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# MOBILIZING OUR SCIENCE AND TECHNOLOGY



*S&T at Natural Resources Canada*

Canada 





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## Foreword

In advancing the priorities of the Government of Canada, in particular, the responsible development and use of Canada's natural resources, Natural Resources Canada (NRCan) works with a wide range of partners in the pursuit of complex, multi-disciplinary scientific issues and challenges. The Department applies its significant science and technology (S&T) capacity in pushing the frontiers of knowledge and is well known as one of the Government's leading S&T-based organizations. S&T accounts for about half of the Department's operating budget, or about \$500 million per year, and more than half of NRCan employees are involved in S&T in one way or another. This report demonstrates that S&T makes a significant contribution to the achievement of the Department's three strategic outcomes while maintaining alignment with the federal S&T Strategy, *Mobilizing Our Science and Technology to Canada's Advantage*.

The paramount role of S&T in shaping the contribution of NRCan to Canada's public interest drove a need to strengthen the governance of S&T to ensure the best return from our ongoing investment in this critical asset. As a first step in this direction, in March 2011, the first meeting was held of the newly formed NRCan Science and Technology Board that I chair with support from our Chief Scientist. The Board was comprised initially of the Department's Assistant Deputy Ministers with a responsibility for S&T. At a later meeting, three external members joined the Board, each an expert in the management of S&T, but from different perspectives from across the innovation ecosystem of Canada. The Board has been the main vehicle for increasing the capacity of the Department to oversee and enhance the management of its S&T.

At about the same time, NRCan was developing its suite of corporate priorities, the product of a series of discussions at our executive table and in dialogue with the leadership of the Department from right across the country. In recognition of the importance of the S&T efforts, one of the four corporate priorities identified was Mobilizing Our Science and Technology (MOST). The S&T Board was identified as the governance body responsible for coordinating the implementation of this priority.



One of the first tasks was to find a convenient way to provide a clearer view of NRCan's S&T. As it turns out, the Department's Program Alignment Architecture (PAA) provided a natural, complete and detailed blueprint of all of NRCan's S&T activities. Twenty-three signature S&T projects, each nested within the structure of the PAA, were identified that, in a sense, provide a portal into NRCan's S&T. The signature S&T projects do more: they provide a backdrop against which management tools can be applied for improving the management of S&T and for Department-wide, horizontal approaches. In large part, this is the task of the S&T Board going forward.

This MOST report provides an overview of the 23 signature S&T projects, their accomplishments and impacts. The report describes the work of the S&T Board to date. It also takes the Blueprint 2020 initiative as a starting point for looking at government science, and therefore NRCan science, toward the year 2020.

I wish to thank Geoff Munro, NRCan's Chief Scientist and his staff for their efforts in preparing this report and in bringing to life the initiative of Mobilizing Our Science and Technology. I welcome Brian Gray as the new Chief Scientist of NRCan who will have the mandate to mobilize colleagues in carrying our agenda forward.

Most importantly, I reach out to all of NRCan's science community with an invitation to engage, as part of Blueprint 2020, and as an ongoing enterprise, in bringing forward the very best means to plan, deliver, measure and communicate our science in the interest of serving well, and always better, our fellow Canadians.

**Serge Dupont**

Deputy Minister  
Natural Resources Canada

**Brian Gray**

Assistant Deputy Minister, Earth Sciences  
Natural Resources Canada

**Geoff Munro**

Chief Scientist  
Natural Resources Canada  
(Retired December 30, 2013)

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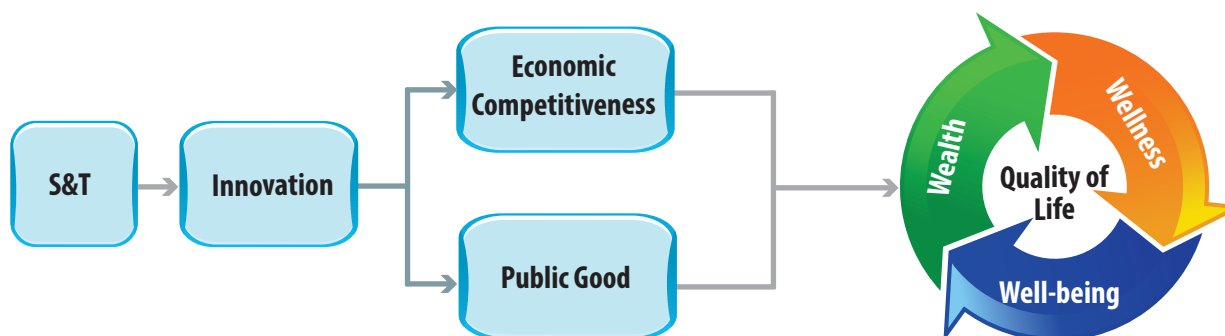
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## 1. The Importance of Science and Technology: NRCan Contributing to Canada's Goals

