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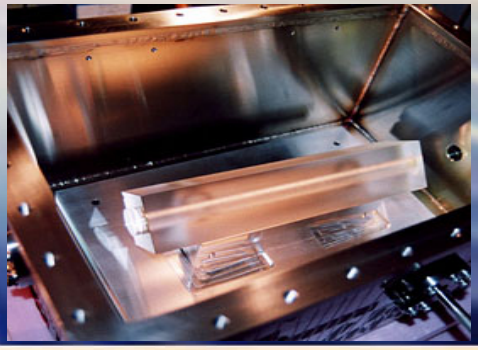
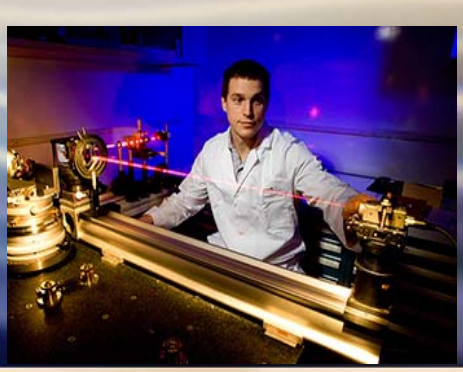
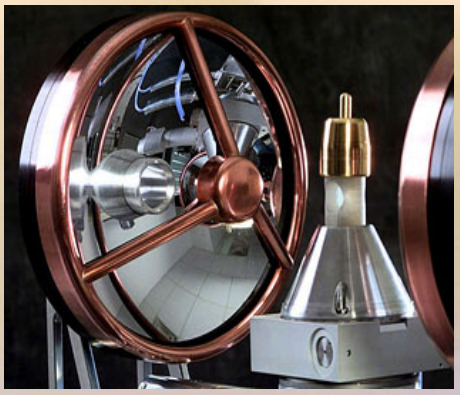
FINAL REPORT

Evaluation of the NRC Institute for National Measurement Standards (NRC-INMS)

July 9, 2009







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Canada

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Approved by:
The National Research Council President, July 24th 2009

Additional information and a summary of this report are available on the National Research Council's website at:
http://www.nrc-cnrc.gc.ca/aboutUs/evaluation_e.html

EXECUTIVE SUMMARY

The *National Research Council Act* mandates NRC with "the investigation and determination of standards and methods of measurement" for Canada. This responsibility is vested in the Institute for National Measurement Standards (NRC-INMS), Canada's national metrology institute (NMI). NRC-INMS not only performs R&D that translates science into applicable technologies, but also provides a wide variety of calibration and measurement services that underpin the accuracy of millions of measurements annually in public and private sector testing laboratories.

An evaluation of NRC-INMS was undertaken in fiscal year 2007-2008. The primary reasons for conducting an evaluation of the NRC-INMS program were:

- The last evaluation of NRC-INMS took place in 1999. Because the landscape of metrology in Canada has changed significantly since that time and to follow good management practices, NRC-INMS was selected as the site of an institute-wide evaluation study.
- The development of a plan for metrology at NRC was underway when the evaluation work began. The evaluation of NRC-INMS was designed to provide information on the impacts and outcomes of the Institute's activities and feed into this broader planning process.

The evaluation was conducted in accordance with NRC's approved evaluation plan for 2007-08 and Treasury Board Secretariat (TBS) policies. The evaluation covers the period 2002-03 to 2007-08 inclusive and addresses issues related to relevance, success, cost-effectiveness and effectiveness of design and delivery.

The key methods used in the study included a review of documents; a review of administrative and performance data; key informant interviews; an international comparison study; case studies; a cost-benefit analysis of the socio-economic impacts of metrology in Canada; and a review of key comparisons conducted by the Institute.

Overview of the NRC Institute for National Measurement Standards

The mission of NRC-INMS is to provide "the technical and infrastructural foundation for the national measurement system and thereby strengthen Canada's innovation and competitiveness, support international trade, and advance social well being of Canadians". Its vision is "to be acknowledged globally as a model national metrology institute, and to be recognized nationally as an essential component of Canada's innovation system".

In order to fulfill its mission and achieve its objectives, NRC-INMS has three on-going programs:

- **Development of measurement standards**: This program focuses on research activities to develop new methods for the realization of base SI units (International System of units) and the measurement of fundamental constants, the maintenance and improvement of existing measurement capabilities and of laboratory infrastructure, and the production of certified reference materials.
- **Dissemination of measurement science**: This program uses NRC-INMS expertise to benefit Canadian industry through technology transfer activities, collaborative projects with public and private partners, calibration and measurement services, and sales and distribution of Certified Reference Materials (CRMs). Training and outreach activities include metrology workshops and courses and conference organization and participation.

- **Support for Canada's National Measurement System**: NRC-INMS represents Canada on a number of international metrology and standards organizations (e.g., Bureau international des poids et mesures (BIPM) and the Inter-American Metrology System, known as SIM) and participates in the consultative committees of Comité international des poids et mesures (CIPM) Mutual Recognition Arrangement (MRA). In addition, NRC-INMS maintains the quality management system required by the CIPM MRA (ISO 17025) and coordinates with Canadian partners in the national measurement system (Measurement Canada, Standards Council of Canada, and others).

General Conclusion

The evaluation study points to the international reputation of NRC-INMS as a clear indication of the quality of its research, dissemination efforts, and support for Canada's measurement system. The Institute is highly regarded, both within the Canadian metrology community and by international organizations as a leader in its field. Specific recommendations made below focus on certain administrative processes and suggest possible areas for improvement.

Summary of Findings and Recommendations – Relevance

The extent to which the activities and mandate of NRC-INMS remain relevant to current priorities and respond to the needs of Canadians was examined based on a review of internal and external documents and through interviews with NRC-INMS representatives as well as key clients and stakeholders. The role of the Canadian federal government in measurement science appears to be supported by studies focusing on the development and maintenance of standards as a public good. In addition, the evaluation findings point to the fact that NRC-INMS continues to meet the needs of government and industry through its mandated activities in terms of enabling innovation, protecting trade interests and enhancing the quality of life of Canadians. Given the underpinning nature of metrology, the activities of NRC-INMS can be linked to the scientific priorities of the federal government. Ongoing work in new areas, such as nanotechnology and biotechnology, demonstrate the institute's commitment to making a contribution to new economic and societal issues that will increase in importance in future years.

> **Recommendation 1:** NRC-INMS should continue to focus its efforts in developing new and emerging areas of metrology based on strategic thrusts identified by the government. However, investment of human and financial resources in these areas must be carefully weighed against its mandated responsibilities as Canada's National Metrology Institute.
>
> **Management Response and Proposed Actions: Accepted.** The NRC-INMS Business Plan articulates the strategic importance of investments in human resources and in infrastructure (capital). HR investments address succession needs for critical, on-going activities, while providing flexibility to address research needs for emerging technologies. In fiscal year of 2008-09 NRC-INMS hired 5 new research associates and invested $2.6M in equipment and infrastructure. Strategic investment in these areas will continue in the upcoming years of the 3 year Business Plan.

Summary of Findings and Recommendations – Success

<u>Development of Measurement Standards</u>

As the main research program of NRC-INMS, the development of measurement standards can be considered a key driver in the achievement of the scientific, economic, and social impacts of the Institute. By leading research and development activities that aim to ensure that current and future Canadian needs for primary measurement standards and methods are met, NRC-INMS contributes to many areas

of Canadian economic and social activity, with a direct link to the potential enhancement of the quality of life of Canadians.

Although the broader scientific, economic, and social impacts of the research conducted by NRC-INMS could be identified through various means in the evaluation study, the more concrete contributions of the Institute were difficult to pinpoint due to a lack of information on the outcomes associated with specific projects. The performance measures collected by the Institute provided important and useful information regarding scientific and administrative outputs stemming from the activities conducted by Institute staff. However, details regarding the immediate and intermediate outcomes were difficult to obtain from interviews and other research methods and thus limit the analysis presented here.

Dissemination of Measurement Science

The dissemination of measurement science involves an outward-looking set of activities aimed at sharing research findings with the scientific community and industrial partners. Overall, clients of NRC-INMS are highly satisfied with the calibration and measurement services received from Institute staff, although some administrative issues remain to be resolved. These stem mostly from recent changes in the fee-for-service structure and should be relatively simple to improve in the future. The findings of the evaluation also point to an issue related to a perception of the metrology community in regards to the CLAS program. In brief, this issue speaks to how the CLAS certification is perceived outside of Canada given a certain lack of awareness of international agreements such as the International Laboratory Accreditation Cooperation (ILAC). There were also misconceptions associated with the role of CLAS laboratories in providing routine measurements to clients and the role of NRC-INMS in providing similar services. Finally, the evaluation was only able to identify anecdotal findings related to the course offerings of the Institute. A more systematic approach to performance measurement should be implemented in order to obtain management information on course selection, delivery, and outcomes.

> **Recommendation 2:** The administrative mechanisms associated with the changes in the fee-for-service structure and the contracting process should be streamlined in order to reduce the burden on the partners and clients of the Institute. Further, a tracking system for education and outreach activities should be developed to enable the Institute to capitalize on participant interests and needs and to maximize the potential benefits of these activities.
>
> **Management Response and Proposed Actions: Accepted.** A variety of communications means will be employed to reach partners and clients in a timely manner regarding fee increases. This will include customized mailings for key clients before changes take effect; meetings with partners; enhanced, interactive internet communications and contract administration.
>
> **Recommendation 3:** The misconceptions held by some members of the measurement and calibration community regarding the duplication in the calibration services provided by NRC-INMS and the CLAS laboratories should be corrected through the communication of internal analyses conducted by NRC-INMS and other means deemed appropriate by the Institute. NRC-INMS should also pursue its ongoing efforts in rectifying issues associated with the international recognition of the CLAS certification by requesting specific information from CLAS laboratories on inappropriate requests and by continuing to participate in international fora on this question.
>
> **Management Response and Proposed Actions: Accepted.** A communications strategy that addresses the misconceptions will be developed. INMS will market the information content and

search functionality of the CLAS database to provide up-to-date information to potential clients regarding the capabilities of CLAS laboratories. CLAS, through its outreach program, will proactively solicit information regarding the acceptance of CLAS certification internationally and represent the CLAS laboratories' interest in international bodies such as ILAC, IAAC, APLAC, NUPIC, etc.

Support to Canada's National Measurement System

The role of NRC-INMS in supporting Canada's national metrology system takes different forms, from its participation in international key comparisons to ensuring that Canada's interests are well represented through committee work. Overall, the findings of the evaluation point to the fact that the Institute carries out this mandate well and is touted as a leader within the international metrology community.

Summary of Findings and Recommendations – Cost-Effectiveness

Collaborative Activities

The collaborative activities undertaken by NRC-INMS with other NMIs are highly regarded in the international metrology community, where the Institute has clearly established its role as that of leader. Opinions within Canada were more mixed, however. It appears as though the definition of collaborative research is different for NRC-INMS than it is for its partners, who typically perceive the Institute as a service provider rather than collaborator. In addition, very little data were available on the concrete outcomes of these partnerships, especially from collaborators.

Greater linkages within Canada in coming years may result in the identification of problems or issues of relevance to OGDs and Canadian industry. Working with partners on resolving these issues through measurement science will raise the profile of the Institute while protecting Canadian trade interests, enabling innovation, and enhancing Canadians' quality of life.

Recommendation 4: The Institute has made some headway in recent years in terms of actively pursuing research collaborations and of increasing the awareness of potential collaborators who support/have a stake in the Institute's mandate. These activities should be encouraged further, not only at the executive level, but for all scientific staff of the Institute. This should include a greater level of involvement from the Business Development Office in the framing of research agreements in order to encourage the development of collaborative activities.

Management Response and Proposed Actions: Accepted. Our natural partners for collaborations related to new primary standards for physical measurements and certified reference materials for chemical measurement are other national metrology institutes (NMIs). Many of our scientific staff are engaged in such collaborations. Many of them are not formalized in collaborative R&D agreements, but they are a vital means by which we execute our mandate. Collaborations with other NRC institutes are also increasing, in particular in the area of nanotechnology. Selection criteria for new research projects will favour collaborative projects. The Business Development Office (BDO) will actively participate in the development and negotiation of research agreements. The BDO will also ensure that agreements are worded in accordance with NRC's directives, appropriate levels of signatures are obtained and the administration of each project reflects the principles of good project management.

Resource Allocation

NRC-INMS derives its resources from continuing funding as well as from revenue obtained for services rendered. When compared to other NMIs, the evaluation showed that it is achieving important results on the international stage with fewer resources than most of the major players.

However, the current allocation levels will become increasingly insufficient in future years due to the increase in activities. The Institute may experience difficulty in maintaining its core activities as Canada's NMI given the need to conduct R&D in emerging areas of science.

Summary of Findings – Effectiveness of Design and Delivery

Recent changes in the administrative structure of the Institute are generally perceived as positive and have had some impact on increasing collegiality within NRC-INMS. The fact that the Institute is divided into four separate buildings is a cause for concern among some researchers, although it does not currently seem to have a significant impact on intra-Institute communications and management. Other notable administrative achievements include the implementation of the quality management system (QMS) and the standardization of the fee structure. A comparison to other organizational structures used in different NMIs revealed that the current model is most appropriate for NRC-INMS given its size, resources, and mandate.

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1.0 INTRODUCTION

An evaluation of the National Research Council Institute for National Measurement Standards (NRC-INMS) was undertaken in fiscal year 2007-08. The evaluation was conducted in accordance with NRC's approved evaluation plan for 2007-08 and Treasury Board Secretariat (TBS) policies. The evaluation covers the period 2002-03 to 2007-08 inclusive.

The primary reasons for conducting an evaluation of the NRC-INMS program were:

- The last evaluation of NRC-INMS took place in 1999. Because the landscape of metrology has changed significantly since that time and to follow good management practices, NRC-INMS was selected as the site of an institute-wide evaluation for fiscal year 2007-08.
- The development of a plan for metrology at NRC was underway when the evaluation work began. The evaluation of NRC-INMS was designed to provide information on the impacts and outcomes of the Institute's activities and feed into this broader planning process.

The purpose of this document is to present the findings, conclusions and recommendations stemming from this evaluation. Section 2 of this report provides a description of NRC-INMS and a brief overview of the Canadian National Metrology System. Sections 3 to 6 include discussions of the evaluation findings and conclusions organized around key evaluation issues (relevance, success, cost-effectiveness, and design and delivery). Section 7 presents the general conclusions and recommendations resulting from the evaluation. The evaluation questions related to the issues as well as a description of the methodology used can be found in Appendix A.

Multiple lines of evidence were used to address the evaluation issues identified in the report. The specific methods used in the study include:

- An internal and external document review;
- An administrative and performance data review;
- Key informant interviews (internal and external);
- Case studies;
- An international comparison study; and
- A socio-economic impact analysis.

Each of these methods has its strengths and limitations. These are addressed more fully in Appendix A. In general, difficulty in obtaining reliable quantitative data on the social and economic impacts of the activities of the Institute was a main limitation and had to be mitigated by using creative approaches to data collection and analysis, such as the use of proxies (e.g., patents) in the socio-economic impact analysis. These mitigating strategies proved to be of help in identifying the key findings of the evaluation and in developing evidence-based recommendations for the future.

2.0 PROFILE OF THE INSTITUTE FOR NATIONAL MEASUREMENT STANDARDS

The *National Research Council Act* mandates NRC with "the investigation and determination of standards and methods of measurement" for Canada. This responsibility is vested in the NRC Institute for National Measurement Standards (NRC-INMS), Canada's national metrology institute (NMI). NRC-INMS not only performs R&D that translates science into applicable technologies, but also provides a wide variety of calibration and measurement services that underpin the accuracy of millions of measurements annually in public and private sector testing laboratories[1].

2.1 Mission, Vision, Objectives and Activities

The mission of NRC-INMS is to provide "the technical and infrastructural foundation for the national measurement system and thereby strengthen Canada's innovation and competitiveness, support international trade, and advance social well being of Canadians". Its vision is "to be acknowledged globally as a model national metrology institute, and to be recognized nationally as an essential component of Canada's innovation system". [2]

The Strategic Plan developed by NRC-INMS in 2002 outlines six objectives for the Institute. These objectives are directly linked to the core functions of NRC-INMS in its role as Canada's NMI:

- Lead research and development activities to ensure that current and future Canadian needs for primary measurement standards and methods are met.
- Lead research and development activities to ensure that current and future Canadian needs for measurement and calibration capabilities are met.
- Ensure adequate dissemination of calibration and measurement services, including improved and expanded Calibration Laboratory Assessment Service (CLAS) services, and calibration services arising from research and development.
- Maintain a recognized leadership role in supporting Canada's national and global trade interests through strengthened participation in international metrology activities intended to enhance trade opportunities.
- Provide leadership for the creation of a national coordinating body for the Canadian national measurement system.
- Lead the dissemination of measurement-related knowledge and technologies to all sectors of Canada through adequate outreach and training.

[1] NRC-INMS Internal Document, Fall 2007
[2] NRC-INMS Internal Document, June 2002

In order to fulfill its mission and achieve its objectives, NRC-INMS has three on-going programs[3]:

- **Development of measurement standards**: This program focuses on research activities to develop new methods for the realization of base SI units (International System of units) and the measurement of fundamental constants, the maintenance and improvement of existing measurement capabilities and of laboratory infrastructure, and the production of certified reference materials.
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- **Support for Canada's National Measurement System**: NRC-INMS represents Canada on a number of international metrology and standards organizations (e.g., Bureau international des poids et des measures (BIPM) and the Inter-American Metrology System (SIM) and participates in the consultative committees of Comité international des poids et mesures (CIPM) Mutual Recognition Arrangement (MRA). In addition, NRC-INMS maintains the quality management system required by the CIPM MRA (ISO 17025) and coordinates with Canadian partners in the national measurement system (Measurement Canada, Standards Council of Canada, and others).

These three programs are operationalized through a number of research activities and services, which include electrical power measurements, electrical standards, thermometry, acoustical standards, dimensional metrology, mass standards, time standards and optical frequency, chemical metrology, photometry and radiometry, ionizing radiation standards, the Calibration Laboratory Assessment Service (CLAS), and other calibration and measurement services.[4]

The research conducted by the Institute focuses on future needs of industrial clients in the automotive, aerospace, marine, forestry and electrical industries, although by focusing more generally on improving measurement standards, the research work of the institute can benefit all sectors of the economy. Calibration of reference standards for other government departments is the foundation for legal metrology in Canada.

2.2 The Role of INMS in the National Metrology System and Global Metrology Framework[5]

Figure 1 displays the operating environment of NRC-INMS. The hub of national and international measurement systems is the Système International or SI, a rationalized, coherent system of units used throughout the world for trade and commerce, and especially for science.

As the primary centre of reference for the accuracy, validity, and traceability to the SI, NRC-INMS anchors Canada's National Measurement System (CNMS) and provides a fundamental technical infrastructure that supports Canadian industry and the Canadian public. NRC's partners in this system are: Measurement Canada, Standards Council of Canada, National Defense Quality Engineering Laboratories, and CLAS laboratories.

