be a powerful agent of change; the credibility and expertise of its members will have to be brought to bear in a hands-on manner. While relevant scientific expertise will be important, the primary criterion in the selection of board members should be their experience in implementing effective management practices in large R&D organizations. The board should include the deputy minister of the department and the chief executive officer of the S&T institute as *ex officio* members. In addition, an institute should have at least five other board members selected from senior executives of universities and technology-intensive corporations. The board chairman should be appointed from outside government. Board members could be drawn from both Canadian and foreign S&T organizations.

The main responsibilities of the board would be threefold:

- First, advising the minister on matters relating to the needs and opportunities of the department in regard to the use of S&T in the pursuit of the department's mandate and mission. In so doing, the board would bring an important external perspective to such matters, although one informed of departmental requirements through the participation of the deputy minister on the board. The board would thus contribute to better integration of the planning and budgeting processes of the department and its S&T institute by identifying trends and technological developments and by protecting its long term capabilities.

- Second, the board would ensure that evaluation of quality is given highest priority. The board would direct comprehensive evaluations of the agency's activities and personnel at least every three years. These evaluations would replace program evaluations carried out by departments under the aegis of the Office of the Comptroller General. The focus of current program evaluations is, appropriately, departmental programs for which funding is received from Parliament. This would not be affected; a department's programs would still be subject to program evaluations. At the same time, however, they would not apply to the department's S&T institute, since the evaluation issue here is the quality of the institute's S&T functions. These functions should be evaluated according to the criteria of quality of S&T through an evaluation process outlined below.

- Third, the board would report to the minister on the management of the institute by its chief executive officer. The president of the S&T institute, as chief executive officer, would report and be accountable to the board for the management of the institute. The institute's distinct status would ensure that there is a clear and explicit line of accountability for quality and performance.

The institute's status as a visible and distinct organization would also serve to enhance the identification of its personnel with the mission of the S&T institute, to protect the institute's mandate with respect to its long term roles, to promote the values, criteria and methodologies of the scientific community in assessing its work and personnel, to facilitate joint undertakings with industry and universities across Canada, and to enable the government to recruit outstanding R&D managers, thus strengthening the management of S&T within government. This attribute would be particularly valuable with respect to the recruitment and selection of the president of the institute.

Certain S&T establishments have preserved and nurtured a distinct identity over many years. This proposal does imply their elimination. On the contrary, the institute model will facilitate and reinforce these long-standing traditions by ensuring that these S&T establishments conserve their identity and by adopting a management regime that allows them to build on their scientific tradition with greater autonomy.

6.3.1 Contractual Relationships

With a single S&T institute for each department, funding becomes a matter to be determined by the department and its institute through a process of negotiating numerous contracts for the S&T services the department requires to fulfil its mandate and meet its program objectives. Two purposes are served by a contract funding mechanism linking departmental programs, in a discrete and precise fashion, with the department's S&T establishments in the institute:

- First, it provides greater incentives for the department and its institute to clarify their objectives, set priorities, and establish meaningful criteria for evaluating the results achieved.

- Second, it places the institute and its R&D establishments in a relationship with the department and its program managers whereby the departmental programs buy into the institute's services but where the organizational separation of the institute from the department and its line operations remains intact.

The department's program managers, as clients, will be responsible for establishing objectives and criteria for assessing results, that is, defining the deliverables, but not for the management of S&T activities. Responsibility for these activities would reside with the institute as contractor.

The contractual relationship is the principal mechanism linking the department and its S&T institute. Also important, however, is the position of the deputy minister on the board of directors of the institute. This should serve to ensure that the institute's board is knowledgeable about the mandate and objectives of the department and is continually informed of changes to policies, programs and priorities. To strengthen this relationship further, the president of the institute should also be appointed chief science adviser to the department and be included in the deputy minister's senior management team. This should serve to ensure that departmental management is well advised on matters relating to S&T as they affect the department's mandate and objectives. In particular, this should ensure that the expertise of the S&T institute influences the policies, directions and decisions of the department.

In these ways as well, the potential for mission drift on the part of the S&T institute should be decreased. It is recognized that these arrangements introduce complications with respect to reporting and accountability. While the president, as chief science adviser to the department, will serve in a staff position to the deputy minister, the deputy will have no authority to direct the president in regard to the management of the S&T institute. With regard to the latter dimension, the deputy minister's influence will stem from the contractual relationships and the fact that the department is a major client. The evidence indicates that arrangements of this kind have proven successful in the practices of the leading R&D organizations. Notwithstanding their initial concerns about potential conflicts of the sort that immediately come to mind, the record of success in these organizations demonstrates that assumed problems can be overcome.

6.3.3 Revenue-Dependent Funding

Funding a department's S&T institute through a contractual relationship will place it in a revenue-dependent relationship with its department or other departments or agencies of government. The department will receive annual appropriations from Parliament for its S&T programs. In effect, the funds allocated for each of the department's programs would be discussed through the normal budgetary process with Treasury Board. The funds required to carry on S&T activities would form an intrinsic part of these appropriations. Departmental program managers, in turn, will contract with the S&T establishments for the S&T services they require and that the institute can provide. Departmental managers will act as the clients and buy these services from the institute as the contractor. This will require that departmental program managers be delegated sufficient authority and responsibility to enter into contracts for the services they require. Supply and Services Canada regulations regarding contracts will not apply in these cases, as these contracts will be internal to government.