Natural Resources Canada (NRCan) is one of several federal science-based departments and agencies (SBDAs).<sup>1</sup> The SBDAs undertake two broad categories of science and technology. The first, *Research, Development and Demonstration (RD&D)*,<sup>2</sup> develops, tests and helps to apply new knowledge. For example, RD&D can take the form of improvements to industrial processes or the finding of new, cleaner sources of energy. The second, *Related Scientific Activity (RSA)*, includes such endeavours as the mapping of Canada's landmass and the use of scientific methods for regulation and testing. Both types of activity support achievement of the Department's three strategic outcomes, strengthen industry and Canada's innovation ecosystem and help open doors to international markets.

Canada's resource industries are global in nature and employ about 1.6 million people both directly and indirectly. Innovation, supported by science and technology (S&T) makes an essential contribution to the lessening of environmental impact, to the reduction of costs, to improvements in quality and to the production of unique, higher-value products. The reduction of the environmental "footprint" is key to establishing the social license needed to proceed with major resource projects, and as illustrated in the following diagram, maintain and grow the contributions of S&T to the quality of life for all Canadians.



<sup>1</sup> The science-based departments and agencies are Agriculture and Agri-Food Canada, Canadian Food Inspection Agency, Canadian Space Agency, Communications Research Centre Canada, Defence R&D Canada, Environment Canada, Fisheries and Oceans Canada, Health Canada, Industry Canada, National Research Council of Canada, Natural Resources Canada, Public Health Agency of Canada, and Transport Canada.

<sup>2</sup> This is normally referred to as Research and Development (R&D) with "Demonstration" included as part of "Development." Given the important role of NRCan in supporting demonstration projects, the second "D" is added for emphasis. Statistics Canada follows the definition provided in the *Frascati Manual* (OECD, 2002) of research and experimental development.



These contributions by NRCan to Canada’s innovation ecosystem do not happen in isolation; NRCan works closely with partners including industry, academia, provincial/territorial governments, non-governmental organizations and communities. As well, the Department cooperates and coordinates with other science-based departments and agencies through various federal interdepartmental S&T committees. As noted earlier, S&T in the federal government is guided by a strategy called *Mobilizing Science and Technology to Canada’s Advantage*. NRCan has also developed its own S&T Strategy that aligns with the federal one.

Canada is an ardent participant in international research efforts; this parallels the export-oriented, outward-looking character of the economy. Indeed, science has added to the “language” of international relations in matters of international public science such as regulation and safety, environmental protection, health, security, standards and basic research as well as in terms of international business. For example, with growth in global markets for clean and “green” technology, NRCan’s work on Green Mining is opening doors in global markets for Canadian manufacturers and suppliers of these products and services.





NRCan's CanmetMATERIALS Laboratory, colocated with McMaster University in Hamilton, Ontario

## 2. Science and Technology at NRCan

### Context

NRCan is an established leader in S&T in the fields of energy, forests, and minerals and metals. As well, the Department uses its world-leading expertise in earth sciences to build and maintain an up-to-date knowledge base of Canada's landmass. To fulfil the responsibilities of its legal mandate, NRCan is organized to achieve three strategic outcomes:

- Canada's natural resource sectors are globally competitive.
- Natural resource sectors and consumers are environmentally responsible.
- Canadians have information to manage lands and are protected from related risks.



The Department's S&T plays a central role in achieving these strategic outcomes. As well, the Department represents Canada at the international level and takes a leadership role in efforts to meet the country's global commitments related to the sustainable development of natural resources.

NRCan has 19 major scientific establishments (see the map) supported by smaller facilities, research sites and permanent sample plots that are found from coast to coast to coast across

Canada. In these diverse facilities, the Department conducts innovative science to generate and transfer new knowledge, technologies and tools as well as develop S&T products and services to support regulations and standards.