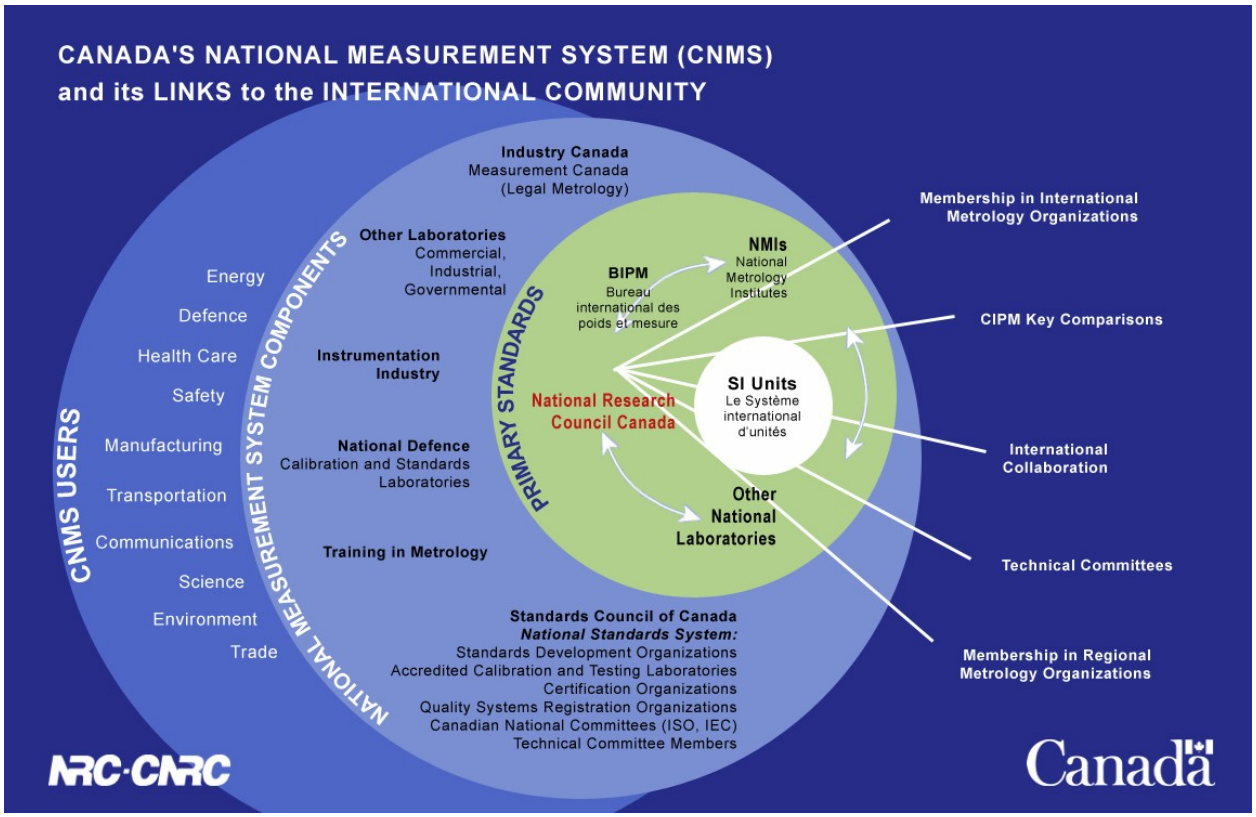
To achieve international recognition of Canada's measurement standards, NRC-INMS participates in the international community of metrology organizations. This is considered to be an important component of the Institute's activities, given that 30-40% of the Canadian GDP depends on exports.

[3] NRC-INMS Internal Document, November 2007.
[4] *NRC-INMS*. http://inms-ienm.nrc-cnrc.gc.ca/main_e.html (accessed December 4, 2007).
[5] The information in this section was provided by NRC-INMS communications personnel for the purposes of the evaluation study.

Regionally, NRC-INMS participates in the Inter-American Metrology System (SIM) along with all 34 member nations of the Organization of American States, and the North American Calibration Cooperation (NACC) supporting NAFTA.

In 2007, the Institute was engaged in 63 networks of comparisons of measurement standards at worldwide and regional levels. Staff participated in the activities of 163 international and 46 national metrology-related committees. As a result of this work, Canada's measurement standards continue to be recognized by all of Canada's major trading partners.

Figure 1: Canadian National Measurement System



2.3 Program Resources

This section briefly describes the resources available to support NRC-INMS' achievement of its objectives.

2.3.1 Financial Resources

Resources are provided to NRC-INMS under the legislative authority of the National Research Council Act. NRC-INMS' total expenditures from 2003-2004 to 2006-2007 are shown in Table 1.

Table 1: NRC-INMS Total Expenditures and Income from 2003-2004 to 2006-2007 (in thousands of dollars)[6]

Fiscal Year / (000)	2003-2004	2004-2005	2005-2006	2006-2007
Total Salaries and Benefits	10,934	10,464	9,533	10,156
Total Operating Expenditures	2,860	2,729	2,004	2,737
Total Capital Expenditures	1,659	1,903	2,589	2,711
Grants & Contributions	-	560	622	617
TOTAL INVESTMENTS	**15,453**	**15,656**	**14,748**	**16,221**
Income (Revenues, Collaborations, OGDs)	2,912	3,298	4,184	3,639[7]

2.3.2 Human Resources

NRC-INMS currently employs 120 full-time equivalents (FTEs)[8]. The specific breakdown of human resources per year is provided in Table 2.

Table 2: NRC-INMS Human Resource Distribution from 2003-2004 to 2006-2007

Fiscal Year	2003-2004	2004-2005	2005-2006	2006-2007
Total full-time staff (FTEs)	118	114	108	102[9]
Total term staff (FTEs)	13	11	7	10

[6] Figures provided by NRC-INMS, Spring 2008.
[7] Institute income varies over the years for a number of reasons, including variability in royalties, fees-for-service, etc.
[8] NRC-INMS Internal Document, November 2007.
[9] The decrease in staff observed in the reporting period is due to a reorganization of the Institute, in which two groups were shifted to the Institute for Microstructural Sciences, as well as the creation of spin-off companies.

3.0 FINDINGS – RELEVANCE

The relevance of government intervention in metrology was examined through two evaluation questions. The first focused on the needs of government and industry in terms of measurement science and metrology, while the second dealt more specifically with the extent to which the objectives and planned activities of NRC-INMS are linked to government and industry priorities in the area of metrology.

3.1 Needs of Government and Industry in the Area of Measurement Science

- *Finding: Metrology underpins the Canadian economy and quality of life by providing the measurement infrastructure to manufacture products, engage in international trade, and ensure the health and safety of Canadians.*

Metrology responds to three needs of Canadian government and industry: it is a protector of trade interests by providing confidence in the measurement system and by contributing to the reduction of Technical Barriers to Trade (TBTs); it enables innovation by ensuring reproducible manufacturing processes; and it contributes to the quality of life of Canadians through its environmental and health and safety applications.[10] In other words, metrology underpins the activities undertaken to meet these needs by providing the measurement infrastructure and confidence in the measurements required to conduct trade, develop and manufacture new products, and develop new means of ensuring the well-being of Canadians.

3.1.1 Protection of Trade Interests

Expectations towards traceability to the International System of Units (SI) can be found in almost all aspects of international trade.[11] Metrology has historically been a protector of Canadian trade interests and is likely to increase in importance over the next few decades, as new products in the areas of agriculture, health, and the environment are introduced by Canadian firms to foreign markets[12].

The Standing Committee on Foreign Affairs and International Trade recently identified Technical Barriers to Trade (TBTs) as one of the five major market access issues affecting Canadian exporting firms.[13] TBTs are "technical regulations and voluntary standards that set out specific characteristics of a product, such as its size, shape, design, functions and performance, or the way a product is labeled or packaged before it enters the marketplace".[14] Although these regulations and standards are developed to protect human health and safety, they are sometimes used to restrict market access and the ability of businesses to export their products. Metrology shows potential in combating TBTs, because of its focus on internationally-standardized measurement.[15]

[10] NRC-INMS Internal Document, November 2007.
[11] *Evolving Needs for Metrology in Trade, Industry and Society and the Role of the BIPM*. Bureau international des Poids et Mesures, Paris, 2003.
[12] External Interviews, Other Government Departments (n=5).
[13] Industry Canada, http://www.innovationstrategy.gc.ca/gol/innovation/site.nsf/en/in02337.html (accessed December 13, 2007).
[14] Organization for Economic Co-operation and Development, http://www.oecd.org/document/62/0,3343,en_2649_36251006_1842622_1_1_1_1,00.html (accessed February 12, 2009).
[15] Ekos Research Associates, *International Comparison Study*: 1.

3.1.2 Enabling Innovation

Canada's capacity to innovate and compete in the knowledge-based global economy depends heavily on its strengths and capabilities in science and technology.[16] To remain competitive, Canada must ensure that its industrial sector is able to keep up with an accelerating pace of technology development. By meeting ever-increasing requirements for accuracy and precision in standards and measurements needed for manufacturing and other segments of the economy, metrology provides the basis on which innovation can take place. In addition to this, measurement techniques affect other stages of economic activity, such as marketing and quality assurance, which are deemed essential to commercial success.[17]

An example of the way in which metrology enables innovation was provided by focus group respondents participating in the socio-economic impact study conducted within the context of this evaluation. The participants stated that to reduce trade barriers associated with new market entry, manufacturers sometimes increase the level of precision of their measurements to 10-20 microns. In these instances, manufacturers need to combine their knowledge of the market with advanced measurement science and often rely on organizations such as NRC-INMS to achieve their goals.

3.1.3 Enhancing Quality of Life

The potential of metrology in enhancing the quality of life of Canadians can range from increased precision and accuracy in manufacturing and laboratory testing to the development of new methods for cancer treatment.[18] These types of activities support the most basic purpose of government intervention and adequately reflect governmental and industrial needs across a wide range of scientific disciplines. For example, on the regulatory front, NRC-INMS works in areas such as environmental protection and remediation, where measurement is required for policymaking.[19] The importance of the link between metrology and regulation is recognized in Europe, where the European Commission has supported projects aimed at improving these connections. Some of the issues identified include: regulations that have requirements that cannot be easily tested or measured, ambiguity around methods of measurements that can lead to a large range of values, a lack of certified reference materials, and specified limits that reach or exceed current methods of detection. One frequently cited example is the European regulations on genetically modified organisms, where it has been recognized that methods of detection do not exist that could meet labeling requirements.[20]

Other areas in which NRC-INMS is increasingly playing a role include the regulation of natural health products (NHP), nanometrology, and the nuclear protection industry.[21] In many of these areas, the importation of products to Canada will require stringent testing methods to ensure these meet national regulatory and safety standards. This will play a role in protecting Canadians from harmful substances in food as well as other types of imported products.

3.2 Role of Government in Metrology

- *Finding: The role of government in measurement science has been well-established internationally as well as within Canada, where metrology can be linked to the four roles of government in science and technology.*

[16] Committee on the State of Science and Technology in Canada, Council of Canadian Academies, *The State of Science and Technology in Canada*, September 2006.
[17] J. Klein, "Measuring the Economic Benefit from R&D: The Case of the National Measurement System." *Science in Parliament*, 53 no. 2 (1996).
[18] T. J. Quinn and J. Kovalevsky, "Measurement and Society." *C. R. Physique*, 5, 2004.
[19] Internal interviews, INMS Executive (n=5).
[20] *Metrology for Improved Measurements in International Regulation and Trade: the Regmet and Metrotrade Projects.* Proceedings of the XVII IMEKO World Congress, June 22-27, 2003, Dubrovnik, Croatia.
[21] Internal interviews, INMS Staff (n=8) and External interviews, hospitals and research centres (n=4).

In addition to highlighting the ways in which metrology meets the needs of government and industry in the area of measurement science, the issue of relevance also requires an in-depth examination of the role of government in delivering metrology. At a high level, the roles of government related to science and technology are as follows:

- support for decision-making, policy development and regulations;
- development and management of standards;
- support for public health, safety, environmental and/or defence needs; and
- enabling economic and social development.[22]

The importance of government-based measurement science is apparent for all four of these roles. As described in the previous section, metrology and its associated standards are used in resolving trade disputes and in ensuring measurement equivalence between countries, which clearly delineates the importance of government intervention in this area. [23] Government involvement in measurement science is further supported by its role in the development of strategic economic advantages for the nation, which can lean on metrology and standards-based regulations, as well as the long-term social benefits which are accrued from reduced consumer risk due to the establishment of common standards and compatibilities and by requiring minimum quality levels.[24]

In fact, metrology is considered the responsibility of government, at least to some extent, in all major industrialized countries.[25] The "development and management of standards" is a governmental role for a number of reasons. First, metrology has a pervasive, underpinning character that is not generally well known and often taken for granted.[26] Measurement techniques affect all stages of economic activity from R&D through production and then to marketing. They provide the structure upon which industrial economies rely for measurement quality assurance. This is essential for commerce, science, engineering, consumer and environmental protection and public health and safety.[27] Although it supports the development and use of new techniques and products, its nature as a public good does not make it a viable option for the private sector since measurement standards must be equally available to all companies. Market failure has been identified elsewhere as being the core reason behind governmental intervention in metrology.[28] Governments are better suited to undertake these activities than the private sector, given the broad national objectives involved and the difficulty for private firms to recoup investments.[29]

The role of government in metrology is also clear from the creation of international organizations directed by committees of member country representatives. In 1875, a diplomatic conference on the metre took place in Paris where 17 governments signed a treaty called "the Metre Convention". The signatories created and financed a permanent scientific institute known as the Bureau International des Poids et Mesures (BIPM). The Conférence Générale des Poids et Measures (CGPM) discusses and examines the work performance by NMIs and the BIPM and makes recommendations on new fundamental metrological

[22] Council of Science and Technology Advisors, Industry Canada, *BEST: Building Excellence in Science and Technology*, March 2000.
[23] J. Birch, *Legislating for Metrology in Developing Countries, OIML Seminar: Why and How to Legislate on Metrology* (speech), October 2007.
[24] Klein, "Measuring the Economic Benefit from R&D: The Case of the National Measurement System."
[25] Ekos Research Associates, *International Comparison Study*.
[26] Klein, "Measuring the Economic Benefit from R&D: The Case of the National Measurement System."
[27] *Ibid*.
[28] Department of Trade and Industry National Measurement System Policy Unit (UK), *Review of the Rationale for and Economic Benefit of the UK National Measurement System*, November 1999.
[29] *Ibid*.

determinations and all major issues of concern to the BIPM. As of April 2008, 51 states were members of the Metre Convention and a further 27 states were associates of the CGPM. A number of Joint Committees of the BIPM and other international organizations have been created for particular tasks.[30]

In October 1999, the Mutual Recognition Arrangement (MRA) for national measurement standards and for calibration and measurement certificates issued by National Metrology Institutes was signed. Currently, NMIs of 45 signatory states of the Metre Convention, two international organizations and 26 Associates of CGPM have signed the CIPM MRA. The objectives of the MRA are to provide governments and other parties with a foundation for wider agreements related to international trade, commerce and regulatory affairs. This is achieved through establishing the degree of equivalence of national measurement standards maintained by the participating NMIs, and by involving mutual recognition in the calibration and measurement certificates issued by participating NMIs. Currently, around 90 per cent of world trade in merchandise exports is between CIPM MRA participant nations.[31]

3.3 Alignment with Government and Industrial Priorities

- *Finding: By nature, metrology supports the economic activity undertaken in all developed nations. As Canada's National Metrology Institute, NRC-INMS plays a lead role in representing the interests of Canada internationally in matters of measurement science.*
- *Finding: NRC-INMS also focuses its activities on new and emerging areas of priority for the federal government and industry, such as nanotechnology and biotechnology, in order to anticipate future needs for measurement standards.*

3.3.1 Alignment with Government Priorities

The *National Research Council Act* mandates NRC with "the investigation and determination of standards and methods of measurement" for Canada. As Canada's National Measurement Institute, NRC-INMS plays the role of Canadian representative in matters related to measurement science. No other Canadian organization has the ability or mandate to fulfill this role. Because measurement science underpins economic activity at all levels, it can be said that overall, metrology aligns with governmental priorities. For example, the activities of NRC-INMS align with the government's priorities in the area of international trade through the work conducted to demonstrate traceability to the SI, and through the selection of specific areas of focus relevant to Canadian industry.

Beyond the consideration of metrology as a basic infrastructure underpinning the scientific priorities of any developed economy, it is also possible to identify specific instances in which projects undertaken at NRC-INMS over the last five years reflect an alignment with current government priorities. For instance, the federal Science and Technology Strategy, titled *Mobilizing Science and Technology to Canada's Advantage*, focuses on trade through its Entrepreneurial Advantage section, as well as health and wellness, mentioned in its Knowledge Advantage section:

- Entrepreneurial Advantage: The S&T Strategy discusses the work being done by Health Canada on the standardization and regulation of Natural Health Products. It also discusses the ongoing collaboration of the Canadian government with the US and Mexico targeting the reduction of TBTs by reducing redundant testing and certification requirements in the S&T area.

[30] Bureau International des Poids et Mesures, *Committee Structure of the Metre Convention*, http://www.bipm.org/en/committees. (accessed July 8, 2008).
[31] Euromet, *Metrology in Short*, 2nd Edition, http://www.euromet.org/docs/pubs/docs/Metrology_in_short_2nd_edition_may_2004.pdf. (accessed February 21, 2008).

- Knowledge Advantage: The Strategy identifies four Canadian S&T strengths and opportunities where Canada can leverage its research strengths to achieve economic and social advantages. These are: health and related life sciences and technologies, natural resources and energy, the environment, and the information and communications technology sector. [32] The alignment between these areas and the activities of NRC-INMS are identified in sections 4.0 through 6.0 of this report.

Health and wellness is a particular area in which NRC-INMS has increased its activity during the past five years. The Chemical Metrology group has been particularly involved in this area, focusing on the development of Certified Reference Materials for Natural Health Products (NHP). In addition to its long-standing calibration and research work in support of cancer clinics, the Ionizing Radiation Standards group has also been involved in health-related initiatives through a two-year Memorandum of Understanding (MOU) with the Canadian Nuclear Safety Commission.[33]

3.3.2 Alignment with Industrial Priorities

With respect to current industry priorities, the Institute has used the work of the United States National Institute of Standards and Technology (NIST), which recently conducted a large-scale assessment of the U.S. measurement system to identify measurement barriers to innovation. In 2008, NRC-INMS tasked a consulting firm with reviewing this report and identifying those areas of metrology thought to be most important to Canada. These eight areas are: Building and Construction, Chemicals, IT Software, Nanotechnology, Semiconductor Electronics, Agriculture and Food Processing, Telecommunications, and Transportation/Aerospace.[34] NRC-INMS contributes to the development of measurement science in many of these areas through its operational research groups as well as through collaborative initiatives.

3.3.3 Shifting Priorities: New Areas of Metrology Research

New priorities based on technology development have been identified in recent years by the government and industrial sectors.[35] Two of these, nanotechnology and biotechnology, are noteworthy in terms of the recent activities of NRC-INMS. Although these areas are outside the more traditional areas of metrology, "it is now recognized that metrology provides a fundamental basis not only for the physical sciences and engineering, but also for chemistry, the biological sciences and related areas such as the environment, medicine, agriculture, and food".[36]

3.3.3.1 Nanotechnology

Increasing miniaturization in physical and biological/chemical sciences has led to the evolution of technology across a number of different sectors. As a result of this major change in scientific approaches and their industrial applications, new quantitative and traceable measurements are required which pose a significant challenge to traditional metrology areas, and which may require entirely new methods of measurement.[37] Basic methods and techniques for measurement and characterization on the nanoscale are required not only to support commercialization of the innovations resulting from nanoscience discoveries, but also to avoid adverse effects on human health and the environment.[38]

[32] Public Works and Government Services Canada, *Mobilizing Science and Technology to Canada's Advantage*, 2007.
[33] NRC-INMS Internal Document, May 2007.
[34] D.R. Senik and Associates Inc. & Doyletech Corporation, *An Analysis of the U.S. National Institute of Standards and Technology (NIST) Publication 1048: To Determine How it Might Impact the National Research Council's (NRC) Strategy for Measurement Standards,* December 2007.
[35] *PWGSC, Mobilizing Science and Technology to Canada's Advantage*.
[36] T.J. Quinn, *Open Letter Concerning the Growing Importance of Metrology and the Benefits of Participation in the Metre Convention, Notably the CIPM MRA*. August 2003.
[37] Bureau international des Poids et Mesures, *Evolving Needs for Metrology in Trade, Industry and Society and the Role of the BIPM*, 2003.
[38] NRC-INMS Internal Document, January 2008.