This funding approach will force S&T establishments to establish close relationships with the users of their research and technology services because they must earn the funds that come to them by way of these contracts. Thus the approach forces a better definition of the products the institute is to deliver to the department on the one hand and the resources required to produce those products on the other. This should also apply to R&D services that are funded by the department but undertaken on behalf of external users. In both cases the department, as the purchaser, is the primary client for the services provided. This relationship forces a clear understanding of mission on the part of the institute and a better definition of program requirements on the part of the institute and its S&T establishments. Since this report does not suggest a mandatory requirement on the department to use the institute, it gives departmental managers a more explicit choice about where to obtain the best possible product and value for money. This fact ought to constitute an important incentive for institutes and their constituent S&T establishments to strive for quality and to avoid mission drift.

Contracts between departments and their S&T institutes should be of two kinds:

- A long term contract covering only the costs of maintaining the institute's physical plant and equipment, including, for example, research ships, experimental farms and laboratories. This should cover, at a minimum, a five-year plan.
- Annual or multi-year contracts, subject to annual departmental appropriations and program objectives, to provide operating revenues for specified undertakings as negotiated between the departmental program managers and those of the S&T establishments in the institute.

The institute should also have the authority to enter into contractual relationships with other departments or private sector organizations and to retain any revenue generated in this way. These external relationships would be subject to limits that may be established by the minister following consultations with the institute's board of directors and the deputy minister.

In line with the best practices in leading R&D organizations, there should be annual institute research funding to support unspecified basic research and the exploration of enabling technologies. The amount of the funding should be on the order of 10 percent of operating revenues generated by the institute from federal government sources. This funding should be separate from the contractual relationship to ensure that no bias is introduced through the contracting mechanism. It is recommended that this funding be appropriated directly from Treasury Board. The Committee believes this arrangement to be preferable to funding by the parent department because of the importance of encouraging joint projects and rationalization of S&T activities among the institutes. If the parent department were responsible for providing the 10 percent institute research fund, it would tend to restrict the institute to serving its own interests rather than contracting with other departments, whereas the overall interest of government would be better served if such interdepartmental activities were undertaken. The institute research charge should also be applied to contracting with external organizations. In this case, the institute should collect the 10 percent charge directly and allocate it to the fund. This institute research funding should support projects selected by the president of the institute and be designed to encourage co-operative research undertakings involving universities and industry.

These contractual linkages are an essential feature of leading research organizations. They should also facilitate much greater use of temporary interorganizational structures and personnel assignments to promote interaction between S&T and departmental line operations, especially on matters relating to technology transfer.

The revenue-dependent regime may create some pressure for the institutes to compete with private research contractors, industry or even universities. Care must be taken to ensure that this does not develop into a problem. Several measures should be adopted to this end. First, it is not proposed that institutes benefit from a mandatory franchise in contracting with their parent department. Program managers should be free to contract for their S&T requirements with whomever they believe to be the best able to meet their need. Second, the decoupling of S&T activities from departmental programs should provide government with a unique opportunity to renew its emphasis on the contracting-out policy. Third, institutes should be strongly encouraged to undertake joint programs with universities and industry. The present institutional arrangements where S&T establishments are often buried within departmental bureaucracies make such joint undertakings very difficult to establish. This proposal would correct this situation and open the door to constructive relationships that will facilitate the diffusion of knowledge and innovation. Fourth, it is recommended that the board of directors be required to develop within the first three years after the establishment of an institute a proper full cost system of accounting, including the cost of the capital employed to ensure that no hidden subsidies are provided to outside clients and that the institutes do not compete unfairly with private research contractors.

6.3.4 Management Processes

To gain the benefits of institute status and contractual funding relationships, the new S&T institutes require an administrative regime that affords considerable managerial authority and flexibility. It is proposed that they be given authority both to enter into contracts and to establish their own personnel and financial management systems.

In particular, the institutes should be designated separate employers and be exempt from the Treasury Board personnel policies that apply to departments and departmental corporations. They should have the authority to recruit and staff their establishments, implement personnel appraisal systems, and assign and reassign personnel, as well as have full disciplinary authority. However, the employees would continue to enjoy the usual benefits offered to government employees.

At the same time, arrangements should be put in place to facilitate the movement of scientists into positions in the parent department or other government institutes. These arrangements might include, for example, competitions that limit eligibility for the position to those with experience in S&T institutes.

Because of the proposed management control systems for S&T institutes, these institutes should be exempt from the current Treasury Board administrative controls related to PY allotments, organizational changes, classification structures, performance incentives, program evaluation, operating costs, revolving funds, lapsing funds, procurement requirements and procedures, and retention of externally derived revenues.

The institutes should have the authority to formulate technology transfer policies and to enter into contracting and licensing agreements, to own intellectual property, to set fees, and to retain earnings generated by this activity. Once such policies and regulations are adopted by the board of directors, an institute should automatically be exempted from the mandatory requirement that it use the patenting policies and procedures administered by CPDL and the contracting procedures of Supply and Services Canada. Under such institute policies, incentives should be devised to encourage scientists and engineers to obtain patents and other intellectual property. Such incentives are standard in leading R&D organizations; they also constitute an important benchmark for evaluating the quality of researchers and laboratories.