NRCan is the only S&T organization in Canada with *national* capabilities in earth science, energy, minerals and materials, and forestry. NRCan's S&T effort covers a broad range of disciplines and must respond to regional differences in geography and differing patterns of natural resource availability and use across the country. The Department's S&T is recognized to be of high quality given the worldwide reputation of NRCan's scientific and technical specialists in many fields.





## How NRCan Manages its Science and Technology

Like all federal departments and agencies, NRCan is accountable to Parliament and the Canadian public for the activities it undertakes and the resources it spends. While the departmental strategic objectives provide an operational framework, it is the Deputy Minister's S&T Board that provides department-wide leadership and governance that is specific to the Department's S&T.

NRCan, as part of the Mobilizing Our Science and Technology (MOST) initiative, has created a financial reporting system for S&T to provide timely and accurate financial reporting – an essential tool for ensuring accountability. Beginning with fiscal year 2013–2014, reports can be obtained on expenditures of 23 signature S&T projects at any time. Finances are broken down by "vote" to be able to report on expenditures on salary, operations, grants and contributions, and capital equipment.<sup>3</sup> This system will have the flexibility to meet the data requirements of the Integrated Business Plan and the Investment Plan. A sample of this financial management system can be seen in the Appendix to this report.

NRCan's S&T governance system comprises the Department's three strategic outcomes and the 23 signature S&T projects that work to achieve those outcomes and to implement the Department's own S&T Strategy. This system is a pioneering attempt, within the federal S&T community, to combine such tools to create an S&T management system.

<sup>3</sup> Votes refer to the votes in Parliament that establish spending authority for the Department.

Under the MOST priority, NRCan is improving capacity to manage its vast array of S&T activities. A number of tools have been developed and are being implemented by the S&T Board and to date they include

- As noted previously, NRCan's S&T activities are described in 23 **signature S&T projects** that range from green mining to several efforts in clean energy, to forest sector innovation to geo-hazards and public safety. All 23 of these projects are aligned with and designed to help achieve one or more of the Department's three strategic outcomes. These projects also provide a backdrop against which the Department can hold itself accountable and report on its S&T enterprise.
- A departmental **Intellectual Property Policy** that was approved on October 10, 2013, will encourage uptake of NRCan's intellectual property – achieving maximum impact for Canada through broad dissemination where suitable or through commercialization as needed to respect the investment of collaborators.
- The financial reporting system described above was developed to allow **detailed tracking of S&T financial expenditures** based on the Department's Program Alignment Architecture (PAA) financial codes. This tool will allow the S&T Board to monitor expenditures in each signature S&T project, components of projects or combinations of projects and array them in different ways to analyse both tactical and strategic S&T investment opportunities.
- To ensure that the Department's international S&T collaborations are effective and support departmental priorities, an **international S&T framework** has been developed. The framework, while not a policy, guides decision making and provides useful tools to assist in the preparation of international S&T agreements.
- To effectively communicate NRCan's science to the policy community and to the Department and to Canadians at large, while ensuring appropriate and consistent management of publications across the Department, an **S&T Publications Policy** was implemented March 1, 2013.

Each of these tools is posted, for internal departmental use, on the NRCan wiki page called Mobilizing Our Science and Technology<sup>4</sup> to provide a single point of access for all staff in the Department.



<sup>4</sup> [http://wiki.nrcan.gc.ca/index.php/Mobilizing\\_our\\_Science\\_and\\_Technology](http://wiki.nrcan.gc.ca/index.php/Mobilizing_our_Science_and_Technology). For those external to the Department who wish to obtain a copy of this documentation, contact the NRCan Office of the Chief Scientist.

## Moving Forward

When it was created, the S&T Board had a long “to do” list. The accomplishments previously listed indicate that some of the items can be checked off. However, there is more to be done and the S&T Board has a forward agenda that includes the following:

- a cluster of **S&T human resources issues** including development of guidelines for the role of **emeritus scientist**, establishing a policy with respect to **adjunct professorships** and addressing the matter of **research integrity**. The latter will involve a review of principles in the context of the **NRCan Values and Ethics Code**.
- development of a **Science and Technology Performance Measurement** system to ensure the continuing relevance, impact and quality of NRCan S&T
- coordinated implementation of an **S&T Outreach Strategy** to bring S&T to the general public and especially to students with a view to encouraging careers in science and engineering
- responding to an expected **refresh of the federal science and technology strategy**. First released in 2007 and last updated in 2009, the strategy is due for a “refresh,” likely in early 2014. It is anticipated that the refreshed strategy will address emerging issues related to Open Data and Open Science – addressed in this report in Chapter 3.
- responding to the results of the **Blueprint 2020** initiative and development of S&T related components of an action plan



The future will bring new issues and challenges related to managing NRCan’s S&T in addition to the ones listed above. It is one of the roles of the S&T Board to review the departmental S&T efforts on a continuing basis and to guide the implementation of the MOST priority within NRCan.