NRC-INMS has expanded its activities to reflect this new priority in the past five years. Within NRC, the Institute is one of the partners of the NRC Nanotechnology Project. Externally, NRC-INMS is active in a network of 22 federal departments and agencies mandated to study various issues related to nanotechnology and is leading a peer-reviewed project on nanometrology as part of this involvement.[39]

3.3.3.2 Biotechnology

Another area of growth has been biotechnology, more specifically as it pertains to agriculture and food products. Standardizing measurements of genetically modified (GM) food products has reached a level of urgency, as large export markets depend upon public acceptance of the results of measurements of the presence or absence of GM products in food:[40] "Reliable and comparable metrology in food testing is becoming increasingly important not only because of the high volume and the large export value of food products in international trade but also because of the questions raised by society with respect to matters of food safety, including the content of GMOs".[41] One example of the work of NRC-INMS in this area is the development of mixtures of flour samples prepared from GM and conventional canola seeds.[42]

3.3.3.3 Supply and Demand for Future Metrology

The International Comparison Study conducted as part of this evaluation featured an examination of anticipated supply and future demand for metrology over the next five to ten years. The results of interviews conducted with international metrology experts are helpful in illustrating future worldwide demand for metrology expertise. Almost all respondents made reference to biological metrology, chemical metrology, and nanotechnology. These areas are linked to the development of new products, the genetic modification of organisms, a renewed interest in environmental solutions to industrial problems, and the development of new technologies. These areas are consistent with the emerging areas of science identified above for Canada, and to which NRC-INMS is contributing.

One aspect to the planning recently undertaken by other countries in terms of metrology is the forward-looking investments that are planned to meet these new demands. Representatives of individual NMIs consulted in the International Comparison Study were asked to describe these investments. Although most representatives were unable to provide specific figures for the planned investments, some included considerable funding for new laboratories and equipment (Brazil and Mexico), strengthening of international relations on issues related to metrology (Denmark), focusing on specific areas of metrology (Finland, Japan, United States), and involvement in international metrology research collaborations (France).

3.4 Summary of Findings and Recommendations

The extent to which the activities and mandate of NRC-INMS remain relevant to current priorities and respond to the needs of Canadians was examined based on the review of internal and external documents and through interviews with NRC-INMS representatives as well as key clients and stakeholders. The role of the Canadian federal government in measurement science appears to be supported by studies focusing on the development and maintenance of standards as a public good. In addition to this, the evaluation findings point to the fact that NRC-INMS continues to meet the needs of government and industry through its mandated activities in terms of enabling innovation, protecting trade interests and enhancing the quality of life of Canadians. Given the underpinning nature of metrology, the activities of NRC-INMS can be clearly linked to the scientific priorities of the federal government. Ongoing

[39] NRC-INMS Internal Document, May 2007.
[40] *Bureau international des Poids et Mesures, Evolving Needs for Metrology in Trade, Industry and Society and the Role of the BIPM.*
[41] Ibid.
[42] External interviews, OGDs (n=5).

work in new areas, such as nanotechnology and biotechnology, reflect an interest in contributing to new economic and societal issues.

> **Recommendation 1:** NRC-INMS should continue to focus its efforts in developing new and emerging areas of metrology based on strategic thrusts identified by the government. However, investment of human and financial resources in these areas must be carefully weighed against its mandated responsibilities as Canada's National Metrology Institute.

4.0 FINDINGS – SUCCESS

The extent to which NRC-INMS is meeting its stated objectives as well as its intended broader socio-economic impacts was examined through multiple lines of evidence. The findings identified through the application of these methods are summarized according to the three main programs of NRC-INMS: development of measurement standards, dissemination of measurement science, and support of Canada's national metrology system.

4.1 Development of Measurement Standards

- *Finding: By leading research and development activities that aim to ensure that current and future Canadian needs for primary measurement standards and methods are met, NRC-INMS contributes to many areas of Canadian economic and social activity, with a direct link to the potential enhancement of the quality of life of Canadians.*

The Development of Measurement Standards program comprises:

- research to develop new methods for the realization of base SI units and measurement of fundamental constants;
- maintenance and improvement of existing measurement capabilities;
- maintenance and improvement of laboratory infrastructure; and
- production of Certified Reference Materials.[43]

The strategic goal of this program, as described in internal documents, is to "lead research and development activities to ensure that current and future Canadian needs for primary measurement standards and methods are met".[44]

4.1.1 Scientific Outputs

The main research outputs produced as a result of the work of NRC-INMS on the development of measurement standards, taken from NRC-INMS performance measurement tables, are summarized in Table 3. The high relative number of technical reports compared to the other types of publications presented in the table reflects not only the scientific work done towards the development of measurement standards, but also the work done in terms of individual calibration services provided to NRC-INMS clients. These activities are closely linked to those described in the following section, which focus on the dissemination of measurement science.

Table 3: Scientific Outputs by Year

	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007
Total Papers in Refereed Journals	51	74	41	59	60
Total Papers in Refereed Conference Proceedings	58	34	36	21	34
Total Technical Reports	1,029	718	798	663	459[45]

[43] NRC-INMS Internal Document, January 2008.
[44] NRC-INMS Internal Document, June 2002.
[45] The decreasing number of technical reports produced by the Institute over the reporting period may be due to the increase of certified CLAS laboratories over the same five-year span (CLAS laboratories grew from 23 to 40 during this period).

	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007
Total Papers in Refereed Journals	51	74	41	59	60
Other Types of Publications[46]	3	18	1	25	1

In addition to research reports, patent and license information can also be considered in the estimation of research outputs. Table 4 presents the patent and license outputs of NRC-INMS by year.

Table 4: Patent and License Outputs by Year

	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007
Total number of active patents in portfolio	50	52	42	54	52
Number of patent applications	3	10	3	4	1
Total number of patents issued	6	6	8	10	0
Total number of patents issued in Canada	4	2	0	0	0
Total number of patents issued in the United States	2	4	8	0	0
Number of licenses issued	3	2	6	6	0
Total licensing revenue from IP	$455,734	$156,091	$418,432	$954,517[47]	$220,225

Some of the lower numbers observed in Tables 3 and 4 starting in 2004-2005 are likely due to the implementation of the quality management system required by the CIPM MRA. The development and implementation phases were labour-intensive for the Institute's scientists, who in some instances spent 30-40% of their time on this project. Another associated explanation for the lower scientific productivity may be found in the development of a management system for the conduct of international key comparisons.

Although performance measures are important and useful in determining the level of scientific activity of a research institution, an assessment of its scientific, economic and social impacts provides a more complete picture of the overall performance of the institution. The impacts of NRC-INMS in these spheres are described in the next three sections.

4.1.2 Scientific Impacts

The main impacts generated through the scientific activities of NRC-INMS focus on reducing the uncertainties associated with specific measurement standards. For example, the Institute was successful recently in reducing the uncertainty in the development of the measurement standard for length. Ongoing efforts continue to reduce the uncertainty of the second and the metre through the development of a new atomic clock, as well as the ultraviolet part of the spectrum in photometry.[48] The long-term benefits of these efforts include ensuring the maintenance of Canada's position on the international metrology stage (through the maintenance of traceability to the SI) and its associated impacts on innovation, trade, health and safety. The scientific impacts generated through the activities of the Institute extend further to its economic and social impacts.

Some of the impacts of NRC-INMS were identified through the International Comparison Study conducted as part of the evaluation. The findings of this study reveal that NRC-INMS has had a significant impact in certain key areas of metrology, such as ionizing radiation, electrical metrology, and spectrometry. In the words of one metrology expert, "The NRC-INMS Ionizing Radiation department has played a lead role in

[46] These may include books, book chapters, non-peer reviewed conference proceedings, etc.
[47] This number includes equity from the sale of shares held by the Institute at that time.
[48] Internal Interviews, INMS Executives and Staff (n=13).

advancing the standards for ionizing radiation". Another participant echoed these comments by stating that: "…in the area of ionizing radiation, I would not have seen very much happening on the international stage without their involvement". Finally, another metrology expert, commenting on the work done by the Electrical Standards group, felt that "…in electrical metrology – they are certainly one of the leaders internationally".[49]

Metrology experts participating in the International Comparison Study were also asked to comment on the overall quality of the measurement science of NRC-INMS. Responses reveal that NRC-INMS is generally perceived as a strong metrology institute. While respondents noted that it is a small institute with limited access to resources, many share the view that NRC-INMS "chooses carefully what it wants to do and does it well". Many also noted that the quality of NRC-INMS measurement science and several of its other activities are on par with those of top metrology institutes around the world.

4.1.3 Economic Impacts

Because metrology is considered part of Canada's economic infrastructure, an analysis of the economic impact of metrology in Canada was undertaken as part of the evaluation.[50] The analysis looked at a number of different issues in its attempt to quantify and qualify the socio-economic impacts of metrology in Canada. The analysis included a review of past studies conducted in this area and also looked at patent data and international trade figures. The findings of the analysis are summarized in this section.

4.1.3.1 Impact on Gross Domestic Product (GDP)

The approach used in this component of the analysis was based in part on work conducted in the United Kingdom, where an economic impact model was developed using patent data. This model was adapted and refined further to produce an estimate of the impact of metrology on the Canadian GDP for a select number of industries (i.e., those assumed to make use of measurement standards). The results obtained through this analysis were positive, with the total expected net present value (NPV) of the impact on Canadian GDP estimated at $1,434.2 million, falling within the range of $393.3 to $2,811 million (estimated impact within a 95 percent level of confidence for both lower and upper bounds).

Perhaps more interestingly, the same study documented the impact of Canadian metrology on the Canadian GDP (for 2007) based on the metrology patents owned by NRC. These impacts were expressed as benefit cost (or leverage) ratios that ranged from a lower bound of 2.9 to an upper bound of 48.6, with a mid-point of 17.5. Again, these findings point to a significant economic impact: "In essence, increased precision in metrology facilitates private sector innovation that enhances GDP and with it choice and quality of life".[51]

The analysis conducted on the impacts of metrology patents, although useful in identifying the bounds of potential economic impact, cannot be considered the only measure of NRC-INMS impacts. The use of patents as a proxy measure poses an important limitation to the analysis, as it is not the sole source of technology and knowledge transfer to Canadian and international companies. Also, "metrology" patents could only be inferred from other descriptions of the patents; this means that some patents based on measurement science may have been missed in the analysis.

[49] Ekos Research Associates, *International Comparison Study*: 15.
[50] Detailed information about the analysis and its results are found in the Acton White Associates (2008) Working Paper for the Evaluation of NRC-INMS.
[51] Acton White Associates Inc., *Development of a Cost-Benefit Analysis of the Socioeconomic Impacts of Metrology in Canada,* 2008: 17.

4.1.3.2 Impact on Trade

The socio-economic analysis also considered the impact of metrology on international trade. As discussed elsewhere in this report, metrology has the potential to reduce or to mitigate Technical Barriers to Trade and to enable exporting countries to demonstrate the specific qualities of their products without retesting in the importing country through the CIPM MRA. One estimate of this cost is approximately $10,000 Cdn per test for each type of product traded among the 43 signatories.[52]

In 2006, Canada exported $389.5B in merchandise and a further $57.8B in services, which accounts for 3.2 percent of the world's merchandise exports and 2.1 percent of services exports. At that time, the 43 signatory members of the CIPM MRA accounted for 83.5 percent of the world's $12.1 trillion in merchandise exports and 86.3 percent of the $2.8 trillion in global exports of services. The 23 associate members of the MRA accounted for less than a third of the rest of the world's exports and non-signatories accounted for "others" shown in the following table. On the other side of the equation, as shown in the table below, MRA signatories accounted for over 85 percent of the world's imports with associates attracting half of the remaining trade in merchandise imports and a considerably smaller share of the remaining imports of services.

Table 5: Percentages of World Trade by MRA Signatories in 2006[53]

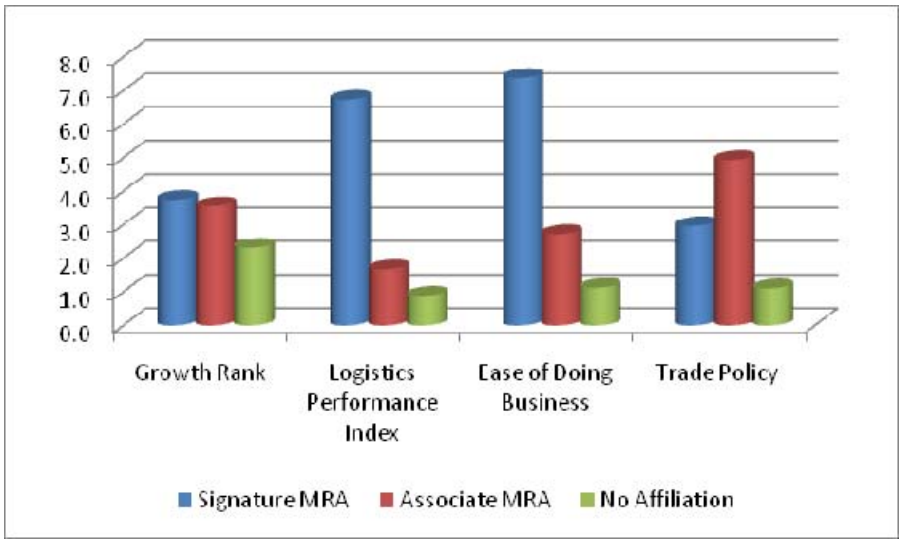
Status	Merchandise Exports	Services Exports	Merchandise Imports	Services Imports
MRA Signatories	83.5	86.3	85.5	85.2
MRA Associates	5.0	5.3	7.0	3.5
Others	11.5	8.4	7.5	11.2

Figure 2, on the following page, presents relative indicators of economic performance among MRA members and associates and unaffiliated countries. The indexes are the average rank of all countries included in the data divided by the country's rank. Thus ranking the 167 countries from 1 to 167 for which there are data on growth yields an average of 83.5, so that the index for the fastest growth country, China, is 83.5/1 or simply 83.5. The faster growth countries then obtain the higher scores as do those ranked highest in logistics and the other indicators of ease of doing trade and business.

By all these measures, full MRA members outrank associates and unaffiliated countries, except for the higher ranking of associate members with respect to trade policy. While relative rankings among countries for logistics performance and ease of doing business clearly encompass more that simply metrology standards and testing, the establishment and measurement of such standards facilitate these two dimensions and may serve as a precondition.

[52] Ibid: 24.
[53] Ibid.

Figure 2: Growth and Trade Facilitation[54]



4.1.3.3 Impact on Health Care Costs

Another area in which the economic impact of metrology can be derived is the cost of health-related laboratory testing. The impact of calibration error in medical decision-making was studied by NIST in 2004. This study specifically looked at the sources of systematic error in the analytical phase of testing for hypercalcemia, a medical condition caused by various disorders, including hyperthyroidism and cancer. Detection of hypercalcemia typically leads to follow-up testing through x-rays, thyroid imaging, and other laboratory tests.

The study conducted by NIST examined the results of over 89,000 serum calcium tests administered at the Mayo Clinic in 1998-1999. The study found, at a general level, that the number of follow-up procedures, and hence health care costs, was directly related to the initial calcium test values. Based on interviews with laboratory managers and equipment manufacturers, it was determined that calibration error has the potential to lead to biases of 0.1 to 0.5 mg/dL in up to 15 percent of calcium tests.

The cost impact associated with an analytical bias (measurement error) of 0.1 mg/dL was estimated to range between $8 to $31 per patient. The cost associated with a bias of 0.5 mg/dL was estimated to range from $34 to $89 per patient. Given that approximately 3.55 million patients per year receive screening serum calcium test, the potential economic impacts range from $60 million to $199 million per year for analytic biases of 0.1 and 0.5 mg/dL, respectively.

Although the example presented here does not specifically speak to the direct impact of NRC-INMS, it does show the economic consequences of measurement or calibration error, which is directly linked to the availability of measurement standards and traceability to the SI.

4.1.4 Social Impacts

Although the scientific and economic impacts attributable to the activities of NRC-INMS are, in and of themselves, interesting and highly relevant, the less tangible social impacts of this work were also examined in the study. A clear example of the potential social impact of NRC-INMS was illustrated in one

[54] Ibid: 25.

of the case studies conducted for the purposes of the evaluation. One of these cases focused on a project involving the licensing of software source code from NRC-INMS by an international radiotherapy company. The objective of this project was to develop an improved technique for simulating radiation treatment using electron beam therapy in order to improve the treatment of cancer patients. Electrons and photons do not travel in a straight line; simulations are required to estimate what path they will follow. This then determines where the radiation will be applied so as to reach the desired cells. The simulation method used at the time the project was first conceptualized produced simulation results quickly, but was not as accurate as other simulation methods based on the Monte Carlo approach. Monte Carlo simulations, although accurate, took a long time to process, making them impractical in a clinical setting. The goal of the project was to find a way to run the simulations as accurately and in the same time frame as the methods in use.

The main result of this research project is the development of the source code licensed by the international firm. The software developed by the Institute can be used by desktop computers rather than a mainframe, thereby facilitating the generation of radiation treatment programs by medical physicists in clinical settings. Between 2003 and 2007, the company sold 333 copies of the software, including 12 licenses installed at 7 different sites in Canada. Interviewees stated that one of the main objectives of the project was to improve the quality of life of people with cancer, both within Canada and internationally, through more accurate radiation treatments that result in more damage to cancerous cells and less damage to surrounding, healthy cells. At this time, studies are underway to determine the impact of this new simulation technique on radiation treatment. Experts consulted as part of the case study felt that this software has made an improvement in the accuracy of radiotherapy treatments and, while it is only one part of a larger system that administers treatments, they felt that this has contributed to an overall improvement of cancer treatment.

4.1.5 Summary of Findings

As the main research program of NRC-INMS, the Development of Measurement Standards can be considered a key driver in the achievement of the scientific, economic, and social impacts of the Institute. By leading research and development activities that aim to ensure that current and future Canadian needs for primary measurement standards and methods are met, NRC-INMS contributes to many areas of Canadian economic and social activity, with a direct link to the potential enhancement of the quality of life of Canadians. In order to ensure that these contributions are properly identified and documented, NRC-INMS may consider ongoing outcomes monitoring.

Although the broader scientific, economic, and social impacts of the research conducted by NRC-INMS could be identified through various means in the evaluation, the more concrete contributions of the Institute were difficult to pinpoint due to a lack of information or difficulties in recalling the outcomes associated with specific projects. The performance measures collected by the Institute provided important and useful information regarding scientific and administrative outputs stemming from the activities conducted by Institute staff. However, details regarding the immediate and intermediate outcomes were difficult to obtain from interviews and other research methods and thus limit the analysis presented here. Other sources of information were used to estimate the impact of the Institute in various economic and social spheres.

4.2 Dissemination of Measurement Science Program

- *Finding: Clients of the Institute are generally satisfied with the services provided by NRC-INMS. Some misconceptions exist in the community with regards to the CLAS laboratories.*

This program is comprised of activities related to calibration and measurement services, certified reference material sales and distribution, the Calibration Laboratory Assessment Service (CLAS), as well as education, training and outreach activities.[55] These activities are connected to those described in the previous section: before the Institute is able to provide a new calibration service, it first needs to develop a measurement standard to which it can be linked. In other words, the calibration services offered to clients are based on research conducted by Institute scientists. Calibrations are the vehicle through which research findings are disseminated to the larger metrology community.

4.2.1 Calibration and Measurement Services and Certified Reference Materials

Calibration and measurement services are provided by the Institute on an "as-needed" basis. The strategic goal behind these services is to "ensure adequate dissemination of calibration and measurement services …, and calibration services arising from research and development".[56] This includes activities linked to the sale and distribution of certified reference materials (CRMs), since these represent an important vehicle for the dissemination of chemical standards. By its own accounts, NRC-INMS sells about 2 000 CRMs per year to approximately 300 clients.[57]

In addition to the more formal, paid calibration and measurement services, NRC-INMS researchers often provide advice free of charge to other scientists in their communities of practice.[58] The Institute is also responsible for providing reference levels for standards to CLAS laboratories.