The managerial authority and flexibility thus created are in line with the best management practices of leading R&D organizations. They provide the capacity needed to pursue quality on the one hand and efficiency and effectiveness on the other. This does not imply that managerial practices will be loose. Instead, tight management controls will be tailored to the circumstances of the S&T institute, including the culture and values of the scientific community, and coupled with sufficient delegation to their managers. The aim of doing so is to avoid the micro-management overload now imposed on S&T managers by departmental and central agency controls. At the same time, it is strongly recommended that S&T institutes use appropriate departmental common services, such as legal services, in order to avoid unnecessary duplication of staff and administrative costs.

Managerial authority will be vested in the president, who will report and be accountable to the board for establishing and maintaining management information, control and reporting systems and management practices. The board will direct internal audits to ensure compliance with established policies and practices.

These proposals do not imply that each institute should separately create its own management processes, but rather that a common but distinct framework and set of administrative policies be devised for all S&T institutes drawing upon the best practices of leading organizations. At the same time, however, these should allow for sufficient flexibility so that once the major elements are in place, the board and senior management of each institute will have significant authority to interpret the rules accordingly.

The Committee recognizes and accepts that even as distinct and visible organizations, the S&T institutes are part of the Government of Canada and as such must comply with public policy legislation such as bilingualism, health and safety regulations, and hiring practices. In addition it is expected that the S&T institutes will adopt a mode of behaviour that conforms to and respects the fabric and priorities of the nation.

6.3.5 Evaluation Regime

The final element in the model proposed concerns the need to enhance the capacity within government to evaluate the quality of S&T activities and the personnel who undertake and manage them. It is proposed that the board of directors of each S&T institute be charged with ensuring that independent quality evaluations are conducted at least every three years.

These quality evaluations would be in addition to the rigorous personnel performance appraisal systems recommended for the new institutes. At the same time, these quality evaluations will replace the existing program evaluation system insofar as the activities of the institute are concerned.

The committee believes that institutes should contract, at least for the first round of evaluations, with one of the three granting councils (NSERC, MRC and the Social Sciences and Humanities Research Council) to administer the evaluation. These councils are already managing strong peer review systems, have the organizational infrastructure to manage evaluations, have knowledge of and access to the national and international networks from which peer assessors are drawn, and have developed the capacity to ensure that the quality of government laboratories is assessed in relation to the highest standards of other private and public sector laboratories. Evaluation panels should be selected jointly by the institute in question and the granting council administering the evaluation, with each having a veto over the other's nominations if the qualifications or specializations of nominees are considered inappropriate. Each panel should include members of the international scientific community.

Quality evaluations are crucial to ensuring that the best possible use is made of the S&T institutes. Quality evaluations will serve their purposes, however, only: if the very best scientists, engineers and R&D managers are chosen to conduct them; if evaluation panels include those who fully understand the particular nature of government S&T activities; if they include those from university, industry, and government who bring an international perspective; if evaluations are conducted in ways which are perceived by those being evaluated as fair and credible; and, finally, if evaluations serve to increase the appreciation of those inside and outside government of what constitutes quality, what does not, and what can and must be done to correct deficiencies.

To achieve these objectives, it is recommended that a mechanism be established whereby every three years, scientists, engineers and R&D managers within departmental S&T institutes elect, from among their peers, a pool of 100 potential peer reviewers. It is recommended further that one-quarter of the members of each evaluation panel be drawn from this pool as the institute and granting council make their selections. Each evaluation panel should have a cross section of members from the relevant fields of science, engineering and management and from industry, universities and government R&D establishments in Canada and abroad. No panel member, whether in the pool or not, should participate in an evaluation of their own research establishment.

Evaluation results would be reported to the board of directors of the institute in question. They would also be forwarded to a national panel on quality in evaluation for its assessment of the methodologies and standards employed in the evaluation and of the people conducting it. This panel, appointed by the governor-in-council from among the nation's leading scientists in government, the private sector and the universities, would ensure that evaluation procedures meet the highest international standards, reporting its assessments to the board of the institute in question and to the Comptroller General. The sole responsibility of the national panel would be to ensure that the peer review process is conducted with a high standard of rigour and conforms with best practices in this field; that there are no conflicts of interest among the peer reviewers; and that evaluation panels contain a good cross section of peers from different sectors and disciplines. The national panel will play an important role in ensuring the integrity and fairness of the peer review process. It will replace the central agency mechanism for overseeing program evaluations, including serving as an appeal body for the institutes and scientists under review.

Quality evaluations should deploy the full range of methods appropriate to the evaluation of S&T activities. In addition to the use of external and international peer reviewers on evaluation panels, bibliometric analyses should constitute an important instrument for these evaluations. The best practices of leading research organizations, as well as the committee's investigation of the use of this instrument, demonstrate clearly how useful bibliometric analysis can be. Although evaluations of this scope and thoroughness would require the commitment of scarce resources, the savings gained by using these evaluations in place of existing program evaluations should more than offset the resources required to conduct them. More important, they will serve a vital purpose in promoting quality and productivity.

6.3.6 The Overriding Need for Departmental S&T

During the committee's consultations, alternative models were identified and discussed. One such option would call for government to contract-out all departmental R&D activities. However, the major proportion of departmental intramural S&T activities is undertaken to maintain the technical knowledge necessary: to fulfil regulatory mandates; to test methodologies, products or physical conditions; or to constitute, maintain and enhance sophisticated inventory data bases. These S&T activities are substantial and essentially for the public good and are therefore best positioned within government. Nevertheless, they do require that best practices management and operating policies be adopted to ensure quality and value for money.