With governance and management tools in hand, and with more to follow, the S&T Board is better positioned to strategically manage the S&T investments of the Department as described by the 23 signature S&T projects,<sup>5</sup> which are detailed in the following section.

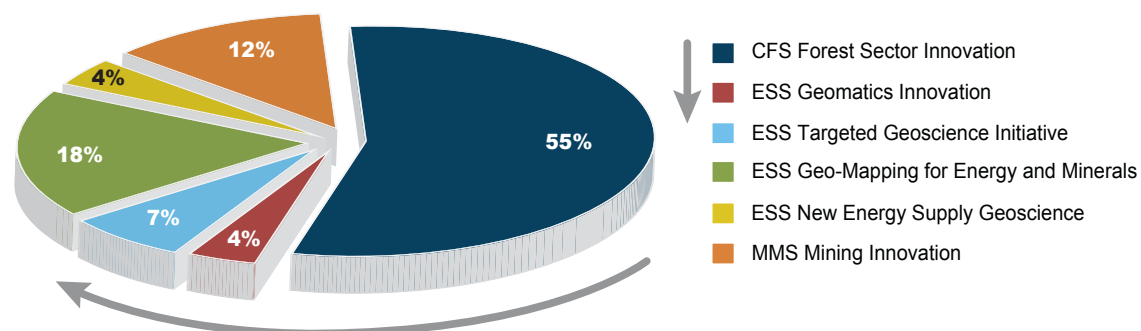
<sup>5</sup> Descriptions are based on activity for fiscal year 2013–2014.



## Strategic Outcome 1. Canada's natural resource sectors are globally competitive.

Under the rubric of activities intended to achieve the first strategic outcome are six signature S&T projects, including support for innovation in three areas: the forest sector, geomatics and green mining. As well, there are three earth science projects in this group supporting efforts to achieve this strategic outcome: the Targeted Geoscience Initiative; Geo-Mapping for Energy; and Minerals and New Energy Supply Geoscience. The pie chart below provides a breakdown of science and technology resources devoted to this outcome based on approximations for the 2012–2013 fiscal year.

### Resource Sectors are Globally Competitive (\$155.7 million)



Canadian Forest Service (CFS); Earth Sciences sector (ESS); Minerals and Metals sector (MMS)

The **Forest Sector Innovation** signature S&T project performs research and funds partnerships that develop new or improved products and processes and create new markets for Canadian forest products. This activity, over the last 10 years, has encouraged the industry to move away from process innovation toward product innovation such as the development of nano-crystalline cellulose. NRCan played a pivotal role realigning forest sector S&T institutions to reduce fragmentation in forest sector R&D. This was accomplished through the consolidation of three national forest sector research institutes – FERIC, Forintec and Paprican – into FPIInnovations. The Department was also instrumental in the creation and integration of the Canadian Wood Fibre Centre into FPIInnovations.

In a joint effort with the Natural Sciences and Engineering Research Council (NSERC) and FPIInnovations, NRCan worked to create a Forest Sector R&D Initiative with a commitment from NSERC of \$34 million over five years. This supports four existing forest research networks and created four new networks: NSERC Innovative Green Wood Fibre Products Network; NEWBuildS – NSERC Network on Engineered Wood-based Building Systems; NSERC

### Nano-crystalline cellulose

Nano-crystalline cellulose (NCC), derived from the cell walls of trees and plants, has special properties making it suitable for new and advanced bio-products. The potential for the use of NCC in materials development is wide and varied. Reinforced polymers, high-strength textiles and advanced composite materials are being explored for potential use of NCC. It could also enhance the properties of paints, varnishes and other coatings. Eventually, NCC could be used in the manufacture of lightweight components for automobiles and airplanes, leading to much lighter, more durable and greener products. The estimated North American market potential is more than \$1 billion annually.