Internal interview findings reveal that all NRC-INMS groups are involved in providing these services to the broader measurement and industrial community. Areas in which calibrations are often done for clients include laser frequency and laser systems, stopwatches, tachometer, and dosimetry devices.[59] For example, the chemical metrology group often works with the semi-conductor industry, earning about $3M per year of revenue for the Institute. In the area of electrical measurement, NRC-INMS scientists perform on-site calibrations around the world for power utilities that sell some of their power to other jurisdictions (e.g., Ontario Power Generation). One of the main outcomes of this activity is to provide accurate measurements used for electricity billing purposes.[60] A cost-benefit analysis conducted as part of the evaluation demonstrated the importance of accurate electricity and natural gas measurements in a discussion on consumer surplus. This study showed that measurement errors in these areas result in considerable loss in economic benefits.[61]

4.2.1.1 Client Satisfaction

Generally, clients are satisfied with the calibration and measurement services provided by the Institute. Many clients feel that NRC-INMS provides them with an essential service unavailable elsewhere in Canada. In addition, the calibration and measurement services provided by NRC-INMS give the clients' own customers increased confidence, and in the opinion of many respondents, this has a direct impact on their sales. However, some external interviewees raised concerns with delays in service delivery, the fact that NRC-INMS facilities are no longer available for special experiments conducted by clients, and errors made by Institute staff in their manipulation of samples. It should be noted that very few formal complaints were made by clients to the Institute, despite the implementation of the new Quality Management System. The Institute is also currently developing a tracking system to further improve client service. This new

[55] NRC-INMS Internal Document, January 2008.
[56] NRC-INMS Internal Document, June 2002.
[57] NRC-INMS Internal Document, November 2007.
[58] Internal Interviews, INMS Group Leaders (n=5).
[59] Internal Interviews, INMS Group Leaders (n=5).
[60] Internal Interviews, INMS Executives (n=5).
[61] Acton White Associates Inc., *Development of a Cost-Benefit Analysis of the Socioeconomic Impacts of Metrology in Canada,* 2008: 2.

system will enable the Institute to track and adjust its turnaround time estimates in an ongoing manner in order to better inform clients of the time required to conduct calibration and measurement work.

The implementation of the new fee-for-service structure (described in Section 7) was also perceived as problematic for most of the clients interviewed. Several interviewees stated that they had received no warning about the upcoming fee change, which resulted in a significant amount of work on their part to modify their company's purchase orders and other administrative processes to accommodate the new fees. Although most of the interviewees understood the reasons behind the fee change, they deplored the fact that they had not had sufficient time to prepare, and in some cases, research new options in terms of obtaining the same service elsewhere.

Another problematic issue for clients was the online contract generation process. In most cases, clients are required to complete a new contract request every time they plan on sending a standard to the Institute for calibration. For some, this means starting the process every month. The contracting process is seen by clients as burdensome, with repeated emails and phone calls from NRC-INMS administrative staff once they submit the online form. Because industrial clients measure success based on revenue and other business outcomes, any action on the part of NRC-INMS to reduce the administrative burden would result in time and cost savings. It should be noted, however, that these client perceptions may not be fully accurate: the Institute advised its clients of the fee changes several months before they were implemented, and high volume clients are routinely offered "bulk" contracting processes to reduce the administrative burden. Very few clients have taken advantage of this opportunity. Information provided by the Institute also points to the fact that in some cases, clients add contractual clauses to the standard form provided by NRC-INMS, which results in further delays since the Institute is bound by law to the clauses in its forms.

4.2.1.2 Impact on Clients

An illustration of the impact of NRC-INMS in enabling innovation through its dissemination efforts can be found in a case study conducted as part of the evaluation. This case focused on the development of a technology that provides a standard for electrical resistance. This technology was licensed from NRC-INMS by Measurement International Limited (MIL), a Canadian company based in Prescott, Ontario. The objective of the research project was to develop a Quantum Hall Resistance (QHR) primary standard with an acceptable level of uncertainty that would also be more economical and simpler to operate than the existing system.

This new addition to the firm's product line had an impact on its growth. At the time of the evaluation, MIL had sold 7 systems, which have generated approximately $2.2M in sales. This represents a 15% increase in annual sales since 2002 for the company. In the words of the President of MIL, "it represents a significant benefit for the company in terms of dollar revenue". The positive impact of the QHR system project on the position of the firm on the export market can also be demonstrated by the fact that NRC and MIL received the *Eastern Region Award of Merit for Excellence in Exporting* at the *Ontario Global Trader Awards* in 2002.

Socio-economic impacts related to the role of NRC-INMS as enabler of innovation are clearly demonstrated through the QHR technology case study: not only did the development of the system result in an increase in the licensee's sales, it had a direct impact on other NMIs and laboratories around the world (NMIs without the resources to develop their own QHR have purchased this model from MIL). The product developed through the research efforts of NRC-INMS solved a concrete problem experienced in the metrology community.

4.2.2 Calibration Assessment Laboratory Service

The CLAS program provides quality system and technical assessment services and certification of specific measurement capabilities of calibration laboratories in support of the Canadian National Measurement System. This program was developed and implemented by the Institute to allow a second tier of calibration laboratories to demonstrate their competence and gain national, regional and international recognition for specific measurement capabilities. The CLAS program also enables large companies to obtain the required certification to perform their own calibrations. The purpose of this certification process, delivered in conjunction with the Standards Council of Canada (who provides the accreditation), is to support and develop a network of laboratories and improve the channels by which INMS can disseminate traceable measurements. In the words of one respondent, it is an "enormous chunk of disseminating measurement science".[62] The number of accredited CLAS laboratories grew from 23 to 40 during the evaluation period.

One of the outcomes of implementing the CLAS program has been a reduction in the number of routine calibrations previously conducted by NRC-INMS. Although this was not a primary goal of the program, NRC-INMS has benefited by redeploying its resources to areas that cannot be adequately served by the accredited laboratories.

Within Canada, many of the clients interviewed as part of the evaluation perceive CLAS as providing them with a unique advantage in terms of their ability to use the certification to demonstrate the quality of their products and services. CLAS-certified laboratories also find that the NRC-INMS branding provides them with a competitive advantage beyond the efficiencies implemented as a result of the assessment process. For the most part, CLAS clients are highly satisfied with the services received and appreciate the linkages established between their laboratories and NRC-INMS experts. Many clients feel that the certification process has greatly contributed to the improvement of the service that they provide and has had an impact on the professional development of laboratory staff. [63]

4.2.2.1 Perceived Overlap of Services Provided by NRC-INMS and CLAS Laboratories

Some clients interviewed felt that there is a lack of clarity in terms of the types of calibration services offered by NRC-INMS, and that the Institute often performs calibrations that it has certified other laboratories to perform. Given the choice, the CLAS laboratories feel that their clients will bypass their services if they can obtain the same calibrations from NRC-INMS, which puts them at a financial disadvantage. This perception was the object of an internal review conducted by NRC-INMS staff in December 2008. The purpose of this review was to determine whether NRC-INMS laboratories were, in fact, competing for clients with CLAS laboratories. This work focused on a review of the documents posted on the NRC-INMS website and a study of the conditions that need to exist in order for NRC-INMS to compete with the CLAS laboratories. This included the identification of potential overlap in the ranges and uncertainties offered by NRC-INMS and those offered by CLAS laboratories.[64]

The review of documents undertaken as part of the analysis identified two key pieces of information that are presented to potential clients: one is the NRC-INMS webpage, which states that "*The National Research Council of Canada (NRC) does not wish to compete with any Canadian organization, public or private, whose income is derived from calibration contracts. Therefore, before making a calibration, NRC asks for a statement to the effect that the client is not prepared to have any organization other than NRC perform the work, together with the reasons for that decision*".[65] In addition to this, Section 2 of the Standard Services Agreement Form, through which clients contract NRC-INMS services, states: "The

[62] Internal Interviews, INMS Executives (n=5.)
[63] External Interviews, CLAS Laboratories (N=6).
[64] Internal document, NRC-INMS, December 2008.
[65] http://inms-ienm.nrc-cnrc.gc.ca/calserv/calibration_services_e.html

Customer chooses to work with NRC because of NRC's unique capabilities and does not expect NRC to perform work that would be in conflict with NRC's obligations to Canadian firms with respect to competitiveness…".[66] It appears, therefore, that potential clients are sufficiently informed as to the role of the Institute vis-à-vis other CLAS laboratories.

The second component of the analysis involved the identification of potential instances in which NRC-INMS is competing with CLAS laboratories. For the Institute to truly be in a competitive position with CLAS laboratories, the following three conditions have to be met:

- The range offered by the CLAS laboratory is sufficiently wide to cover the needs of Canadian industry;
- Calibrations within the same range and with similar uncertainties are offered by NRC-INMS;
- Those calibrations are offered by NRC-INMS as a similar or lower fee.

Three areas of potential overlap were identified by comparing the published ranges and uncertainties of CLAS laboratories with those of NRC-INMS. The possible cases in which this could occur were identified by the Institute and include Electrical Standards, Thermal and Mechanical Metrology, and Electrical Power. In all three cases, the analysis demonstrated that at least one of the three conditions was not met, and therefore, did not result in competition between NRC-INMS and the CLAS laboratories. Other factors, such as slower turnaround time due to volume and other research and international activities, contribute to the fact that NRC-INMS is usually not the best choice for routine calibrations available from other laboratories.

Although NRC-INMS has exercised due diligence in ensuring that there are no misconceptions about its role and that of the CLAS laboratories, the fact that some clients still prefer to obtain calibration services from NRC-INMS (and this, despite much higher fees) may indicate a lack of understanding in the metrology community. The Institute may want to improve its communications to the CLAS community about its role as well as that of the CLAS laboratories.

4.2.2.2 International Recognition of CLAS Certification

One of the issues raised by clients is that some international regulators do not recognize accreditation, such as the one provided by the SCC, as a means of approving calibration suppliers. This runs counter to the ILAC MRA signed by Canada and other countries and is considered to be unacceptable in the international calibration community. However, there is some evidence that this is occurring elsewhere in the world. For instance, the European Union is currently considering legislation whereby only one governmental accreditation organization would exist in each of the member countries. When international regulators or other clients demand a specific accreditation, CLAS laboratories feel as though they have to comply, regardless of the legality of the request. This typically results in increased expenses and efforts for the CLAS laboratory.[67] It should be noted that this issue was raised as a perception and does not necessarily reflect what is occurring in most CLAS laboratories. Cases in which these misconceptions exist should be addressed by the Institute whenever possible through increased communications with the CLAS laboratories and other international organizations.

4.2.2.3 Other Operational Issues

Another difficulty raised by CLAS-certified laboratories is the chronic understaffing of the NRC-INMS CLAS program. Although CLAS staff members offer an excellent service, time delays in terms of issuing certificates, measured in months, have resulted in additional costs and/or loss of business for certain laboratories.[68] Related to this is the perceived lack of "policing" of the certification in the metrology

[66] http://inms-ienm.nrc-cnrc.gc.ca/calserv/INMS_standardservices_e.doc
[67] External Interviews, CLAS Laboratories (N=6).
[68] External Interviews, CLAS Laboratories (N=6).

community. Some interviewees stated that they had seen false CLAS certification stickers on pieces of equipment owned by clients, and that this undermines the importance and relevance of the certification.[69] It should be noted here that no instances of this have been reported to CLAS, despite a rigorous system of client feedback processes tied to the implementation of the Quality Management System required by the CIPM MRA.

4.2.3 Education and Outreach

NRC-INMS undertakes education and outreach activities as part of its dissemination efforts.[70] The purpose of these in-house courses, which often include laboratory visits, are to create receptor capacity among NRC-INMS clients as well as a stronger technical base within the Canadian metrology community. These activities are important to the community, as there are currently few course offerings in metrology in universities. This is a small revenue-generating activity for the Institute, but it is undertaken as part of the Institute's role as Canada's NMI. The most popular course focuses on understanding uncertainty, but there are plans to increase the number of courses to cover issues related to traceability, internal capabilities, and international work. [71]

Scientists from the Institute are also regularly asked to give presentations at the North American Measurement Science Conference (NCSLI); their presentations and courses are highly sought-after and well-attended.[72]

Other outreach activities include the NRC Time Services, which disseminate Canada time in a variety of ways, such as dedicated phone lines (with approximately 500,000 calls annually), the network time protocol, and a shortwave radio service called CHU.[73]

Although it was possible to obtain some information about the education and outreach activities of NRC-INMS staff, no systematic data collection mechanism has been put in place to generate basic data on attendance, course topics, or to collect information about the participants' learning outcomes. This makes it difficult to assess the merit or impact of these activities and to make recommendations on these topics.

4.2.4 Summary of Findings and Recommendations

The dissemination of measurement science involves an outward-looking set of activities aimed at sharing research findings with the scientific community and industrial partners. Overall, clients of NRC-INMS are highly satisfied with the calibration and measurement services received from Institute staff, although some administrative issues remain to be resolved. These stem mostly from recent changes in the fee-for-service structure and should be relatively simple to improve upon. The findings of the evaluation also point to a more diffuse issue related to the perceptions of the metrology community in regards to the role of CLAS laboratories and their accreditation in other jurisdictions. Finally, the evaluation was only able to identify anecdotal findings related to the course offerings of the Institute. A more systematic approach to performance measurement should be implemented in order to gain management information on course selection, delivery, and outcomes.

> **Recommendation 2:** The administrative mechanisms associated with the changes in the fee-for-service structure and the contracting process should be streamlined in order to reduce the burden on the partners and clients of the Institute. Further, a tracking system

[69] External Interviews, CLAS Laboratories (N=6).
[70] NRC-INMS Internal Document, June 2002.
[71] Internal Interviews, INMS Group Leaders (n=8).
[72] Internal Interviews, INMS Executives (n=5).
[73] Internal Interviews, INMS Group Leaders (n=8).

for education and outreach activities should be developed to enable the Institute to capitalize on participant interests and needs and to maximize the potential benefits of these activities.

Recommendation 3: The misconceptions held by some members of the measurement and calibration community regarding the duplication in the calibration services provided by NRC-INMS and the CLAS laboratories should be corrected through the communication of internal analyses conducted by NRC-INMS and other means deemed appropriate by the Institute. NRC-INMS should also pursue its ongoing efforts in rectifying issues associated with the international recognition of the CLAS certification by requesting specific information from CLAS laboratories on inappropriate requests and by continuing to participate in international fora on this question.

4.3 Support to Canada's National Metrology System

- *Finding: The Institute is considered a leader within the international metrology community and is recognized for the quality of its work.*

This program includes activities related to the maintenance of quality management systems, international representation in various metrology organizations, performance of international measurement comparisons, and outreach and coordination with key Canadian partners in the national measurement system. The strategic goal for this program is to "provide leadership for the creation of a national coordinating body for the Canadian national measurement system".[74] The main objective of the activities conducted in this program is to ensure confidence in the Canadian measurement system and reduce technical barriers to trade for Canadian companies.[75]

The last evaluation of NRC-INMS, conducted in 1999, found that "INMS activities assist in the development of consistent standards across countries. The traceability of INMS standards to international norms and the Institute's participation in formal intercomparisons help individual Canadian companies in their international marketing efforts. They also have an impact on industries as a whole by helping them to deal with trade barriers related to metrology".[76]

4.3.1 Quality Management System Implementation and Maintenance

The implementation and maintenance of the quality management systems (QMS) required by various international organizations is critical to the ongoing recognition of Canada's calibration and measurement capabilities. These QMS include the ISO 17011 (Laboratory Assessment and Accreditation), ISO 17025 (Calibration and Testing Laboratories), and ISO Guide 34 (Certified Reference Materials). These standards differ from the more generic ISO 9000 series commonly found in industry because of the emphasis that they place on documented procedures to ensure the accuracy, and not just the reproducibility, of measurement results.[77]

As a requirement of the CIPM MRA, the ISO 17025 system ensures that NRC-INMS maintains its international standing and acceptance, a condition for continued access by Canadian industry to global markets. The Calibration and Measurement Capabilities (CMCs) for all 11 NRC-INMS scopes are now included in Appendix C of the CIPM MRA, confirming the compliance of NRC-INMS with the terms of the MRA and the international standing and acceptance of the Institute's capacities. [78] Section 6 of this report, on the effectiveness of design and delivery, addresses the recent implementation of the ISO 17025 QMS

[74] NRC-INMS Internal Document, June 2002.
[75] NRC-INMS Internal Document, November 2007.
[76] ARA Consulting, *Assessment of the Institute for National Measurement Standards*, *Summary Final Report*, October 1999.
[77] NRC-INMS Internal Document, May 2007.
[78] Ibid.

in more detail. The economic impacts of not complying with the requirements of the CIPM MRA are identified in a previous section of the report dealing with international trade.

4.3.2 Key Comparisons

Key comparisons are scientific activities meant to demonstrate participating countries' technical competence on the international stage. The results of key comparison exercises are published in a database maintained by the Bureau International des Poids et Mesures (BIPM) and are made publicly accessible. The key comparisons are an integral part of the CIPM MRA: it is through these exercises that countries can establish equivalence and traceability and thus are thought to have an impact on the reduction of non-tariff trade barriers.[79] As established in a report published by the CIPM in 2003,

> *One important TBT is the lack of mutual recognition of measurement and test results. This leads to duplication of measurements and tests in the exporting and importing countries with a corresponding increase in costs and waste as well as delays and the risk of dispute concerning the results. A reliable infrastructure of mutual confidence in measurements and demonstrable verification must first be there… The implementation of trade agreements under the WTO requires the existence of an internationally recognized system of comparable and traceable measurements. As international accreditation agreements are tools for creating confidence in the competence of measurement and testing laboratories, they are based on the understanding that the measurement and test results carried out are reliable, traceable and comparable. This requires the existence of an international network of national metrology laboratories, recognized by regulators and legislators and in which trading partners can have confidence, and to which all the industrial and other measurement, calibration and testing laboratories can refer*.[80]

Key comparison exercises can be conducted within regional metrology organizations or at the international level. These exercises require several years to plan, implement, document and establish equivalence.[81]

Because of the relatively recent implementation of the CIPM MRA, only one international study has been conducted thus far to identify the impacts of such an initiative. The study, conducted by KPMG in 2002, hints at the importance of the CIPM MRA in reducing technical barriers to trade but does not provide concrete evidence of this impact.[82] Representatives from the Department of Foreign Affairs and International Trade stated in interviews that they rely on NRC-INMS in the resolution of trade disputes related to TBTs but could not provide examples of specific instances in which this has occurred. At this point, it is clear that the impacts of NRC-INMS and other NMIs in reducing TBTs remain anecdotal.

Having said this, however, the performance of NMIs in key comparison exercises remains a crucial element of a country's sovereignty in matters related to calibration and measurement. The BIPM web site offers information on the extent to which CIPM MRA signatories participate in Key Comparisons.[83]

According to the information presented by the BIPM, Canada has participated in nearly 150 Key Comparisons and has served as the pilot laboratory for a relatively large proportion of these. In comparison, Germany has participated in more than 400 KCs, the UK and the US have participated in

[79] NRC-INMS Internal Document, July 2005.
[80] *Bureau international des Poids et Mesures, Evolving Needs for Metrology in Trade, Industry and Society and the Role of the BIPM.*
[81] NRC-INMS Internal Document, July 2005.
[82] KPMG, *Potential Economic Impact of the CIPM Mutual Recognition Arrangement*, April 2002.
[83] http://www.bipm.org/utils/common/pdf/Participation_in_KCs.pdf

over 300 KCs, and other countries, such as China, France, Japan, Korea and Russia, have participated in over 200 KCs..
In addition to its participation in the Key Comparison exercises, NRC-INMS currently has a total of 554 internationally recognized calibration and measurement capabilities (CMCs) in Appendix C of the CIPM MRA.

International metrology experts were asked about the participation of NRC-INMS in key comparisons and the results that it has obtained in these. Responses reveal that NRC-INMS is considered to be highly successful in this regard. It was noted, for example, that NRC-INMS "have been leaders in conducting these comparisons". Interview respondents remarked: "they worked extremely hard to get a good system in place", "their results are highly accurate", and "the results they get have a strong effect on development of methods to make these comparisons closer".[84]

Beyond the actual exercises, however, NRC-INMS is also involved in the extensive and on-going international review processes that take place following the completion of the comparisons.[85] In the words of one internal interview respondent, "INMS does very well in international comparisons and are (sic) a leader in many aspects, including the analysis of the results. This is where INMS puts in its largest effort. The world uses Canadian statistics to analyze data, Canada leads or pilots many comparisons. This is important in terms of reputation".