Another option would be to group all S&T establishments in a single government-wide institute. The apparent rationality of such a proposal has some intuitive appeal. It was first recommended by the Gendron task force, which recommended that all S&T establishments be merged within NRC. Upon careful review the government decided not to implement its recommendation; this analysis leads to the same conclusion.

The critical shortcoming of this option stems from its failure to recognize that intramural departmental S&T activities should be undertaken first and foremost to inform and support a specific mandate, regulatory or other, of a department. Therefore, unless very tight links exist between S&T establishments and their program managers, mission drift will soon become the norm. As a result, this process would lead gradually to efforts by good program managers to rebuild internal establishments that better respond to their needs, causing unnecessary duplication. Another outcome, even more serious, would be for the drift process to contribute to a further erosion of the already weak technological proficiency that exists at senior levels of many departments.

The Committee's proposal recognizes that in our system of government, each department has been given a specific mandate by Parliament. Inherent in this mandate is the responsibility to conduct the S&T activities necessary for it to fulfil its mission and to allocate the funds accordingly. For departments, intramural S&T activities must be undertaken to fulfil a well-defined purpose, as a means to an end. The comprehensive management system recommended here is designed to ensure that departmental S&T activities are performed in a manner and under conditions that will optimize their contribution to the fulfilment of the mandate of their parent department.

6.4 Recommendations for Change

To implement the organizational model just described, fundamental changes to existing departmental arrangements and central controls are necessary.

The Committee's ultimate recommendation is for Parliament to enact legislation amending, among others, the *Financial Administration Act*, the *Public Service Staff Relations Act*, the *Canadian Patents and Development Limited Act* and the *Public Service Inventions Act* to accommodate this new type of institute. Such an act of Parliament would symbolize in no small measure the crucial role of S&T establishments and the increasing importance that S&T will play in modern and competitive governments. However, if immediate legislative change is deemed impractical under the current parliamentary agenda and the likelihood exists that several years will pass before these urgent and fundamental changes can be made in the S&T machinery of government, the recommendations should be implemented to the extent possible within the present legislative framework. Rather than waiting for legislative changes, the government should make maximum use of the flexibility provided by those same acts to introduce a new regime implementing best practices for the organization and management of S&T establishments. However, the Committee urges the government, in due course, to enact the legislation that would give full effect to the proposed institute model. Detailed recommendations follow.

6.4.1 Distinct and Visible Institutes

It is recommended that:

1. **S&T institutes be established as distinct and visible organizations, one for each department with major S&T activities, incorporating all of that department's S&T establishments.**

This recommendation is designed to provide the framework and basis for S&T institutes as they may be created by order-in-council proclamations in each case where it is decided that a department's S&T establishments should be grouped into a single S&T institute for purposes of creating new contractual relationships, management systems and quality evaluation processes.

Under this framework the Committee envisages the establishment of eight S&T institutes, one for each of the following departments: Agriculture Canada; Communications Canada; EMR; Environment Canada; Government of Canada Fisheries and Oceans; Forestry Canada; HWC; and National Defence. While these recommendations pertain primarily to these departments, each of which spends in excess of $50 million per year on intramural S&T, smaller S&T departments may wish to apply these same principles over time. In particular, program managers and researchers in these departments should ensure that the missions of the S&T establishments are clearly defined, that contractual relationships are established, and that structural and management processes to help inculcate a distinct culture are put in place. These departments should also be encouraged to adopt the proposed peer review evaluation process. Other measures such as independent status could be considered in some cases.

A separate institute for each department establishes the parent department-S&T institute relationship that has served leading R&D organizations so well in several respects. First, the value for money invested in departmental S&T programs will be increased by forcing the issue of quality through the visibility, distinctiveness and revenue dependency of the institute. Second, the linkages obtained by this relationship between the department and its institute will enhance the ability and capacity of the department to use S&T to fulfil its mandate and program objectives.

A separate institute for each department is also not intended to preclude interdepartmental alliances and joint projects. Rather, it is intended to provide the stability of a permanent structure, within which collaborative activity in the form of temporary project teams can be accommodated. It is also recognized that S&T activities with a common technological underpinning are performed in different departments and that in some areas a case could be made to consolidate them into the same institute. Departments would not be limited to contracting with their own institute; in fact, contracting-out, interdepartmental contracting and joint contracts should be encouraged. In the same vein, it is not envisioned that a sunset clause would be applied to the institutes themselves, but rather that the contracting process would provide the mechanism to ensure that projects are reviewed on a frequent basis for their continuing relevance.

The committee would expect a constructive partnership between program managers and scientists to develop in which the program managers become champions of the research programs. As one senior research executive pointed out to the Committee:

> The crucial step is to put in place real program champions and make these champions accountable for the results of the expenditures. As these are put in place, work will soon be contracted to the best resources – either in the government laboratories or outside.

The Committee also dismisses the view that the contractual relationship will lead to lower quality R&D. In fact, it is anticipated that over time the contractual process will select and support the better performers. The Committee is also confident that instituting the peer review process will safeguard the quality of work in the institutes and provide useful feedback information to the deputy minister if some program areas are neglected by the S&T establishments. Fundamental to an effective contracting approach will be the presence of scientific knowledge and understanding within the departments. To this end, it is important that there be an active flow of scientists and engineers from the institutes to the departments at the program manager level and that increasingly the departments become populated with employees with recognized scientific capability.