4.3.3 Representation of Canada

NRC-INMS researchers and staff members represent Canada on a number of international organizations. The strategic goal of this participation is to "maintain a recognized leadership role in supporting Canada's national and global trade interests through strengthened participation in international metrology activities intended to enhance trade opportunities".[86] The organizations in which NRC-INMS represents Canada include the CIPM and its Consultative Committees, the Inter-American Metrology System (SIM) and its Technical Working Groups, as well as other organizations related to the accreditation of calibration laboratories. The Institute spends about $1.5M per year on international activities. This includes salary, travel, and the purchase of equipment.[87]

The expertise of NRC-INMS staff is well-recognized in these international organizations through their appointment or election to prestigious positions and through repeated requests for NRC-INMS staff to act as peer reviewers.[88] For example, the Director of Metrology was recently appointed as Chairman of the Technical Committee and a senior research officer from NRC-INMS is the Chair of the CODATA Committee of the CIPM.[89]

The role played by NRC-INMS on the international stage was examined in detail in the International Comparison Study. Interview respondents participating in the study reported that the participation of NRC-INMS representatives on BIPM-related committees and working groups has likely enabled Canadian industry to remain internationally competitive. In the words of one participant, "I can say that the role of an NMI is to enable their respective country to remain internationally competitive…our impression is that NRC-INMS is carrying out that role very well from a technical perspective". Others noted that the work of NRC-INMS has enabled Canadian industry to remain internationally competitive by facilitating trade. It was suggested that NRC-INMS is able to ensure that Canadian exports meet international standards and

[84] Ekos Research Associates, *International Comparison Study*: 16.
[85] NRC-INMS Internal Document, July 2005.
[86] NRC-INMS Internal Document, June 2002.
[87] NRC-INMS Internal Document, July 2005.
[88] NRC-INMS Internal Documents, 2001, 2007, Ekos Research Associates, *International Comparison Study*: 17.
[89] Internal Interviews, INMS Executives and Group Leaders (n=13) and Ekos Research Associates, *International Comparison Study*: 16-17.

imports are safe for consumers. One explained: “They are major players in the international Mutual Recognition Arrangement – this gives international recognition and confidence to their measurement capabilities and so Canadian users of NRC-INMS services should be able to avoid Technical Barriers to Trade which might result from a lack of equivalent measurement standards to those in trading partners”. Another respondent described more succinctly, “I am sure it has helped Canadian industry in opening up doors for their products”.[90]

In addition to committee work, the Institute has invested time and resources in developing the metrology capabilities of other members of SIM. This work can take many different shapes: researchers from NRC-INMS go to SIM member countries as guest speakers, participate as peer reviewers in some accreditation processes, and train guest workers who visit NRC-INMS.[91] In addition to supporting SIM member countries, this investment benefits Canada indirectly: by being grouped into regions, the success of Canada in terms of international metrology is related to the success of the broader region: “Now when there are international meetings Canada is grouped with SIM, so Canada needs to help these countries in order to help the whole group be successful”.[92]

The relatively small number of researchers at NRC-INMS means that most of the scientific staff of the Institute is involved in international activities to some extent. A comprehensive list of the committees in which NRC-INMS participates was provided by the Institute for the purpose of the evaluation and is provided in Appendix D. Table 6 provides a summary of some of the ways in which NRC-INMS researchers are involved in national and international metrology activities.

Table 6: Recognition of NRC-INMS Scientists

	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007
Number of Journal Editorships	15	13	12	12	11
Total Invited Presentations	42	64	34	34	42
Total Participation in National Committees	51	26	53	74	58
Total Participation in International Committees	158	150	147	141	153
Total International Conferences with I/P Representation	142	187	114	20	68
Number of International Conferences and Workshops Organized or Sponsored	6	7	1	6	4
Number of Foreign Delegations Received	3	2	3	6	3
Total Number of External Conferences/Workshops/Seminars Organized	6	7	4	17	9
Number of External Awards[93]	12	6	3	13	10

[90] Ekos Research Associates, *International Comparison Study*: 19.
[91] Internal Interviews, INMS Executives and Group Leaders (n=13).
[92] Internal Interviews, INMS Executives and Group Leaders (n=13).
[93] This includes prestigious honours bestowed by organizations such as the IEEE and the BIPM. Multiple recipients or group awards are only counted once in the table.

4.3.4 Metrology Research and International Outcomes

The linkages that exist between the research conducted at the Institute and its role in terms of protecting the trade interests of Canada can be illustrated through a case study conducted for the purposes of the evaluation. This case focuses on a project conducted by the chemical metrology group of NRC-INMS and a Montreal-based bio-tech firm. The objective of the project was to develop robust, reliable methods for the speciation of selenium in selenized yeast supplements and to produce a certified reference material (CRM) for selenium species in yeast. Although the project yielded several important scientific outputs, such as thirteen peer-reviewed publications, six conference presentations, and the training of four post-doctoral fellows and one PhD student, as well as an international intercomparison exercise organized by the NRC-INMS project lead, expected socio-economic impacts have not yet occurred, as described below.

One of the key objectives of this project was to enable Canadian companies such as the partner firm to gain access to international markets for their selenium-enriched mineral supplements through the availability of robust and reliable characterization. In theory, the presence of this new CRM should provide measurement standards not previously available and therefore reduce TBT. It was felt that by measuring their products against the new CRM, manufacturers of selenized yeast products can make reasonable, credible claims about the potency and effectiveness of their products.

However, this objective has not yet been achieved. International acceptance of enriched yeast has been slow and has not yet brought a financial advantage to the partner company: “it’s very good information to have, but we’re not able to leverage it”. This may be due to a lack of understanding of mineral-enriched yeast at the international level. The company has attempted to access European and Japanese markets though the usual regulatory channels, but so far has been unable to export its selenium-enriched products overseas.

The lack of socio-economic impacts observed in the case of the selenized yeast products case study cannot be attributed to the research conducted at NRC-INMS. The scientific work of NRC-INMS in this particular project earned a cover page of a prestigious scientific journal. The case does, however, highlight some of the challenges faced by industry in marketing products internationally, regardless of the measurement science that underpins these products. Longer-term economic impacts for the partner company may be seen in the future, if the partner is successful in bringing its projects to international markets. For the time being, this case demonstrates the complexities associated with the reduction of trade barriers, especially in emerging areas such as natural health products.

4.3.5 Coordination with Other Stakeholders in the National Metrology System

Part of supporting Canada’s national metrology system involves coordination activities with other metrology organizations, such as Measurement Canada and the Standards Council of Canada[94]. As noted in the background information provided in section 2.0, these organizations partner with NRC-INMS in the delivery of legal metrology (Measurement Canada) and in the accreditation of calibration laboratories (SCC). Other organizations in the government sector also partner with NRC-INMS to deliver their services to the public. The following points identify the major linkages that NRC-INMS has established with Canadian metrology stakeholders, based on external interviews conducted with representatives from these partner organizations.

- Measurement Canada (MC): NRC-INMS provides traceability to MC; use of NRC-INMS equipment by MC scientists and calibration of reference standards; collaboration regarding the certification of the

[94] ARA Consulting, *Assessment of the Institute for National Measurement Standards*, *Summary Final Report*.

MC fluid flow laboratory to ISO 17025; NRC-INMS provides testing services for new measuring devices obtained by MC.

- Standards Council of Canada: accreditation of CLAS laboratories through the PALCAN program.
- Canadian Standards Association (CSA): The greatest interaction between the two organizations occurs in the area of electrical standards, although the CSA is becoming increasingly involved, along with NRC-INMS, in the field of nanotechnology. NRC-INMS representatives sit on a CSA Working Group to standardize measurements and test methods for nanoparticles.

The key impact of NRC-INMS involvement for these three organizations is the link to international standards and quality systems. As Canada's primary coordinator for international metrology activities, NRC-INMS facilitates access of these organizations to international organizations with similar mandates and provides traceability to the SI when required.

4.3.6 Summary of Findings

The role of NRC-INMS in supporting Canada's national metrology system takes different forms, from its participation in international key comparisons to ensuring that Canada's interests are well represented through committee work. Overall, the findings of the evaluation point to the fact that the Institute carries out this mandate well and is touted as a leader within the international metrology community.

5.0 COST-EFFECTIVENESS

A few evaluation questions focused specifically on the leveraging of resources through collaborative research activities and on the extent to which the resources allocated to NRC-INMS compare to those allocated to other NMIs.

5.1 Collaborative Research

- *Finding: The Institute regularly engages in important collaborative research activities with other national metrology institutes; however, the extent to which it works collaboratively with others within Canada is more limited.*

The extent to which NRC-INMS researchers have been involved in collaborative research activities is thought to have increased in the past five years. The nature of these projects, which have been conducted with partners from other NMIs, other NRC institutes, other governmental organizations, and the private sector, was examined more thoroughly in order to gain a better understanding of these collaborations and their impacts.

5.1.1 Other National Metrology Institutes

The bulk of the collaborative research activities undertaken by NRC-INMS is conducted with partners from other NMIs. For example, NRC-INMS "is currently engaged in a global collaboration involving the NMIs of Australia and China, and the laboratories of the BIPM to build a new generation of devices that will enable a better realization of the SI unit of capacitance, known as the farad. INMS was invited to join this multi-year project by the NMI of Australia because of its expertise in electrical metrology. Similarly, NIST and NRC-INMS have long collaborated in the development of CRMs for chemical analysis, sharing complementary measurement facilities and expertise and avoiding unnecessary duplication of effort".[95] Interview findings from the International Comparison Study point to the fact that NIST feels that it has a very close and friendly relationship with NRC-INMS. The two metrology organizations often sign memoranda of understanding, and are currently collaborating on projects related to the development of quantum standards and on the development of carbon nanotube CRMs.[96] Other NMIs currently involved with NRC-INMS include the UK's Laboratory of the Government Chemist, Germany's Federal Institute for Materials Research and Testing (BAM), Japan, Korea, Norway, Australia and China. The Institute is also involved with a number of South American NMIs as part of its contribution to the activities of SIM.[97]

Collaborations with other NMIs have allowed NRC-INMS to lever its resources by participating in larger projects than it would have been able to complete on its own, such as the work currently conducted in conjunction with Australia on the calculable capacitor.[98] Other NMIs are experiencing a lack of ongoing resources in the same way as NRC-INMS; collaborating on common research goals allows participating NMIs to pool resources and achieve a critical mass in terms of expertise and funding that would otherwise be out of the reach of individual NMIs. These collaborations then make establishing international consensus on standards easier and quicker.

Other international metrology experts explained that although there are a number of ongoing relationships and collaborations between NRC-INMS and their respective NMIs, no formal memoranda of understanding have been signed in most cases and no financial transfers have been made between

[95] NRC-INMS Internal Document, January 2008.
[96] Ekos Research Associates, *International Comparison Study*: 25; Internal Interviews, INMS Group Leaders (n=8).
[97] Internal Interviews, INMS Executives and Group Leaders (n=13).
[98] Internal Interviews, INMS Executives and Group Leaders (n=13).

countries.[99] Examples of these informal relationships include staff exchanges (Brazil, Finland, France, Japan), ongoing consultations on common issues (France, Japan), and tri-national discussions on nanotechnology (Mexico, US).[100] One person interviewed is of the opinion that partnering opportunities in international research and related activities have not been fully realized: "I'm not so sure that they are as well integrated into collaborative networks like the watt balance or other work on the fundamental constants maybe I don't see it but, there doesn't seem to be as much in North America as in Europe, where integrated or collaborative projects are much more evident and are supported by EU money."[101] It should be noted however, that European Framework programs are not open to Canadians, and no similar mechanism exists in North America. In many international collaborations, money does not exchange hands, with each partner making an in-kind contribution to the project financed from its own operational funds.

The extent to which NRC-INMS activities complement, overlap with, or duplicate those of other NMIs was examined in the International Comparison Study. While the answers and explanations varied by interview respondent, all participants in the study believe that NRC-INMS does duplicate the work of other organizations, but that this duplication and overlap is productive and complementary in the context of international metrology. For example, one NMI representative explained that duplication is actually a much-needed practice as the robustness of international metrology systems is directly related to the realization of the same quantities by NMIs. This duplication is also critical in avoiding the danger of relying on a singular source for information. One representative felt that Canada has maintained a very good balance and a healthy level of duplication while "not unnecessarily reinventing the wheel".[102]

5.1.2 Other NRC Institutes

Over the past few years, the level of interaction between NRC-INMS and other NRC institutes has increased. The relevance of metrology to other areas of science, such as materials science and nanotechnology is gaining recognition, and this has generated new opportunities for cooperation and collaboration. This represents a significant change for NRC-INMS: traditionally, the Institute has focused its efforts towards developing collaborative relationships with other international metrology organizations rather than with other NRC Institutes.[103]

Representatives from other NRC institutes who have participated in collaborative projects with NRC-INMS find that generally, the collaborations are developed and established by researchers from both institutes; in one case, post-doctoral fellows from one Institute have been hired as researchers by NRC-INMS, while in other cases, other NRC institutes contacted NRC-INMS for help with a specific problem. Although most interviewees from other NRC institutes feel that these collaborations are helpful and valuable, many have mentioned the need to adapt to the different organizational cultures between institutes and feel that NRC-INMS provided them with a service rather than participated in collaborative activities. This differs from the descriptions of the projects offered by NRC-INMS staff and executives, who define these projects as collaborative research.[104] This difference in opinion may be explained in part by a lack of knowledge about the scientific work that underpins the development of measurement standards. A major hindrance to the development of research collaborations with NRC-INMS as with other Institutes mentioned by respondents was the lack of financial and human resources required to build the relationships and fund the projects.[105]

[99] Ekos Research Associates, *International Comparison Study*: 25.
[100] Ibid.
[101] Internal Interviews, INMS Executives and Group Leaders (n=13).
[102] Ekos Research Associates, *International Comparison Study*: 22-23.
[103] Internal Interviews, INMS Executives and Group Leaders (n=13).
[104] Ibid.
[105] Internal Interviews, Other NRC Institutes.

As with the collaborative projects conducted with other NMIs, the collaborations between NRC-INMS and other NRC institutes are mainly informal, with no MOUs signed between parties or transfers of financial resources. A notable exception to this is the agreement signed between NRC-INMS and NRC-IMI to develop new materials for the electrical industry in nanocharacterization.[106]

Because most of these collaborations are somewhat new for NRC-INMS, very few concrete impacts have been observed so far. Many of these projects have produced outputs, but none of the interviewees, either from NRC-INMS or other institutes, spoke of longer-term impacts. Examples of outputs mentioned by other Institutes include the reduction of the costs involved in the development of a new laboratory (NRC-IIT), and sharing methodologies between groups (NRC-IMB)[107]. One noteworthy example of longer-term impacts to be assessed in the future is the work currently underway as part of the more formalized NRC Nano Initiative, which includes NRC-INMS, NRC-NINT, NRC-SIMS and other institutes.[108]

5.1.3 Other Government Departments and Agencies

In addition to coordinating national metrology activities with its Canadian partners, NRC-INMS works with a number of other government departments and agencies (OGD) on projects related to the development of measurement standards. These include research projects, such as the work conducted with the Canadian Food Inspection Agency (CFIA) on the development of standards and reference material for canola, as well as the provision of advice, such as consultations by SCC for new products or standards. Collaborations with OGD can also be special events, such as the nanotechnology workshop conducted by Health Canada, or ongoing cooperation with a specific agency (such as Measurement Canada) in a number of areas related to metrology.[109]

NRC-INMS has also had four of its projects funded under a competitive Defence and Research Development Canada (DRDC) program. These externally peer reviewed projects are contributing to the development of knowledge on terrorism. The chemical metrology group and the ionizing radiation group are most involved in this area.[110]

Table 7 presents the collaborations identified by NRC-INMS Executives and Group Leaders in an effort to describe the types of collaborative activities undertaken by the Institute:

Table 7: Description of Activities Undertaken with Other Government Departments

Partner Organization	Activities
Canadian Nuclear Safety Commission	▪ Special, two-year contract for a particular set of measurements
Department of Foreign Affairs and International Trade	▪ Provision of advice and expertise to facilitate access to foreign markets for Canadian products
Canadian Food Inspection Agency	▪ Link with NRC-INMS provides international recognition for canola products
Health Canada	▪ Work that supports the development of new regulations, especially in the area of Natural Health Products. ▪ Development of new certified reference materials for ginseng and goldenseal, two high-growth, high revenue herbs for Canada.

[106] Internal Interviews, Other NRC Institutes.
[107] Even though NRC-IMB spoke of one particular activity in which they are involved with NRC-INMS, it should be noted that the relationship between these two institutes is longstanding: Certified reference materials (CRMs) for environmental analysis are produced by an NRC program operated jointly by NRC-INMS and IRC-IMB.
[108] Internal Interviews, Other NRC Institutes.
[109] External Interviews, OGD (n=5).
[110] Internal Interviews, INMS Executives and Group Leaders (n=13).

Partner Organization	Activities
	▪ Performing calibrations for Health Canada in the area of radiation safety as well as tanning booth certification and protective eyewear. This is mainly done on an as-needed basis and is usually treated as a service by NRC-INMS to HC.
Department of National Defence	▪ The Institute provides some calibration services to DND, including work for the Quality Engineering Test Establishment (QETE) as well as calibrations of camouflage materials (fabrics and paint). ▪ NRC-INMS provides arbitration services in the case of disputes between DND and its suppliers.
Defence Research and Development Canada	▪ Participation in the CBRN Research and Technology Initiative through four funded projects
Canadian International Development Agency	▪ NRC-INMS received funding for two years to help develop the metrology infrastructure of Costa Rica
Environment Canada	▪ Providing advice in the area of UV rays

Above and beyond immediate project outcomes, one impact of these interactions, as mentioned by external interview respondents, is helping other government departments (OGD) gain a better understanding of metrology in an international context.[111] Other than this, however, external interviewees were unable to provide concrete details on project outcomes. As in the case of NRC institutes, most of these partnerships were considered services provided by NRC-INMS in its role as Canada's NMI.

5.1.4 Industry

The existence of standards is known to offer a number of advantages for the private sector. These include setting a level playing field for businesses, convincing customers of the quality of products and processes, cost-savings in terms of increased product quality and decreased waste levels, facilitating the client-supplier relationship through interoperability, and facilitating innovation and R&D through proper documentation and performance information.[112]

The findings from the internal interviews conducted with NRC-INMS staff point to the development of intellectual property (IP) as a key impact of the Institute's collaboration with industry. These collaborations are often established due to specific industrial problems related to calibration, and the services provided by NRC-INMS can generate opportunities for the development of IP. Table 8 presents the number of patent applications and the total number of patents issued for the period covered by the evaluation. The process undertaken in the identification of potential patenting opportunities involves a review of all publications by the Business Development Office of the Institute as well as preliminary assessments for novelty and marketability before IP decisions are made.[113]

Table 8: Patent Applications and Patents Issued[114]

	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007
Number of Patent Applications	3	10	3	4	1
Total Number of Patents Issued	6	6	8	10	0
Total Number of Licenses Issued	3	2	6	6	0
Total Licensing Revenue from Intellectual Property	$455,734	$156,091	$418,432	$954,517	$220,226

[111] External Interviews, Other Government Departments (n=5).
[112] J. Haimowitz, & J. Warren, *Economic Value of Standardization*, 2007.
[113] Internal Interviews, NRC-INMS Executives and Group Leaders (n=13).
[114] NRC-INMS Performance Data.

Some of the more concrete outputs of the collaborations undertaken between NRC-INMS and its industrial partners (including hospitals and research centres specialized in ionizing radiation) include the development of measurement instruments in the area of colorimetry, services associated with the use of a Glow Discharge Mass Spectrometer (chemical metrology), as well as other individual research projects. External interviewees only spoke generally about the impacts of these collaborations; for instance, one respondent stated that the collaboration had "major positive impacts" in terms of the company's operations, while another felt that NRC-INMS staff "supported him" when he started his company by providing advice.[115]

Other collaborations with industrial or arms-length governmental organizations include work done locally by NRC-INMS researchers. For example, the Electrical Standards group is involved in diagnostic testing of Hydro-Ottawa cables to determine the extent to which these require repairs or replacement. NRC-INMS performs this service free of charge to Hydro-Ottawa in exchange for the opportunity to test its equipment in the field, often under extreme weather conditions.[116]

5.1.5 Summary and Recommendations

The collaborative activities undertaken by NRC-INMS with other NMIs are highly regarded in the international metrology community, where the Institute has clearly established its role as that of leader. Opinions within Canada were more mixed, however. It appears as though the definition of collaborative research is different for NRC-INMS than it is for its partners, who typically perceive the Institute as a service provider rather than collaborator. In addition to this, very little data were obtained on the concrete outcomes of these partnerships, especially from collaborators.

Greater linkages within Canada will result in the identification of problems or issues of relevance to OGDs and Canadian industry. Working with partners on resolving these issues through measurement science will raise the profile of the Institute while contributing significantly to protecting Canadian trade interests, enabling innovation, and enhancing Canadians' quality of life.

> **Recommendation 4:** The Institute has made some headway in recent years in terms of actively pursuing research collaborations and of increasing the awareness of potential collaborators who support/have a stake in the Institute's mandate. These activities should be encouraged further, not only at the executive level, but for all scientific staff of the Institute. This should include a greater level of involvement from the Business Development Office in the framing of research agreements in order to encourage the development of collaborative activities.

5.2 Resource Allocation

The extent to which the stated objectives of NRC-INMS are achievable given existing resources allocations was examined as part of the evaluation study. The Institute's main sources of revenue and funding, as well as its use of resources are considered here, and a comparison is made of the NRC-INMS resources with those of other NMIs.

5.2.1 Financial Resources

The key sources of funding for NRC-INMS are A-base funding (as shown on Table 1) and revenues mainly derived from fees for services rendered, including the sale of CRMs. Groups receive salary dollars from the A-base funding provided to the Institute; however, these funds are insufficient to cover all salaries (on an annual basis, A-base is $1M short of the amount required for salaries). When a group

[115] External Interviews, Industry (n=7).
[116] Ibid.

earns revenue, some funds are taken to cover this shortfall in the A-base budget and some are shared amongst the Institute's groups for minor capital based on a competitive process. Groups who earn revenue keep the rest of the funds for themselves and can invest it however they see fit (e.g., for equipment purchases).

The fee-for-service revenue is generated through activities undertaken with industrial partners or other government departments and agencies. Very little funding is transferred between NMIs or between NRC Institutes. In these collaborations, each participant contributes financially to the achievement of its goals. A project to review all fees for services provided by the Institute was undertaken by the Business Development Office of NRC-INMS over the reporting period. This review was motivated by a desire on the part of the Institute to ensure that its service costs were properly covered by the fees paid by its clients and to ensure that the method used to calculate these fees was uniform across research groups.

Aside from salaries and operating costs, an important expenditure for NRC-INMS comes from its participation in international activities. Annually, the Institute spends approximately $300,000 on international comparisons and the traveling associated with NRC participation in international metrology activities. An additional $500,000 is spent on maintaining the Institute's ISO standards, which are required for traceability purposes. Although NRC-INMS invests these funds on behalf of NRC and Canada, it does not receive funding to cover these expenses.[117] The institute also pays on behalf of Canada a grant to the BIPM ($600K annually).

Participants in the International Comparison Study expressed some concern over the resource allocation provided to the Institute. These interviewees noted that NRC-INMS faces certain issues related to funding that have a definite impact on its current performance and could have a negative effect on its contributions in the future. They suggested that NRC-INMS has to be strategic about its approach as a result of underfunding. Some explained that the Institute's programs are limited in scope by necessity and that it is forced to focus on certain key activities. A few interviewees stated that NRC-INMS has had to scale back on activities, including those related to radioactivity, because of the "reality of available resources". One respondent remarked, "They have taken a somewhat unique approach that is strategically sound – they focus on Canada's needs by providing research that is unavailable elsewhere". NRC-INMS is not seen to reproduce anything that can be procured by other quality sources, but seen instead as focusing its efforts on that which is most pertinent to the Canadian landscape. While this approach is seen as effective for the short-term, it is thought to be problematic in the longer term. One interviewee explained: "The current strategic selection of key areas will serve it well for a few more years, but there is a great need for additional diversity and building of long-term strengths". If the situation does not improve, some feel that it will hinder the ability of NRC-INMS to contribute to the field of metrology in the future.[118]

Aside from future needs related to emerging areas of science, a major concern within the Institute is the state of the facilities and equipment used by researchers. Issues related to building design, availability of space, and accessibility were raised in internal interviews with group leaders. Some interviewees remarked that many countries that are relatively new to metrology, such as Turkey, Korea and China, have better facilities than does Canada.

5.2.2 Human Resources

The main issue faced by NRC-INMS in terms of its human resources is the upcoming eligibility for retirement of many of its scientists. Because metrologists are not generally trained in a university setting, there will be a need for an overlap period between now and the year of retirement of these individuals.

[117] Internal Interviews, INMS Executives and Group Leaders (n=13).
[118] Ekos Research Associates, *International Comparison Study*: 16.

Part of the Institute's income is reinvested into the creation of new positions to fill this gap, and the Institute has had some success in obtaining additional funding for this purpose through NRC's business planning process.

Other than succession planning, there are no other immediate plans to increase the size of the Institute. This is seen as particularly problematic by the Group Leaders, who perceive an increase in the work required of their scientific staff without the proper financial or human resource allocations. There is also a perception that other NMIs are investing more heavily than NRC-INMS in building their capacity, which may eventually result in a loss of influence in international metrology for the Institute.[119] Aside from any financial barriers associated to increasing the size of the Institute, a lack of space makes this even more unlikely in the near-term: "We cannot grow [the group] because there is no space available for them".[120]. The availability of space is a problem for some groups, depending on their current location and specialized needs in terms of infrastructure.

5.3 Comparison to Other NMIs

5.3.1 Comparison of Resource Allocation

One of the key issues for the evaluation was the examination of how NRC-INMS compares to other NMIs in terms of resourcing and organization. Metrology experts participating in the International Comparison Study viewed the Institute favourably when compared with other NMIs, stating that: "NRC-INMS is always considered as one of the top organizations – probably well into the top ten", "they are an institution to be proud of" and "they are a small group who have become internationally renowned".

A summary of the financial data collected as part of the International Comparison Study is provided in the next table. These data were mainly obtained by reviewing OECD reports. It should be noted that because of the different ways in which metrology is organized in all of these countries, the budgets and FTEs **cannot be compared directly from one NMI to the next**. Contextual information about each of the countries selected for the comparison study is provided below to provide a framework for the interpretation of the quantitative data.

- **Australia:** National Metrology Institute (NMIA) is responsible for its national infrastructure in physical, chemical, biological and legal measurements. NMIA (Australia) coordinates Australia's national measurement system while also establishing and maintaining Australia's units and standards of measurement, thereby allowing Australian industry to operate competitively in a global environment.[121] In addition to these activities, the NMIA (Australia) conducts key comparisons on behalf of Australia.
- **Brazil:** INMETRO is a federally run executive secretariat for the larger national metrological committee named SINMETRO. Within SINMETRO there are 10 ministries, and the council is headed by the Ministry of Developing Industry and Foreign Trade. In Brazil, activities related to accreditation, legal metrology and scientific metrology all fall within the mandate of INMETRO (with the exception of ionising radiation metrology, for which INMETRO has designated a distinct national body). The fourth activity, national standards, is the responsibility of Associação Brasileira de Normas Técnicas (ABNT), a private nonprofit which has offices in all the principal Brazilian cities.
- **Denmark:** After 20 years as a government-owned foundation, Danish Fundamental Metrology (DFM) was converted into a non-profit organization fully owned by the Technical University of Denmark

[119] Internal Interviews, INMS Executives and Group Leaders (n=13).
[120] Internal Interviews, INMS Executives and Group Leaders (n=13).
[121] National Measurement Institute, http://www.measurement.gov.au.

(DTU). Though metrology is not structured in academia, two or three universities play a role in the administration of DFM. DFM is the sole national body responsible for the development and dissemination of measurement knowledge[122]. The organization is funded through performance contracts, innovation consortia, and general research grants. The Danish Accreditation and Metrology Fund (DANAK) has the political responsibility for metrology in Denmark and is a service company that handles aspects of administration and accreditation. DANAK was founded in 2002 based on a contract with the Danish Safety Technology Authority which is part of The Danish Ministry of Economics and Business Affairs and is an umbrella organization covering all Danish primary and reference laboratories.

- **Finland:** Centre for Metrology and Accreditation (MIKES) is responsible for internationally accepted measurement units and plays an important role in the efficient operation of the country's advanced industrial and scientific sectors. The area of operations within MIKES dedicated solely to metrological measurement realises the International System (SI) measurement units in Finland, performs high-level metrological research and develops measuring applications in partnership with industry. MIKES is partially funded by industry, academia, the regional metrological organisation EURAMET, and the government in a 70-30 public/private split. The Finnish Accreditation Service (FINAS), situated within MIKES, has been recognized as a national accreditation body under the Ministry of Employment and the Economy.
- **France:** Laboratoire National de Métrologie et d'Essais (LNE) is responsible for steering and coordinating metrological activities in the 10 decentralized laboratories that constitute the national metrology framework. The government plays a key role in funding metrological activity. A considerable amount of funding comes from the Ministère de l'industrie, although the Ministère de la recherche also contributes. Also, throughout the decentralized French NMI structure, there are four national metrology laboratories that conduct research and maintain ties to academia.
- **Japan:** National Metrology Institute of Japan (NMIJ) is devoted to facilitating the development of Japanese economic activities in the international market. They develop policies concerning measurement standards and legal metrology, and conduct research and development activities of measurement standards. They also provide metrological services such as testing and inspections. The NMIJ (Japan) is comprised of the Metrology Institute of Japan and the Metrology Management Center, that cooperate with three other sectors of the National Institute of Advanced Industrial Science and Technology (AIST). Measurement standards, including certified reference materials, are systematized under the standards and certifications policy of the government as the core of the national measurement system, which guarantees the traceability of all measurement results to the national primary standards.
- **Mexico:** Centro Nacional de Metrologia (CENAM) began operation as a government initiative 35 years ago and follows a similar structure of operation to NRC-INMS. Funding is primarily provided by government though privately contracted business provides CENAM with approximately 20 percent of its revenues. Mexico has implemented the National Standardization, Metrology and Conformity Assessment System, which is coordinated by the Dirección General de Normas (DGN), as part of the Ministry of Economy (SE). The general aim of the system is to coordinate the development of standards and regulations and to promote their use. The system consists of three fundamental activities: standardization (including regulations), metrology and accreditation, and conformity assessment.
- **United States:** National Institute of Standards and Technology (NIST) is a non-regulatory agency of the United States Department of Commerce and is mandated to promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways

[122] As outlined in its mission statement.

that enhance economic security and improve quality of life[123]. Though NIST (U.S.) was established in 1901, the government's commitment to metrological study is written into the U.S Constitution where it states that the government is responsible for, "*fix[ing] weights and measures*". Metrology in the U.S is looked at as being inherently governmental, and is very centralized; its 3,000 employees are all considered civil servants. It should be noted that in this case, almost half of the funding provided to NIST is for non-metrology activities, which changes the scope in terms of comparison to other NMIs.

In addition to the different mandates and spheres of activity of the NMIs profiled here, it should be noted that stand-alone metrology institutes have to cover services provided centrally to NRC-INMS, such as grants in lieu of taxes, property management and maintenance, library, procurement, stores, finance, IP support, HR, etc. Including these services would, in fact, double the NRC-INMS investment. It should be further noted that the funding levels presented in the table for Canada only apply to NRC-INMS and do not include funding of Measurement Canada and the Standards Council of Canada; these functions may be included in the mandate of some other NMIs and these organizations' budgets may appear larger as a result.

Table 9: Summary Table of Financial Data[124]

Country	Population	GDP	R&D/ GDP Ratio	Level of Investment in R&D (2007)	Funding to National Metrology Institute (2007)	Number of FTEs at NMI
Canada	**33,212,696**	**$1.43T**	**1.89%**	**$28.9B[125]**	**$19.7M**	**120**
Australia	20,434,176	$785.4B	1.04%	$9.42B[126]	$90M per year ($60M from Australian government, $30M from revenues)	360
Brazil	190,010,647	$1.87T	N/A	$1.84B[127]	$250M	1 500
Denmark	5,468,120	$209.6B	2.52%[128]	N/A	Current performance contract for $2.9M; identified need for additional $8.2M)	18
Finland	5,238,460	$190B	3.46%	$2.8B	$15.8M	80
France	64,057,790	$2.12T	2.2%	$56.75B	Split between Ministère de l'industrie: $23.7M and Ministère de la recherche: $316.6K	250
Japan	127,433,494	$4.32T	3.62%	$133B	$34.2M	290
Mexico	108,700,891	$1.38T	0.7%		$22M	320
United States	301,139,947	$14.20T	2.6%	$320B[129]	$954M	3 000

5.3.2 Summary of Findings

NRC-INMS derives its resources from continuing A-base funding as well as from revenue obtained for services rendered. International experts perceive the contributions of NRC-INMS to be well above expectations given their current budgetary levels.

[123] NIST homepage.
[124] All dollar values are $CDN.
[125] Includes public and private sources.
[126] 2005-06 data.
[127] Investments made since 1999, distributed in 4000 projects.
[128] 2002 data (most recent available).
[129] 2004 data includes public and private sectors.

However, it appears as though the current allocation levels will become increasingly insufficient in future years due to the increase in activities. The Institute may experience difficulty in maintaining its core activities as Canada's NMIs given the need to conduct R&D in emerging areas of science. Some of these issues are addressed further in Section 6 of this report.

6.0 FINDINGS – EFFECTIVENESS OF DESIGN AND DELIVERY

The extent to which the design and delivery of NRC-INMS activities have been effective in supporting the objectives of the Institute were examined through a review of internal documents, performance and administrative data, as well as through internal and external interviews, an international comparison study and case studies. The purpose of assessing issues related to design and delivery is to provide information about Institute management practices and to recommend alternatives where warranted.

6.1 Organizational Structure

- *Finding: The reorganization of the Institute has been effective in increasing contacts between groups and has lead to a better understanding of resource allocation processes.*

The extent to which the Institute's current structure allows for the integration of new activities related to technological advancement was identified as a key evaluation issue during the planning phase of the study. More specifically, the ways in which the Institute has adapted its activities to meet the changing needs of clients and stakeholders were examined and are reported in this section.

The discipline- or group-based organizational structure currently in place within the Institute is generally felt to be appropriate in terms of the Institute's ability to deliver on its objectives. The reorganization that took place late in 2004 has resulted in more opportunities for discussion among group leaders and has lead to a better understanding of the challenges faced by the different groups within the Institute. Generally, internal interviewees feel that the reorganization, which involved the creation of a Director of Metrology position to which all research group leaders report, has resulted in lessening the "silo mentality" that had prevailed up to that point. A systematic process put in place for the distribution of minor capital investments has also provided group leaders with the opportunity to review project proposals from other groups and to collectively determine what projects receive funding in a given year. This new process has resulted in better quality project proposals, since "if a project isn't approved, it is often improved in terms of relevance, collaborations and marketability, and further refined so there is a better proposal if it is resubmitted in a following year".[130] However, the segmentation of the research groups across four buildings on the NRC campus is seen by some group leaders as reducing the communication that occurs between the groups and may hinder potential intra-Institute collaboration as well as the integration of new activities related to technological advancement. In addition to this, some internal interviewees felt that there is some remaining imbalance in the organizational structure in terms of the size of the different groups and the common requirements for all group leaders: "…the group leader level is also difficult because one group leader has 20 people under him and another only has a few and is much more focused. These things also affect the Institute as a whole".[131]

The development of new areas of measurement science, such as nanotechnology and biotechnology, has also contributed to the integration of new activities related to technological advancement within the Institute. Some examples of this integration have been identified in internal documents, such as the development of the first NRC Natural Health Product certified reference materials derived from ginseng, and the involvement of NRC-INMS in the Public Service of Canada Nanotechnology Network.[132]

[130] Internal interviews, INMS Executives (n=5).
[131] Internal interviews, INMS Executives and Group Leaders (n=13).
[132] NRC-INMS Internal Document, July 2005.

6.2 Operational Processes

The reorganization undertaken by the Institute in 2004 has had some impacts on the operational and decision-making processes that have taken place since then. Although it is still early to be assessing the impacts of such a reorganization, early signs are positive for the most part. Generally, internal interviewees at the executive and group leader levels feel that the organization of all of the research groups under one Director of Metrology and the streamlining of the executive team have resulted in more integrated and transparent decision-making. The minor capital competition described previously has also resulted in a more transparent budget allocation process and greater sharing between research groups, both in terms of the scientific work being done and in terms of common management issues such as succession planning, funding, and space: "It has helped to develop a collegial environment. People have an opportunity to evaluate and make decisions about what's happening". A balance between maintaining each group's autonomy while encouraging groups to share resources and ideas is generally thought to have been achieved since the reorganization. An interesting comment made by one interviewee does raise some issues likely to affect the Institute in the future: "We have had some revenue carry-over we have been able to dip into, so no one has really felt the crunch yet… unless there is an increase in funding, some activities will need to be cut, and before too long".

As described in a previous section, a significant administrative change undertaken in recent years is the installation of a new quality management system for the Institute. The ISO 17025 is an international standard for measurement laboratories and is required by the CIPM MRA. The implementation of this quality management system revolves around the documentation of processes and represented an important change for Institute staff. It also requires periodic laboratory audits conducted through peer reviews coordinated by the Standards Council of Canada. Although the peer reviews did not identify ways of improving efficiency and efficacy at the Institute level, NRC-INMS staff feel that "it was very useful to have it done… it gave us some ideas about streamlining". Although this is not necessarily considered a best practice because of its compulsory nature, it was nonetheless an important achievement for the Institute and required extensive efforts throughout the implementation of the system.

Another recent development is the fee-for-service review project undertaken by the Business Development Office of NRC-INMS. The purpose of this project was to develop a methodology to accurately estimate the cost of every routine calibration undertaken by the Institute. The main driver for this project was the impression that calibration fees were determined on a qualitative basis, with no comparison between the actual costs to the Institute of providing the service and the fees charged to clients. One result of this initiative is increased revenue to the Institute through the implementation of higher fees to other government departments – when these fees were studied, it was found that NRC-INMS provided "too much of a discount" to these organizations.

There remain some questions about the extent to which business services and other types of operational support will be effective in the near future. Some of these roles are fairly new to the Institute and are not yet well-known among the research teams. In the words of one internal interviewee, "The jury is still out on whether the business office will be successful. It is difficult for a generalist business expert to sell our specialized services, and we (the researchers) already have the relationships".[133] It may be appropriate at this time for the Institute to undertake a process in which the different roles of the business office, research staff and others are fully documented, to build awareness and understanding within and between groups.

[133] Internal interviews, INMS Executives and Group Leaders (n=13)

6.3 Alternative Approaches

The activities related to the development of measurement standards and the dissemination of measurement science are organized in different ways around the world. A brief examination of some of these alternative approaches was undertaken in this evaluation to identify useful examples and to provide contrasting information to the Canadian organization of metrology.

6.3.1 Structure of NMI and Role of Government

As described in the Institute Profile provided in Section 2, NRC-INMS is Canada's National Measurement Institute. In addition to NRC-INMS, other governmental agencies and regulatory bodies are also involved in metrology, such as Industry Canada through Measurement Canada, the Canadian Standards Association, and the Canadian Standards Council. In comparison to other countries, the Canadian approach is considered to be fairly centralized and similar to the approaches of Mexico, the United States, and Australia. Countries with a decentralized approach, in which the government plays a reduced or different role than the one played by the federal government in Canada, include Brazil, Denmark, Finland, France and Japan.[134]

The way in which NRC-INMS is currently organized as well as potential alternatives were examined in internal interviews with NRC-INMS executives and group leaders. Different models were discussed in these interviews: the "stand-alone" NMI model used in Australia, the current model of an institute within NRC, and an alternative model of the groups becoming part of other NRC Institutes. Generally, interviewees felt that the Australian stand-alone model, although interesting, would not be viable here in Canada because of the relatively small size of NRC-INMS when compared to other NMIs. The current model was thought to still be the ideal structure for Canada's NMI, because as part of NRC, NRC-INMS is thought to more easily work with other institutes who have measurement capability as well as complementary facilities and equipment, as well as "expertise they might not have access to otherwise". Interviewees also felt that the Institute can attract the best personnel because they are a part of NRC. The only disadvantage raised by interviewees is that "we have to work through a high number of channels to make requests to government for more funding and coordinate with other NRC activities such as astronomy and clusters".[135]

Interviewees were also clear that the third option, that of breaking up NRC-INMS groups and distributing them among other institutes, was not viable. They felt that to do their best work, they should be leveraging from other institutes while retaining their role as measurement experts. In addition to this, interviewees felt that the Institute is "already too small to do everything, especially the emerging things, and it would be too diluted if it were split up". However, all interviewees agreed that more collaboration and cooperation is needed between NRC-INMS and other NRC institutes for a variety of reasons, such as the aforementioned access to expertise and equipment, involvement in interdisciplinary science, better responding to the needs of industry, visibility of the Institute, and cost reduction.