In addition, the creation of departmental S&T institutes will foster better interaction among government S&T establishments and those in the university and private sectors, especially with respect to technology transfer and the training and development of scientists in areas of crucial significance to Canada's social and economic well being. And, it will do so across the country, given the distribution of departmental S&T establishments throughout Canada. Equally important, this development will permit better use of existing resources and investments and should facilitate better allocation of scarce resources among identified priorities.

6.4.2 Establishment

It is recommended that:

2. **Upon order-in-council proclamations, S&T institutes be established as corporate bodies with the power to acquire and hold real and personal property and be agents of the Crown in right of Canada.**

3. **Upon proclamation, each institute be given objects that encompass the S&T activities required by its parent department's mandate and missions, including the responsibility to diffuse, transfer and commercialize the scientific knowledge and technologies it develops.**

4. **Upon proclamation, and on the basis of general provisions adopted specifically for these S&T institutes, they be given the following powers to carry out their objectives including, *inter alia:* procuring, managing, maintaining and operating S&T programs and their facilities; entering into contracts with government departments and institutes or persons for the provision of services and facilities and charging fees therefore; licensing, selling or otherwise making available any copyright, trademark, or other like property they hold, control or administer.**

These recommendations are designed to ensure that each institute is established with clear and explicit objectives and powers in order to differentiate it as a separate and distinct organization.

6.4.3 Organization

It is recommended that:

5. **Each institute have a board of directors composed of at least seven but no more than eleven members, including a chair and two *ex officio* directors, namely the departmental deputy minister and the president of the institute, with the external directors selected from senior executives of technology-intensive corporations and universities in Canada and abroad.**

6. **The board be responsible for the management of the institute's objectives and the management of the affairs of the institute.**

7. **The chair of the board and the directors, other than the *ex officio* directors, be appointed by order-in-council and, subsequent to the appointment of the initial board, after consultation with the board, hold office for terms not exceeding three years, their terms being staggered, and with these directors eligible for one reappointment.**

8. **The president of the institute be appointed by the Governor-in-Council to hold office for a term not exceeding five years but eligible for reappointment.**

9. **The departmental deputy minister and the president of the institute be *ex officio* directors.**

10. **The president be the chief executive officer of the institute and, under the direction of the board, have complete responsibility for the supervision and direction of the work and staff of the institute.**

11. **The president be responsible to the board for the exercise of duties and functions of that office.**

12. **The president be appointed by the Governor-in-Council and the chief science adviser to the parent department and in that capacity serve as a member of the executive management committee of the department.**

These recommendations are designed to ensure that the S&T institutes have the necessary organizational form to provide independent advice to the minister, to establish a clear management structure, to hold the institute's management to account for its performance, and to link the department and institute in terms of their senior management structures and personnel.

6.4.4 Management Systems

It is recommended that:

13. **The board have the authority to make by-laws respecting the conduct and management of the affairs of the institute, including the exercise of its powers.**

14. **The board be designated a separate employer and, other than the president of the institute, have the authority to appoint such scientific, technical and other officers as are nominated by the president, and fix the terms and conditions of their appointment.**

15. **The board have the authority to keep books of account and records in relation thereto and to establish and maintain its financial and management and control, information systems and management practices.**

16. **The board have the responsibility to ensure that its books, records, systems and practices are kept and maintained in ways that provide assurance that: its assets are safeguarded and controlled; its transactions are in accordance with its by-laws; financial, personnel and physical resources are managed efficiently and economically; and the operations of the institute are carried out effectively.**

17. **The board have the authority and responsibility to adopt a policy on technology transfer and, on the basis of such a policy and regulations pursuant thereto, to own and patent its intellectual property, to enter into licensing arrangements and set fees for them, and to provide scientists and engineers who develop such intellectual property with a share of the revenues derived from them.**

18. **The board cause internal audits to be conducted as required.**

19. **The board cause financial statements to be prepared annually.**

These recommendations are designed to ensure that each institute has the necessary authority to manage its personnel, financial and physical resources, as well as its intellectual property, in accordance with the best management practices of leading R&D organizations. These recommendations should not be interpreted as meaning that each institute must undertake independently the development of all its administrative policies, including human resources policies. There is no reason to attempt to reinvent the wheel; on the contrary, consultations with leading organizations should allow the development of a common but distinct framework and a set of administrative policies that would correspond to the needs of all institutes. However, this framework should provide sufficient flexibility to the board and senior management of each institute. Moreover the Committee envisages that the employees of the institute would continue to participate in all the usual benefits available to public servants.

From a government-wide perspective, with creation of these institutes, each headed by a senior S&T manager with the authority and flexibility required to pursue quality S&T, the federal government will have created a new dynamic for the effective rationalization and revitalization of its S&T investment. For the first time, this unique group of senior S&T managers will constitute a cadre of S&T advisers capable of ensuring collectively that this investment is put to the best possible use. The Committee expects such a forum to arise naturally and believes that the government stands to gain much more if it is left to operate informally, with no attempt to regulate and co-ordinate it from the centre.

6.4.5 Quality Evaluation

It is recommended that:

20. **The board be required to obtain a quality evaluation of the institute's S&T activities to be conducted at least every three years.**

21. **For at least the first three years, the institute be required to contract with one of the granting councils to administer the quality evaluation and that the composition of each panel of assessors for the quality evaluation be determined jointly by the council and the institute in question, with each having a veto over nominations by the other.**

22. A pool of 100 peer reviewers be elected every three years by and from the scientific, engineering, and R&D management personnel of all S&T institutes; that 25 percent of each quality evaluation panel be composed of persons selected from the pool; and that no person be included on a panel evaluating an establishment in which he or she is employed.

23. Quality evaluations employ internationally recognized methodologies and standards of S&T evaluation as applicable to the S&T disciplines in question, including on-site peer review and bibliometric analysis. Peer review panels should include representatives from the international scientific community.

24. Quality evaluations, when completed, be reported to the board and to a national panel for quality evaluation.

25. A national panel for quality evaluation be established and appointed by the Governor-in-Council to monitor and assess quality evaluations in respect of the methodologies, standards and personnel employed therein and to report their assessments to the boards of institutes so evaluated and to the Comptroller General.

These recommendations are designed to ensure that the most rigorous standards of quality evaluation are applied to the activities of the S&T institutes.

6.4.6 Accountability

It is recommended that:

26. The board report to the departmental minister on the performance, quality and management of the institute.

27. The president report to the board on matters relating to the management and quality of the institute.

28. The board submit an annual report to the minister who shall submit this report to Parliament.

29. Dual auditors be appointed for each institute: the Auditor General and a private auditing firm, preferably one with experience in auditing technology-based organizations.

These recommendations are designed to ensure clear lines of accountability between the institute's president and the board and among the board, the minister and Parliament.

6.4.7 Contractual Funding

It is recommended that:

30. S&T institutes be provided, by way of contracts with their parent departments and the operating units thereof, subject to annual departmental appropriations, (a) a facilities contract reimbursing only the costs for the maintenance of their plants, equipment and facilities to cover a five-year plan; (b) operating revenues by way of negotiated annual or multi-year contracts for specified undertakings required by departmental programs.

31. An institute research fund, in the amount of 10 percent of the preceding year's operating revenues obtained from departments and agencies of the Government of Canada, be paid annually by Treasury Board to each institute to conduct unspecified basic and exploratory R&D activities at the discretion of the president and the board, including co-operative research projects with universities and industry.

32. The institutes have the authority to obtain additional revenues by way of contracts with non-government clients, but not to exceed a certain percentage of annual operating revenues as determined by their respective departmental ministers. Contracts with non-government clients should include a 10 percent charge for the institute research fund.

These recommendations are designed to ensure that each S&T institute is well connected to its departments and to departmental programs by virtue of the contractual relationships between the parent department and its operating units on one hand and the institute on the other, with the former as clients and the latter as contractor. The recommendations thus establish that S&T institutes are revenue-dependent upon departments for their base budgets and all or the largest portion of their operating budgets, providing a measure of support for basic R&D as well as the authority to obtain additional funding via contracts with other clients.

6.4.8 Implementation

Finally, it is recommended that:

33. The Prime Minister appoint a special adviser to consult with departments and central authorities on the preparation of the necessary documents for decision purposes and regulations proposals and on the application of the new organizational design to the departments and S&T institutes in question. This special adviser should be appointed from outside the public service but should be knowledgeable about and experienced in the subject matter.

34. During the implementation period, considerable and consistent efforts be made to inform scientists, engineers and technicians of the objectives and direction pursued and to solicit their input and provide them with an opportunity to participate in the process.

35. Contingency liabilities incurred as a result of changes made pursuant to these recommendations, or decisions by government in response to them, be the responsibility of the relevant departments at the outset. Following these initial changes, the institutes would assume all such responsibility.

36. Provision be made for the personnel transferred to S&T institutes as a result of these recommendations to have during the first two years following their transfer the right to return to the employ of a department and continue their departmental public servant status on the condition that such a position be available.

37. The federal government adopt an explicit personnel policy designed to actively promote the movement of scientists and engineers into program management responsibilities in operating departments and central agencies.

38. In conjunction with the establishment of the institutes, the government should re-emphasize with the departmental managers the need to pursue vigorously the contracting-out policy. With respect to the institutes themselves, the emphasis should be on pursuing joint programs and projects with universities and industry. The board of directors should develop within the first three years after the establishment of an institute a proper, full cost system of accounting including the cost of the capital employed.

39. The government, in due course, enact the proposed legislative changes in order to finalize and give full effect to the establishment of the institutes.

40. The Prime Minister, in his role as Chairman of NABST, establish an awards program to recognize outstanding scientific achievements of individuals as well as groups of scientists and engineers within the institutes and other agencies of government.

With this new organizational design in place, the Government of Canada will have established, with no increase in the level of public expenditures or staffing, a network of eight major S&T institutes, in addition to NRC. It is expected that the more-focused, tighter organizational structure and the new management regime will more than offset the cost of implementation of the changes recommended.

This proposal builds on the scientific values that are strongly held in the department S&T establishments and harnesses them in a manner that will considerably reduce the mission drift that occurs under the present organizational set-up. It ensures that the focus will be placed on the management and quality of these S&T activities, which in turn will increase the value for money, including technology transfer, yielded by this substantial investment. And it gives an organizational structure that can effect intelligent choices, and that is considerably more robust than the present structure in periods of restraint.

The Committee's proposals are those that stand the best chance of converting the nation's enormous expenditure on S&T into a powerful asset, one that can be put to work in every region of the country to renew the tradition of excellence and pride in accomplishment that once characterized government science, and can do so again.