6.3.2 University Involvement

The role played by the academic sector in the production and dissemination of metrology also varies widely around the world. In Finland, for instance, academia provides considerable funding to the NMI, and in Denmark the NMI itself is owned by a technical university (although the representative for the Danish NMI interviewed during the International Comparison Study stated that metrology is not formally structured in academia, with only two or three universities actually involved). Canada is quite similar to the other countries studied in that academia does not play a major role in metrology. Canadian universities

[134] Ekos Research Associates, *International Comparison Study*.
[135] Internal Interviews, INMS Executives and Group Leaders (n=30).

lack metrology programs, although some partnerships do exist between certain universities and NRC-INMS with regards to specific projects. [136]

6.3.3 Industry Involvement

Industry, like academia, appears to play a variable role in metrology, depending on the country. In France, Australia and Denmark, industry is seen more as a client, a consumer of metrology rather than a contributor to it. In Denmark, some industries have metrology laboratories, but a lot of outsourcing has taken place in recent years and those firms that had metrology capacity have recently been reconsidering their actual benefits. In other words, it seems as though it may be beneficial to consider the services rendered by NRC-INMS in the same light as some of the collaborative relationships in which other NRC Institutes engage with industry. In fact, this appears to be the case internationally; in other countries participating in the International Comparison Study, the involvement of industry in metrology varies:

- Brazil's NMI has organized a process to involve industry called sector panels. INMETRO (Brazil) defines several key areas of Brazilian industry and organizes representative panels for these industries to determine what their needs are.
- Japanese industry is seen to contribute to the metrology system by way of on-the-job training in metrology, and as a manufacturer of measuring instruments. Industrial associations act as a governmental channel to collect the opinions of measuring instrument companies and to disseminate government announcements.
- Because Mexico retains some elements of its earlier closed, protective economy, industry is well aware of the need for good instruments in production systems. Therefore, it (industry) has been interested in metrology for many years. Prior to CENAM (Mexico)'s inception, Mexican industry did not have the support of national standards and had to go to the US or Canada for accreditation.
- In the US, NIST does a lot of collaborative work with industry, and also trademarks products.

6.3.4 Summary of Findings

Recent changes in the administrative structure of the Institute are generally perceived as positive and have had some impact on increasing the collegiality within NRC-INMS. The fact that the Institute is divided into four separate buildings is a cause for some concern, although it does not seem to have a significant impact on intra-Institute communications and management. Other notable administrative achievements include the implementation of the quality management system (QMS) and the standardization of the fee structure. A comparison to other organizational structures used in different NMIs revealed that the current model is most appropriate for NRC-INMS given its size, resources, and mandate.

[136] NRC-INMS, http://inms-ienm.nrc-cnrc.gc.ca/common_files/stories/brochure/inms_brochure_e.pdf (Accessed November 6, 2007).

7.0 GENERAL CONCLUSIONS AND RECOMMENDATIONS

The Strategic Plan developed by NRC-INMS in 2002[137] outlines six objectives for the Institute. These objectives are revisited here to summarize the findings of the evaluation:

- Strategic Objective 1: Lead research and development activities to ensure that current and future Canadian needs for primary measurement standards and methods are met.
- Strategic Objective 2: Lead research and development activities to ensure that current and future Canadian needs for measurement and calibration capabilities are met.

These strategic objectives relate to the core mandate of NRC-INMS as Canada's National Metrology Institute. Evaluation issues considered in this study associated with these objectives focused on the Institute's relevance and success. Overall, NRC-INMS is perceived as an essential component of the Canadian metrology system; the role played by the Institute is similar to that of other NMIs worldwide, and should remain a federal responsibility.

The extent to which the activities and mandate of NRC-INMS remain relevant to current priorities and respond to the needs of Canadians was examined based on the review of internal and external documents and through interviews with NRC-INMS representatives as well as key clients and stakeholders. Overall, it appears as though NRC-INMS continues to meet the needs of government and industry through its mandated activities in terms of enabling innovation, protecting trade interests and enhancing the quality of life of Canadians. Ongoing work in new areas, such as nanotechnology and biotechnology, reflect an interest in contributing to new economic and societal issues and will likely increase in importance in future years.

The evaluation did not identify many concrete impacts stemming from the activities of the Institute. This is due in part to the difficulties associated with the study of underpinning infrastructure such as metrology, and due to difficulties in identifying appropriate data sources for such a study. However, a cost-benefit analysis conducted on the overall impacts of metrology in Canada yielded some positive findings and showed that NRC-INMS plays a vital role in creating these economic impacts and benefits.

- Strategic Objective 3: Ensure adequate dissemination of calibration and measurement services, including improved and expanded CLAS services, and calibration services arising from research and development.

NRC-INMS derives its resources from continuing A-base funding as well as from revenue obtained for services rendered. When compared to other NMIs, it appears to be achieving important results on the international stage with fewer resources than most of the major players.

The use of NRC-INMS calibration services in cases where CLAS laboratories are able to offer the same scopes as those of the Institute were identified as problematic by laboratory representatives. However, an internal review conducted by the Institute has established that NRC-INMS is not in competition with CLAS laboratories. The fact that this perception exists, coupled with other perceptions regarding potential discrepancies in the use of the CLAS certification from one laboratory to another, indicate that NRC-INMS may need to pay particular attention to its messaging to external stakeholders.

[137] NRC-INMS Internal Document, June 2002.

Other calibration and measurement services provided by the Institute on an ad hoc basis are perceived to be critical to the ongoing operation of its industrial partners. Some of the difficulties raised by clients of the Institute include problems associated to the contracting process and a perceived lack of information about the changes made in the fee-for-service structure before it was implemented. This has damaged some of the Institute's relationships with major clients, even though the Institute communicated the upcoming changes to its clients well in advance of the implementation of the new service fees.

- Strategic Objective 4: Maintain a recognized leadership role in supporting Canada's national and global trade interests through strengthened participation in international metrology activities intended to enhance trade opportunities.

NRC-INMS is recognized as a leader in international metrology circles. This is evidenced through the number of scientists from the Institute in positions of influence in various metrology organizations and technical committees. The Institute has managed to leverage its limited resources to achieve significant results in terms of guiding the development of measurement standards at the international level.

- Strategic Objective 5: Provide leadership for the creation of a national coordinating body for the Canadian national measurement system.

Partners of the Institute in the Canadian national measurement system, such as SCC, CSA, and Measurement Canada, have emphasized the importance of NRC-INMS in creating a national coordinating body. A notable achievement of the Institute in this area is the development and growth of the network of calibration laboratories through the CLAS program.

- Strategic Objective 6: Lead the dissemination of measurement-related knowledge and technologies to all sectors of Canada through adequate outreach and training.

The courses and other educational activities undertaken by NRC-INMS are highly-regarded, both in Canada and internationally. However, there is little information available on attendance and learning outcomes, which makes it difficult to clearly assess the merit and effectiveness of these courses.

In summary, the following recommendations are based on the findings and conclusions discussed in this report.

Recommendation 1: NRC-INMS should continue to focus its efforts in developing new and emerging areas of metrology based on strategic thrusts identified by the government. However, investment of human and financial resources in these areas must be carefully weighed against its mandated responsibilities as Canada's National Metrology Institute.

Recommendation 2: The administrative mechanisms associated with the changes in the fee-for-service structure and the contracting process should be streamlined in order to reduce the burden on the partners and clients of the Institute. Further, a tracking system for education and outreach activities should be developed to enable the Institute to capitalize on participant interests and needs and to maximize the potential benefits of these activities.

Recommendation 3: The misconceptions held by some members of the measurement and calibration community regarding the duplication in the calibration services provided by NRC-INMS and the CLAS laboratories should be corrected through the communication of internal analyses conducted by NRC-INMS and other means deemed appropriate by the Institute. NRC-INMS should also pursue its ongoing efforts in rectifying issues associated with the international recognition of the CLAS certification by requesting specific information from CLAS laboratories on inappropriate requests and by continuing to participate in international fora on this question.

Recommendation 4: The Institute has made some headway in recent years in terms of actively pursuing research collaborations and of increasing the awareness of potential collaborators who support/have a stake in the Institute's mandate. These activities should be encouraged further, not only at the executive level, but for all scientific staff of the Institute. This should include a greater level of involvement from the Business Development Office in the framing of research agreements in order to encourage the development of collaborative activities.

8.0 MANAGEMENT RESPONSE

Recommendation	Response and Planned Action(s)	Responsibilities	Timelines	Measures of Achievement
Recommendation 1: NRC-INMS should continue to focus its efforts in developing new and emerging areas of metrology based on strategic thrusts identified by the government. However, investment of human and financial resources in these areas must be carefully weighed against its mandated responsibilities as Canada's National Metrology Institute.	**Accepted** The NRC-INMS Business Plan articulates the strategic importance of investments in human resources and in infrastructure (capital). HR investments address succession needs for critical, on-going activities, while providing flexibility to address research needs for emerging technologies. In fiscal year of 2008-09 NRC-INMS hired 5 new research associates and invested $ 2.6 M in equipment and infrastructure. Strategic investment in these areas will continue in the upcoming years of the 3 year Business Plan.	Director of Research	2009-2012	Publication of research results. New hires are fully trained in INMS quality system and engage in dissemination activities, as required.

Recommendation 2: The administrative mechanisms associated with the changes in the fee-for-service structure and the contracting process should be streamlined in order to reduce the burden on the partners and clients of the Institute. Further, a tracking system for education and outreach activities should be developed to enable the Institute to capitalize on participant interests and needs and to maximize the potential benefits of these activities.	**Accepted** A variety of communications means will be employed to reach partners and clients in a timely manner regarding fee increases. This will include customized mailings for key clients before changes take effect; meetings with partners; enhanced, interactive internet communications and contract administration. A centralized client feedback system is being established that captures interest in outreach and educational activities. All verbal and written (via email, internet or mail) expressions of interest are recorded and parties are advised of upcoming activities.	Director of Business and Research Support	December 31, 2009	Client satisfaction survey Streamlined web-based contracting module Well functioning database and outreach activities linked to INMS' educational and outreach program On-line facilities established to capture expressions of interest in training and/or outreach activities

Recommendation 3: The misconceptions held by some members of the measurement and calibration community regarding the duplication in the calibration services provided by NRC-INMS and the CLAS laboratories should be corrected through the communication of internal analyses conducted by NRC-INMS and other means deemed appropriate by the Institute. NRC-INMS should also pursue its ongoing efforts in rectifying issues associated with the international recognition of the CLAS certification by requesting specific information from CLAS laboratories on inappropriate requests and by continuing to participate in international fora on this question.	**Accepted** A communication strategy that addresses the misconceptions will be developed. INMS will market the information content and search functionality of the CLAS database to provide up-to-date information to potential clients regarding the capabilities of CLAS laboratories. CLAS, through its outreach program, will proactively solicit information regarding the acceptance of CLAS certification internationally and represent the CLAS laboratories' interest in international bodies such as ILAC, IAAC, APLAC, NUPIC, etc.	INMS Management Team and Group Leader of CLAS	On-going	Feedback link on website established. The web search functionality of the CLAS database is successfully marketed

Recommendation 4: The Institute has made some headway in recent years in terms of actively pursuing research collaborations and of increasing the awareness of potential collaborators who support/have a stake in the Institute's mandate. These activities should be encouraged further, not only at the executive level, but for all scientific staff of the Institute. This should include a greater level of involvement from the Business Development Office in the framing of research agreements in order to encourage the development of collaborative activities.	**Accepted** Our natural partners for collaborations related to new primary standards for physical measurements and certified reference materials for chemical measurement are other national metrology institutes. (NMIs). Many of our scientific staff are engaged in such collaborations. Many of them are not formalized in collaborative R&D agreements, but they are a vital means by which we execute our mandate. Collaborations with other NRC institutes are also increasing, in particular in the area of nanotechnology. Selection criteria for new research projects will favour collaborative projects. The Business Development Office (BDO) will actively participate in the development and negotiation of research agreements. The BDO will also ensure that agreements are worded in accordance with NRC's directives, appropriate levels of signatures are obtained and the administration of each project reflects the principles of good project management.	Director of Research	On-going	Collaborative activities are encouraged and fully supported by the Business Office.

APPENDIX A - METHODOLOGY

The evaluation covers the period 2003-2004 to mid 2007-2008, inclusive. The scope of the evaluation focuses on NRC-INMS as an Institute, rather than the broader sphere of metrology activity undertaken at NRC. However, since the two are closely linked, some issues speak to both metrology in general and NRC-INMS activities more specifically. The evaluation does not include the inputs, outputs, outcomes and impacts of partner organizations such as the Standards Council of Canada and Measurement Canada as well as international organizations such as the Bureau International des Poids et Mesures (BIPM).

1.1 Evaluation Issues

Evaluation issues, defined in the planning stage, provide the framework for data collection and analysis. These issues define the scope of the data to be collected and, ultimately, the conclusions and recommendations drawn. The specific evaluation issues are based on input by NRC senior management and NRC-INMS management. The evaluation issues identified are also aligned to the requirements of the 2001 Treasury Board Evaluation Policy (i.e., relevance, success and cost-effectiveness).

The evaluation issues examined in this study are as follows:

Relevance – What is the role of the federal government in Canada's metrology system? What is the specific role played by NRC-INMS in this system?

- What are the needs of Canadian government and industry in terms of measurement science and metrology?
- To what extent are the objectives and planned activities of NRC-INMS linked to government priorities in the area of metrology?

Impact Performance/Success – To what extent is NRC-INMS meeting its stated objectives through its ongoing programs? What are the broader socio-economic impacts of NRC-INMS activities in Canada and abroad?

- What are the impacts of NRC-INMS activities on the development of measurement standards, dissemination of measurement science, and support of Canada's national measurement system[138]? How are these outcomes linked to NRC-INMS objectives and NRC priorities?
- What is the role of NRC-INMS in international metrology? How is NRC-INMS perceived internationally in terms of the quality of its measurement science and other activities?
- Have there been other intended/unintended impacts stemming from NRC-INMS activities?
- What factors have facilitated and/or impeded the achievement of NRC-INMS outcomes?

[138] NRC-INMS Internal Document, November 2007.

Cost Effectiveness/Value for Money – Are the most effective and efficient means being used to meet objectives of NRC-INMS?

- To what extent do NRC-INMS activities complement, overlap with, or duplicate other activities internally within NRC and externally within Canada and internationally?
- What is the relationship of NRC-INMS with other metrology-related organizations in Canada and abroad? How effective have the Institute's collaborations been at achieving international traceability and recognition of NRC-INMS measurement and assessment services?
- Given the level of resources allocated to NRC-INMS are its stated objectives achievable?
- Is the distribution of resources across NRC-INMS programs appropriate? What should be the relative emphasis at NRC-INMS on research, dissemination, calibration and accreditation activities?
- Given its current budgetary allocation, how does NRC-INMS compare to other similar organizations worldwide?

Effectiveness of Design/Delivery – To what extent have the design and delivery of NRC-INMS activities (i.e., use of NRC and leveraged financial, human, capital resources, governance structures, management systems and communications) been effective (i.e., supportive of achieving objectives)?

- Does the current structure of the Institute allow for the integration of new activities related to technological advancement? Has the Institute adapted its activities and services to meet the changing needs of its clients and stakeholders?
- Are the current approaches for disseminating knowledge, advice and assistance to clients and stakeholders effective? What changes could be made to improve these?
- Does NRC-INMS have adequate processes in place to support Institute management in the decision-making process and also to assist in the ongoing operation of the Institute?
- Are there alternative approaches to the delivery of metrology and NRC-INMS?
- Are there lessons learned or best practices in terms of design / delivery (e.g., resource allocation, funding structure, planning and priority setting, performance management, governance, implementation, coordination with other institutes, etc.) that should be highlighted?

1.2 Methodological Approaches and Limitations

The evaluation methods used to address the issues identified in the previous section include:

- internal and external document review;
- administrative and performance data review;
- key informant interviews (internal and external);
- case studies;
- international comparison study;
- review of key comparison data; and
- socio-economic impact analysis.

A discussion of the approach used for each of these as well as their limitations is provided in the following paragraphs.

1.2.1 Review of Internal and External Documents

The relevance and impacts of NRC-INMS were in part identified through a review of internal and external documents. Internal documents such as strategic and business plans, performance reports, presentations, special studies done by NRC and NRC-INMS, previous evaluation studies, audit reports, and other reports were reviewed, synthesized and integrated into the evaluation to complement other lines of evidence and support analysis of NRC-INMS relevance and impacts. External documents related to the environment within which NRC-INMS operates were also reviewed for evidence of relevance and impacts and to identify potential alternatives to the organization and management practices in place.

A reference list of selected internal and external documents that were reviewed during the evaluation is provided in Appendix B. Footnotes have been included throughout the report to identify these documents as information sources. No major limitations are associated with this data source: the authorship of each paper reviewed was clearly identified, and the papers selected showed a high degree of relevance to the evaluation of a National Metrology Institute.

1.2.2 Review of Administrative and Performance Data

The evaluation also included a review of the Institute's administrative and performance data. These include:

- data collected as part of the annual call for performance data;
- financial data related to the institute's allocations and expenditures;
- other data provided by the Institute on an ad hoc basis (e.g., project files)

The performance measures collected by the Institute provided important and useful information regarding scientific and administrative outputs stemming from the activities conducted by Institute staff. However, details regarding the immediate and intermediate outcomes were not covered by the performance data and no logic model had previously been articulated for the Institute. These limitations were mitigated through the use of multiple lines of evidence.

1.2.3 In-depth Interviews

Conducting interviews with key informants is an essential element of an evaluation methodology. The information gathered through the qualitative, semi-structured interview process was based on personal experiences, opinions, and expert knowledge. This information contextualizes performance data and other statistics.

Interviews were conducted with both NRC representatives and external clients and stakeholders. The interviews were conducted in person when possible or by telephone. Each interview lasted between 30 and 90 minutes and was conducted using an interview guide. Interview guides provided the common questions to be asked of each interviewee thus ensuring that the same issues were addressed by all relevant interviewees.

A total of 42 interviews were conducted (21 respondents from NRC, 21 external stakeholders within Canada). Potential respondents were identified in conjunction with NRC-INMS. A list of organizations interviewed in provided in Appendix C. Response rates for the interviews are provided in the table below.

Respondent Group	Total number on list	Contacted	Completed interview	Did not complete	Reasons for non-completion
INMS	14	14	13	1	Declined
Other NRC Institutes	10	10	9	1	Declined[139]
Federal and Provincial Govt	11	7[140]	5	2	Unable to contact[141]
Private calibration laboratories	7	6	3	3	Declined (1) Unable to contact (2)
Hospitals and Research Centres	5	4	3	1	Unable to contact
Industry and not-for-profit	19[142]	19	10	9	Could not be reached at predetermined time (2) Declined (1) Unable to contact (4) No contact information (2)
TOTAL	**66**	**60**	**43**	**17**	Declined **(4)** **Unable to contact (8)** **Other (4)**

The main limitation of in-depth interviews is that they are highly dependent on the availability of potential participants as well as their willingness to share their thoughts and observations. The interview response data show that in this case, the participants identified by the Institute were willing to contribute and did so whenever possible. Those who were more difficult to reach were contacted several times and special allowances were made to accommodate them whenever possible.