APPENDIX A

THE MANDATE OF THE COMMITTEE ON FEDERAL SCIENCE AND TECHNOLOGY EXPENDITURES

i) Review the federal government direct involvement in the conduct of S&T activities and assess its effectiveness taking into account the Canadian R&D system that exists in each sector of activity, the competitiveness of each sector in relevant international markets or forums, government established objectives and priorities and the quality of personnel, facilities and R&D results.

ii) Advise the federal government on strategic directions of its direct involvement and participation in Canadian S&T activities as well as the best means to achieve its objectives.

iii) Given the multifaceted functions of the Canadian government in our society and the heterogeneity of industry structures, the Committee will not undertake a global review but will adopt a sectorial (or departmental) approach.

iv) Submit a final report on three sectors.

APPENDIX B

MEMBERS OF THE INTERNATIONAL PEER REVIEW COMMITTEES

Site Team for the Bureau of Drug Research

Dr. Ronald T. Coutts, Chairman
Faculty of Pharmacy and Pharmaceutical Sciences
University of Alberta

Dr. John R. Bend
Department of Pharmacology and Toxicology
University of Western Ontario

Dr. Patrick Du Souich
Department of Pharmacology
University of Montreal

Dr. James D. MacNeil
Chemical Residue Analysis Section
Animal Pathology Laboratory, Saskatoon

Dr. Philip O'Neil
Regulated Drugs
Laboratory of the Government Chemist
Middlesex, United Kingdom

Dr. Jerome P. Skelly
Centre for Drug Evaluation and Research
Food and Drug Administration
Rockville, Maryland

Dr. Peter G. Wells
College of Pharmacy
University of Toronto

<u>MRC Representative</u>
Dr. James D. Wood
Department of Biochemistry
University of Saskatchewan

Composition of the MRC Site Team for the Bureau of Chemical Hazards, Environmental and Occupational Toxicology Division, Health and Welfare Canada

Dr. G.L. Plaa, Chairman
Department of Pharmacology
University of Montreal

Dr. J.A. Heddle
Biology Department
York University

Dr. J.T. MacGregor
Toxicology Consulting Services Inc.
Danville, California

Dr. M. Prior
Toxicology Branch
Animal Sciences Division
Alberta Environmental Centre

Dr. C.C. Travis
Office of Risk Analysis
Health and Safety Research Division
Oak Ridge National Laboratory
Oak Ridge, Tennessee

Dr. M.D. Waters
Genetic Toxicology Division
U.S. Environmental Protection Agency
North Carolina

MRC Representative
Dr. James D. Wood
Department of Biochemistry
University of Saskatchewan

Composition of the Site Team for the Institute for Sedimentary and Petroleum Geology; Energy, Mines and Resources Canada

Dr. F.A. Campbell, Chairman
Department of Geology and Geophysics
University of Calgary

Dr. B. Bally
Department of Geosciences
Rice University
Houston, Texas

Mr. C.J. Bruce
Calgary Research Centre
Shell Canada

Dr. G. Claypool
Mobil Research and Development Corporation
Dallas, Texas

Dr. A.G. Fischer
Department of Geology
University of Southern California

Dr. A. Grantz
U.S. Geological Survey
Menlo Park, California

Dr. C. Sallé
Institut Français du Pétrole
Cedex, France

Dr. R. Weimer
Department of Geology and Geological Engineering
Colorado School of Mines

Dr. Alan C. Frosst
Consultant
c/o McMaster University

Observer
Ms. Catherine Armour
Natural Sciences and Engineering
Research Council of Canada

Composition of the Site Team for the Mineral Sciences Laboratories, CANMET, Energy, Mines and Resources Canada

Dr. Gerry Hatch, Chairman
Hatch & Associates Ltd.
Toronto, Ontario

Dr. Jagdish (Jay) C. Agarwal
Technology Assessment
Charles River Associates Inc.
Boston, Massachusetts

Dr. Gordon Bacon
Bacon Donaldson & Associates Ltd.
Vancouver, British Columbia

Dr. Malcolm Bell
INCO Ltd.
Toronto, Ontario

Mr. André Bisaillon
Laboratoire de Béton Ltée.
Montréal, Quebec

Dr. James Finch
Department of Mining and Metallurgical Engineering
McGill University

Dr. David R. Forshey
Research
Bureau of Mines
Washington, D.C.

Dr. Terry P. McNulty
T.P. McNulty & Associates Inc.
Evergreen, Colorado

Dr. Arpad E. Torma
The Sullivan Centre for In-situ Research
Department of Metallurgical and Materials Engineering
New Mexico Institution of Mining and Technology

Dr. Olli Tudvinen
Department of Microbiology
Ohio State University

Dr. Alan C. Frosst
Consultant
c/o McMaster University

Observer
Ms. Catherine Armour
Natural Sciences and Engineering
Research Council of Canada

Composition of the Site Team for the Communications Devices and Components Research Branch, Communications Canada

Dr. J.K. Pulfer, Chairman
Secretary General and Comptroller
National Research Council

Dr. A. Aitken
Canadian Semiconductor Design Association
Kanata, Ontario

Dr. D. Anderson
Device Physics Group
Royal Signals and Radar Establishment
Worcestershire, United Kingdom

Dr. J.J. Coleman
Department of Electrical and Computer Engineering
University of Illinois

Dr. R.J. McIntyre
Research and Development
RCA Inc., Electro Optics
Vaudreuil, Quebec

Dr. J.G. Simmons
Department of Engineering Physics
McMaster University

Dr. G. Hyde
Comsat Laboratories
Clarksburg, Maryland

Dr. P.J. Dyne
Natural Sciences and Engineering
Research Council of Canada

Observer
Dr. Danielle Ménard
Natural Sciences and Engineering
Research Council of Canada

Composition of Site Team for the Communications Technologies Research Branch, Communications Canada

Prof. Gilles Delisle, Chairman
Département de génie électrique
Université Laval

Prof. Vijay Bhargava
Department of Electrical Engineering
University of Victoria

Prof. Lotfollah Shafai
Department of Electrical Engineering
University of Manitoba

Dr. William Ward
Satellite Operations
Satellite Communications Technology Group
Lincoln Laboratory
Lexington, Massachusetts

Prof. Tudor Jones
Department of Physics
The University
Leicester, United Kingdom

Dr. Joachim Hagenauer
Deutsche Forschungsanstalt fur Luftund Raumfahrt (DLR)
Institut fur Nachrichtantechnik
Federal Republic of Germany

Dr. Peter J. Dyne
Natural Sciences and Engineering
Research Council of Canada

Observer
Dr. David Astles
Natural Sciences and Engineering
Research Council of Canada

APPENDIX C

THE PEOPLE CONSULTED

North America

Canada

Dr. A. A. Bruneau
President
Newfoundland Light and Power Co. Ltd.
St. John's

Dr. D.A. Chisholm
Former Chairman
Bell Northern Research
Mississauga

Mr. Alex Curran
Former President
Telecommunications Research Institute of Ontario
Oakville

Dr. Bob Garvin
Vice-President
Cangene
Mississauga

Dr. Eric James
President
Cangene
Mississauga

Dr. G.M. MacNabb
President
Precarn Associates Inc.
Toronto

Mr. Donald Mills
Director of Research
Ontario Hydro
Toronto

Mr. Robert Pfeffer
Vice-President, Fibre Systems Group
Bell Northern Research
Ottawa

Mr. Roger Purdie
Vice-President, Research
Esso Petroleum Canada
Toronto

Mr. John Vose
Connaught Laboratories
Toronto

United States

Mr. Eric Bloch
President
National Science Foundation
Washington, D.C.

Dr. Wayne Burwell
Vice-President, Research and Development
United Technologies
Hartford, Connecticut

Mr. Alan B. Claflin
Director – Laboratory Management Division
U.S. Department of Energy
Office of Energy Research
Washington, D.C.

Mr. Bruce R. Doe
Assistant Director For Research
United States Geological Survey
Reston, Virginia

Mr. Robert A. Frosch
Vice-President
General Motors Research Laboratories
Warren, Michigan

Dr. Ralph Gomory
President
Sloan Foundation
New York, New York
and former Senior V.P. Research, IBM

Dr. Jim Jackson
Associate Director
Los Alamos National Laboratory
Los Alamos, New Mexico

Dr. Lester C. Krogh
Senior Vice-President
3M General Offices
St. Paul, Minnesota

Dr. Edwin P. Przybylowicz
Senior Vice-President
Eastman Kodak Company
Rochester, New York

Dr. James J. O'Malley
General Manager
Polymer Technology
Exxon Chemical Company
New Jersey, Connecticut

Dr. Rowland Schmidt
President
Renssalear Polytechnical Institute
Troy, New York
and former Senior V.P. Research, General Electric

Dr. Albert R.C. Westwood
Vice-President, Research and Development
Martin Marietta Corporation
Baltimore, Maryland

Dr. F. Karl Willenbrock
Assistant Director
National Science Foundation
Washington, D.C.

Europe

Federal Republic of Germany

Dr. Deffner
Wissenschaftlich _ Technische Abteilung
Gesellschaft Fur Strahlen und Umweltforschung mbH (GSF)
Bonn

Dr. Eitner
Director General, Research and Technology Strategy
Federal Ministry of Research and Technology
Bonn

Dr. Krull
Science and Research Commission
German Research Society (DFG)
Bonn

Dr. Valentin von Massow
Head of Science Policy and Promotion Section
Federal Ministry of Science and Education (BMBW)
Bonn

Dr. Peter Reichel
Diplom-Volkswirt
Fraunhofer-Gesellschaft
Bonn

Mr. Shuster
German Research Society (DFG)
Bonn

Dr. Barbara Spielmann
Referentin fur die Zusammenarbeit
Mit der Volksrepublik China
Max-Planck-Gesellschaft
Bonn

Ms. Ulrike Kasemi
International Relations Division
Max-Planck-Gesellschaft
Bonn

France

M. le Professeur Robert Chabbal
Directeur de la Science, de la Technologie et de l'Industrie
OECD
Paris

M. le Professeur Claude Fréjacques
Président
Centre national de recherche scientifique
Paris

M. Walteufel
Minister's Office
Ministry of Research
Paris

United Kingdom

John Barber
Senior Economic Adviser
Department of Trade and Industry
London

Dr. Ron Coleman
Chief Engineer and Scientist
Department of Trade and Industry
London

Dr. Ken Poulter
NPL National Measurement System Policy Unit
Department of Trade and Industry
London

Dr. J.S.S. Reay
Director
Warren Spring Laboratory
London

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