1.2.4 Case Studies

Three illustrative case studies were conducted in order to capture the essence of some of the recent socio-economic impacts of the work of NRC-INMS. The development of each case study involved a review of relevant documents as well as a number of key informant interviews.

The main limitation of the case study approach is the fact that evaluators were dependent upon the Institute for case recommendations. This raises the potential issue that the Institute provides only highly successful cases and opportunities for learning from more difficult situations are lost. One of the ways in which this limitation was mitigated was by providing the Institute with a selection framework and asking for case suggestions based on specific criteria.

1.2.5 International Comparison Study

One of the more comprehensive components of the evaluation involved a comparison of NRC-INMS with other national metrology institutes (NMI). This study, conducted by an external contractor, involved a review of the documentation of eight comparator NMIs as well as interviews with international experts on metrology. Data on each organization's investment in metrology, scope and mandate, budget allocated to specific measurement programs, number and type of employees, and measurement activities undertaken were collected as part of the study. The findings from the international comparison study are referenced throughout this evaluation report.

[139] The potential respondent felt that another interviewee from the same institute would be better placed to respond to the planned interview questions.
[140] Potential respondents not contacted were found to be part of the same organization as some of the other respondents and so were not contacted because the views of their organization had already been recorded.
[141] "Unable to contact" implies a minimum of 3 separate attempts on the part of the interviewer through at least 2 mechanisms (i.e., voice mail and electronic mail).
[142] 18 on the list supplied by the Institute, plus one added by the evaluation team on the recommendation of another interviewee.

The main limitation of this method was the difficulty in reaching some of the participants suggested by the Institute. These individuals were typically the heads of other National Metrology Institutes, and therefore, were not always available for interviews. This issue was mitigated by involving the Director General of NRC-INMS in connecting the consultants with the individuals targeted through email or phone calls. Another limitation encountered focused on the fact that some of the documentation obtained on other NMIs was not always available in English or French; this reduced the extent to which the consultants were able to understand the issues associated with international metrology. Wherever possible, questions about the material were posed to the international contacts and clarifications were obtained in this way.

1.2.6 Review of Key Comparison Data

As Canada's National Metrology Institute, NRC-INMS participates in international key comparison studies that aim to establish comparability between NMIs and that are a significant component of the CIPM Mutual Recognition Agreement signed by Canada. A brief review of the participation of NRC-INMS in key comparisons was undertaken to generate information about the quality of the scientific work that is done at the Institute. A notable piece of information is the proportion of key comparisons for which NRC-INMS was responsible for piloting the comparison process. Data from the BIPM website were reviewed for this purpose. No major limitations are associated with this line of evidence, as it represents only a small portion of the overall evaluation methodology.

1.2.7 Socio-Economic Impact Assessment

One of the key components of the evaluation focused on identifying the retrospective and potential future socio-economic impacts of metrology in Canada. The information generated from this analysis was used in assessing the performance of NRC-INMS and has provided information used to identify the expected future outcomes of metrology activities conducted by NRC and other Canadian organizations.

The socio-economic impact analysis involved two phases. First, a literature review of academic and unpublished material was undertaken to identify some of the retrospective impacts of metrology in Canada and internationally. Second, a cost-benefit analysis was conducted to identify the specific impacts of metrology on Canadian industry by drawing on quantitative data collected from various sources and supplemented through the use of interviews and focus groups. Both the literature review and the cost-benefit analysis were contracted out to external consultants.

The main limitations associated to this method include the use of proxies for metrology activities as well as a general lack of data on the outcomes of metrology. The consultants hired for this study attempted to mitigate these limitations by making use of multiple lines of evidence to provide a number of different indicators of socio-economic impacts.

APPENDIX B – SELECTION OF DOCUMENTS REVIEWED

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Quinn, T. J. and Kovalevsky, J. 2004. Measurement and Society. C. R. Physique, **5**.

Temple, P. and Williams, G. 2002. Infra-technology and economic performance: Evidence from the United Kingdom measurement infrastructure. Information Economics and Policy, **14**.

APPENDIX C – ORGANIZATIONS INTERVIEWED

A total of 42 interviews were conducted as part of the evaluation. Of this total, 21 were conducted with external organizations. The remaining interviews were conducted internally with individuals across NRC.

NRC
NRC-Senior Executives (1)
NRC-Institute for National Measurement Standards (12)
NRC-Institute for Information Technology (2)
NRC-Institute for Marine Biosciences (2)
NRC-Institute for Microstructural Sciences (1)
NRC-National Institute for Nanotechnology (1)
NRC-Steacie Institute for Molecular Sciences (2)

Federal and Provincial Government Organizations
Canadian Food Inspection Agency (1)
Foreign Affairs and International Trade Canada (1)
Health Canada (1)
Hydro-Québec (1)
Measurement Canada (1)

Private Calibration Laboratories
Canadian Standards Association (1)
Fisher Scientific (1)
TransCanada Calibrations (1)

Hospitals and Research Centres
Carleton University (1)
Ontario Power Generation Inc. (1)
Ottawa Hospital Regional Cancer Clinic (1)

Industry and Not-for-Profits
Atomic Energy Canada Ltd. (1)
Balance Canada Inc. (1)
Canadian Blood Services (1)
CMC Electronics (2)
Firebird Technologies (1)
McGill University (1)
Measurement International Limited (1)
Pulp and Paper Research Institute of Canada (1)
Redlen Technologies Inc. (1)

APPENDIX D – COMMITTEE WORK

The following list includes the names of NRC-INMS researchers and staff sitting on metrology-related international committees and working groups in 2006.

ELECTRICAL POWER MEASUREMENTS GROUP

Comité International des Poids et Mesures (CPEM)

1. **Comité Consultatif d'Électricité et Magnetism (CCEM)**
   E. So, Member
2. **Conference on Precision Electromagnetic Measurements (CPEM)**
   E. So, Chair of the CPEM Executive Committee,
   T. McComb, Secretary of the CPEM Executive Committee

International Electrotechnical Commission (IEC)

1. **IEC Technical Committee 42: High Voltage Test Techniques, ex officio member as chair of CSC TC42**.
   T.R. McComb, Member
2. **TC68 - Magnetic Alloys and Steel.**
   E. So, Member

Conference Internationale des Grands Réseaux Electriques (CIGRE)

1. **WG 12.16 - Instrument Transformers**
   A. T. Bulinski, Member
2. **WGD1.33 - High Voltage Measuring Techniques.**
   T.R. McComb, Member

Institute of Electrical and Electronics Engineers, Inc. (IEEE)
Power Engineering Society (PES)

1. **PES Power Systems Instrumentation and Measurements Committee (PES PSIM)**
   E. So, Past Chair and Liaison
2. **Transformers Committee and Instrumentation and Measurements Society**
   R. Arseneau, Secretary, T.R. McComb, Member
3. **PES/PSIM Digital Techniques in Electrical Measurements Subcommittee**
   T.R. McComb, Member, E. So, Member and Liaison, Transformers Committee
4. **PES/PSIM High Voltage Test Techniques Subcommittee**
   T. McComb, E. So, Members
5. **PES/PSIM Electricity Metering Subcommittee**
   E. So, Chair, R. Arseneau, T.R. McComb, Members
6. **PES/PSIM WG Non-Sinusoidal Situations**
   R. Arseneau, T.R. McComb, Members
7. **PES/PSIM WG Instrumentation for Non-Sinusoidal Situations**
   R. Arseneau, Chair
8. **PES/PSIM WG Diagnostic Field Testing of Power Apparatus**
   E. So, Member and Liaison, Transformers Committee
9. **PES/PSIM WG High Voltage Low Power Factor Power Measurements**
   E. So, Chair
10. **PES/PSIM WG on Optical Instrument Transformers**

E. So, Member

11. **PES/PSIM Awards Committee**
    T. McComb, Coordinator
12. **PES Transformers Committee - Instrument Transformers Subcommittee**
    E. So, Member
13. **PES Transformers Committee - Performance Characteristics Subcommittee**
    E. So, Member
14. **PES Transformers Committee - WG Loss Tolerance and Measurements**
    E. So, Member
15. **PES Transactions on Power Delivery**
    R. Arseneau, Editor
16. **PES 2006 General Meeting**
    R. Arseneau, Technical Committee Program Chair

Institute of Electrical and Electronics Engineers, Inc. (IEEE)
Instrumentation and Measurements Society

1. **Editorial Review Committee**
   T.R. McComb & E. So, Members
2. **TC10 Digital Waveform Recorders**
   T.R. McComb, Corresponding Member

Institute of Electrical and Electronics Engineers, Inc. (IEEE)
Dielectrics and Electrical Insulation Society (DEIS)

1. **DEIS**
   S.S. Bamji, Treasurer; A. Bulinski, Chair of the DEIS Meetings Committee
2. **Conference on Electrical Insulation and Dielectric Phenomena**
   S.S. Bamji, A. Bulinski, Members of Executive Committee
   M. Abou-Dakka, Member of Technical Committee
3. **IEEE International Conference on Solid Dielectrics**
   A.T. Bulinski, International Advisory Committee (IAC) Member
4. **IEEE International Symposium on Electrical Insulation**
   A.T. Bulinski, IAC Member
5. **IEEE International Symposium on Electrets**
   A.T. Bulinski, IAC Member
6. **IEEE International Conference on Liquid Dielectrics**
   A.T. Bulinski, IAC Member
7. **IEEE International Conference on Properties and Applications of Dielectric Materials**
   A.T. Bulinski, IAC Member

International Conference on Electrical Insulating Materials
A.T. Bulinski, Chair of IAC
International Symposium on Discharges and Electrical Insulation in Vacuum
A.T. Bulinski, IAC Member
2007 International Symposium on High Voltage Engineering
A.T. Bulinski, Member of the Organizing Committee
2008 International Conference on Condition Monitoring and Diagnostics
A.T. Bulinski, Member of the Organizing Committee
2007 International Conference on Polymeric Materials in Power Engineering
S.S. Bamji, Member of the Intl. Advisory Committee
Korean Institute of Electrical Engineers
S.S. Bamji, Member of Editorial Advisory Board of Transactions on Electrophysics

Wiley Encyclopedia of Electrical and Electronics Engineering
A.T. Bulinski, Member of International Editorial Board

ELECTRICAL STANDARDS GROUP

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Barry Wood, Peter Filipski members
CPEM 2006 Executive Committee
Barry Wood, member
CODATA Task Group on Fundamental Constants
Barry Wood, chairman
Consultative Committee for Electricity and Magnetism
D. Inglis, member.
Consultative Committee for Electricity and Magnetism's Working Group on the Proposed Modification to the SI
Barry Wood, chairman
Consultative Committee for Electricity and Magnetism's GTRF
Alain Michaud, member.
Consultative Committee for Electricity and Magnetism's Working Group on Low Frequency
D Inglis, Rapporteur
US National Academy of Science's Review Panel of NIST Laboratory of Electrical and Electronic Engineering
Barry Wood, chairman
International Conference on Instrumentation and Measurements IMTC 2007
Peter FIlipski member of the Technical Committee
Electricity and Magnetism Metrology Working Group of SIM
Peter FIlipski, member

THERMOMETRY GROUP

CCT WG1: defining fixed points and interpolating instruments
Ken Hill, Member
CCT WG2: secondary reference points and techniques for approximating the ITS-90
Ken Hill, Member
CCT WG4: thermodynamic temperature determinations and extension of the ITS-90 to lower temperatures
Ken Hill, Member
CCT-TGSI: Task Group on the SI
Ken Hill, Member
SIM MWG3: Thermometry
Ken Hill, Member

ACOUSTICAL STANDARDS GROUP

Comité International des poids et mesures (CIPM)
Consultative Committee on Acoustics, Ultrasound and Vibration (CCAUV)
G.S.K. Wong, NRC-INMS representative
L. Wu, NRC-INMS representative

Sistema Interamericano de Metrologia (SIM)
Metrology WG 9: Acoustics Ultrasound & Vibration
L. Wu, Member
ASA Accredited Standards Committee on Acoustics, S1
G.S.K. Wong, Individual Expert
L. Wu, Individual Expert
ASA Committee on Signal Processing
L. Wu, Member
ANSI S1-1: Standard Microphones and their Calibration
G.S.K. Wong, Member
L. Wu, Member
ANSI S1-5: Band filter sets
G.S.K. Wong, Member
L. Wu, Member
ANSI S1-17: Sound Level Meters and Integrating and Sound Level Meters
G.S.K. Wong, Member
L. Wu, Member
ANSI S1-25: Specification for Acoustical Calibrators
P. Hanes, Member
L. Wu, Member
ISO/TC108/SC3/WG6: Calibration of vibration and shock transducers
G.S.K. Wong, Member
L. Wu, Member
IEC/TC29/WG4: Sound Level Meters
G. S. K. Wong, Member
IEC/TC29/WG5: Calibration of Standard Condenser Microphones
G. S. K. Wong, Member
L. Wu, Member
IEC/TC29/WG17: Sound Calibrators-Test Procedures
G.S.K. Wong, Member
IEC/TC29/WG18: Amendments of relevant IEC/TC29 standards with respect to developments on EMC
G.S.K. Wong, Member
IEC/TC29/MT 19: Revision of IEC 61260 (Filters)
G.S.K. Wong, Member
International Organization for Standardization
ISO/TC43/SC1/WG28: Sound Power Levels of Noise Sources
G.S.K. Wong, Member
ISO/TC43/SC1/WG25: Measurement of Sound Intensity
G.S.K. Wong, Member

DIMENSIONAL METROLOGY PROGRAM

Comité international des poids et mesures (CIPM)
Consultative Committee for Length (CCL)
J.R. Pekelsky, Member
CCL WG on Dimensional Metrology (WGDM)
J.R. Pekelsky, Member
International Organization for Standardisation (ISO)

ISO/TC 213: Dimensional and Geometrical Product Specifications and Verification
K.I. Doytchinov, Member
ISO/TC 213/WG1: Roundness, Cylindricity, Straightness, Flatness
K.I. Doytchinov, Member
ISO/TC 213/WG2: Datums and Datum Systems
K.I. Doytchinov, Member
ISO/TC 213/WG5: Calibration Procedures for Surface Texture
K.I. Doytchinov, Member
ISO/TC 213/WG10: Coordinate Measuring Machines
K.I. Doytchinov, Member
ISO/TC 213/WG11: ISO3650 Gauge Blocks
J.E. Decker, Member
ISO/TC 229 & IEC/TC113 Nanotechnologies
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Interamerican Metrology System (SIM)
SIM Technical Committee
J.R. Pekelsky, Member
SIM Metrology Working Group for Length
J.R. Pekelsky, Member
SIM.L-K2 Long Gauge Block Calibration by Optical Interferometry
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Optical Society of America (OSA)
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American Society of Mechanical Engineers (ASME)
Standards Committee B89.7: Measurement Uncertainty
K.I. Doytchinov, Member

MASS STANDARDS PROGRAM

Consultative Committee for Mass and Related Quantities (CCM)
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CCM WGM: Mass Working Group
C. Jacques, Member
CCM WGD: Density
C. Jacques, Member
CCM WGHP, WGMP, WGLP: High, Medium and Low Pressures
A.K. Agarwal, Member
CCM WGCMC: Working Group on CMC
C. Jacques, Member
SIM and NORAMET TC
C. Jacques, Member
SIM MWG-7: Mass and related quantities
C. Jacques, Chairman
A.K. Agarwal, Member
SIM MWG-7 subWG on mass
C. Jacques, Member
SIM MWG-7 subWG on density
C. Jacques, Member
SIM MWG-7 subWG on NAWI (Non Automatic Weighing Instruments)

C. Jacques, Member

SIM MWG-10: Flow and Related Quantities

C. Jacques, Member
A.K. Agarwal, Member

IONIZING RADIATION STANADARDS GROUP

Calibration Laboratory Assessment sub-committee of the American Association of Physicists in Medicine

Malcolm McEwen

Task Group 105 of the American Association of Physicists in Medicine on Monte Carlo techniques for radiation therapy

Iwan Kawrakow

NRC representative on the CCRI(I) committee of the BIPM

Carl Ross

CHEMICAL METROLOGY GROUP

AOAC Task force on Dietary Supplements

Anthony Windust

AOAC Expert review panel on analytical methods for ginseng

Anthony Windust

NSF Joint Committee on Dietary Supplements

Anthony Windust

Comité Consultatif pour la Quantité de Matière (CCQM), Organic Analysis Working Group

Anthony Windust

Canadian representative to IUPAC division V

Zoltan Mester

Comité Consultatif pour la Quantité de Matière (CCQM), Inorganic Analysis Working Group

Ralph Sturgeon

Joint Committee on Traceability in Laboratory Medicine: Nonelectrolyte metals review section of CCQM Working Group I

Ralph Sturgeon

European Virtual Institute for Speciation Analysis (Advisory Board)

Ralph Sturgeon

OPTICAL FREQUENCY GROUP

Comité Consultatif des Longueurs (CCL), Mise-en-Pratique working group

A.A. Madej, member

Comité Consultatif des Longueurs and Comité Consultatif de Temps et des Frequences (CCL/CCTF), Joint working group on secondary realizations of the second

A.A. Madej, member

National Committee Representative, Division of Atomic and Molecular Physics and Photon Interactions (DAMPhi), Canadian Association of Physicists

A.A. Madej, Division Chair

PHOTOMETRY AND RADIOMETRY GROUP

Commission International de l'Eclairage (CIE):
Division 2: Physical Measurement of Light and Radiation -
J.C. Zwinkels, Canadian member
Division 8: Image Technology
R. Baribeau, Canadian member

TC 1-44 Practical Daylight Sources for Colorimetry
J.C. Zwinkels
TC 1-45 Revision of CIE Publication No. 51 to Include D50 Simulators
J.C. Zwinkels
TC 1-47 Hue and Lightness Dependant Correction to Industrial Colour Difference Equation
A.R. Robertson
TC 1-53 Standard Method of Assessing the Quality of Daylight Simulators
- J.C. Zwinkels
TC 1-55 Uniform Colour Space for Industrial Colour Difference Evaluation
A.R. Robertson
TC 1-56 Improved Colour Matching Functions
A.R. Robertson
TC 1-57 Standards in Colorimetry
A.R. Robertson (Chairman),
J.C. Zwinkels
TC 2-25 Calibration Methods and Photoluminescent Standards for Total Radiance Factor Measurements
J.C. Zwinkels (Chairman)
TC 2-28 Methods of Characterizing Spectrophotometers
A.R. Robertson
J.C. Zwinkels
TC 2-39 Geometric Tolerances for Colorimetry
J.C. Zwinkels
TC 2-42 The Colorimetry of Visual Displays
R. Baribeau
TC 2-43 Determination of Measurement Uncertainties in Photometry
– A.A. Gaertner
TC 2-47 Characterization and Calibration Methods of UV Radiometers
L.P. Boivin
TC 2-48 Spectral Responsivity Measurement of Detectors, Radiometers and Photometers –
L.P. Boivin
TC 2-57 Revision of CIE S014-2
A.R. Robertson (Chairman),
J.C. Zwinkels
TC 2-60 Effect of instrumental bandpass function and measurement interval on spectral quantities
J.C. Zwinkels
R2-35 Uncertainties in Distribution Temperature Determination
A.R. Robertson (Reporter)

International Committee of Weights and Measures:
Comité consultatif de Photométrie et Radiométrie

J.C. Zwinkels
International Key Comparison of Spectral Irradiance (K1a)
– A.A. Gaertner
International Key Comparison of UV Spectral Irradiance (K1b)
– A.A. Gaertner
International Supplementary Comparison #1 (Spectral Radiance)
– A.A. Gaertner
Working Group on Key Comparison #2 (Spectral Responsivity)
L.P. Boivin
Working Group on Key Comparison #5 (Spectral Diffuse Reflectance)

J.C. Zwinkels

International Key Comparison #6 (Spectral Regular Transmittance)

J.C. Zwinkels

International Organization for Standardization:
TC 6/WG 3 Optical Properties of Paper, Board and Pulp
J.C. Zwinkels

Munsell Color Science Laboratory, Advisory Board
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