Value Chain Maximization Network; and Lignoworks – the NSERC Biomaterials and Chemicals Network. Collectively, the eight networks provide opportunities for research and training of 400 graduate students in forestry-related fields. The networks also will improve the technology transfer process by integrating university researchers with industry and government organizations.

A significant part of the **Mining Innovation** signature S&T project is the Green Mining Initiative (GMI).<sup>6</sup> Through the GMI, new mining technologies and processes are developed to improve energy efficiency and to reduce greenhouse gas (GHG) emissions and other environmental impacts. It works to protect ecosystems in areas close to mining sites, such as in northern and remote communities, in support of socially responsible mining practices in Canada and abroad. The initiative addresses the full life cycle of the mine, from exploration to extraction to mine closure and addresses clean water, environmental management, energy efficiency, metals processing, northern mineral development and radioactive waste management. The GMI works to reduce operating costs for the mining industry and improve the competitiveness of the Canadian mining sector. This activity also supports priorities of Atomic Energy of Canada Limited (AECL) and decreases the cost of long-term disposal of spent nuclear fuel and associated risks to the health, safety and security of Canadians.

The **Geomatics Innovation** signature S&T project, which includes the Emergency Geomatics Service (EGS), leverages NRCan's unique capabilities to gather, analyze and disseminate geographic information. The Department is the single largest generator and custodian of geospatial data in the federal government. Its information holdings include the positions of energy transmission lines, railways and transportation infrastructure, as well as public safety and security data related to earthquakes, space weather and flood events derived from satellite sensors, to mention just a few examples. The Department leads the development of systems and tools for more efficient and effective use of vast geospatial data assets across the federal government, in accordance with the concept of open science. For example, over the last 15 years, NRCan has been developing operational policies, standards and framework data to manage geospatial information nationally. This work is the basis of Canada's contribution to the international Arctic Spatial Data Infrastructure (Arctic SDI) project. The Arctic SDI allows the mapping agencies of the eight circumpolar countries to work together on common projects and issues that cross borders such as search and rescue response, pollution monitoring, and changes in biodiversity.

### The GMI helps with gold recovery.

The GMI has developed and licensed an enhanced leaching process to recover gold. Productivity gains of \$28 million from increased gold recovery at two gold mines have resulted from this process.

### Emergency Geomatics Service

NRCan's EGS enables geomatics specialists in emergency management agencies to download large digital files derived from satellite imagery. The 2013 spring flood season was the first test – a successful one – of operations of this new service, with the aim of faster information processing to allow for more strategic emergency management and response.

<sup>6</sup> The Green Mining Innovation signature S&T project transcends competitiveness (Strategic Outcome 1) and environmental responsibility (Strategic Outcome 2) but because of the importance of enhancing the competitiveness of the mining industry, this project is located under Strategic Outcome 1. A significant portion of the Mining Innovation signature S&T project is the Green Mining Initiatives, which is highlighted in this MOST report.

The **Geoscience for New Energy Supply (GNES)** signature S&T project generates knowledge about petroleum resources located in shale formations and in Canada's northern frontier basins. This knowledge helps decision makers determine which areas within a region or basin are viable for exploration by private sector firms. The program provides assessment methodologies to reduce uncertainty and exploration risk and, in the process, attract investment. NRCan's development of this targeted national, pre-competitive energy geoscience contributes to decision making by governments and companies. NRCan brings together partners in the energy geoscience community for collaboration and collective research priority setting. NRCan expertise contributed to the "Scotian Slope" reassessment in Nova Scotia's offshore that fostered renewed investment in exploration of Nova Scotia's petroleum resources.

### The GEM program identifies petroleum resources.

A petroleum resource assessment for the Mackenzie Valley released under GEM in 2010, along with various other publications, indicated large undiscovered reserves of oil and natural gas. Recent exploration licences acquired by five companies are in the area of GEM work, including an airborne gravity survey in the area south of Norman Wells.

### TGI4 – Three ways of detecting ore

Projects were completed using high resolution gravity surveys, multifaceted seismic surveys and geochemical analysis. For example, data acquired using a gravity technique was the catalyst for MacDonald Mines' use of the technique to determine the extent of the large mineralized area over the Ring of Fire region of northern Ontario.

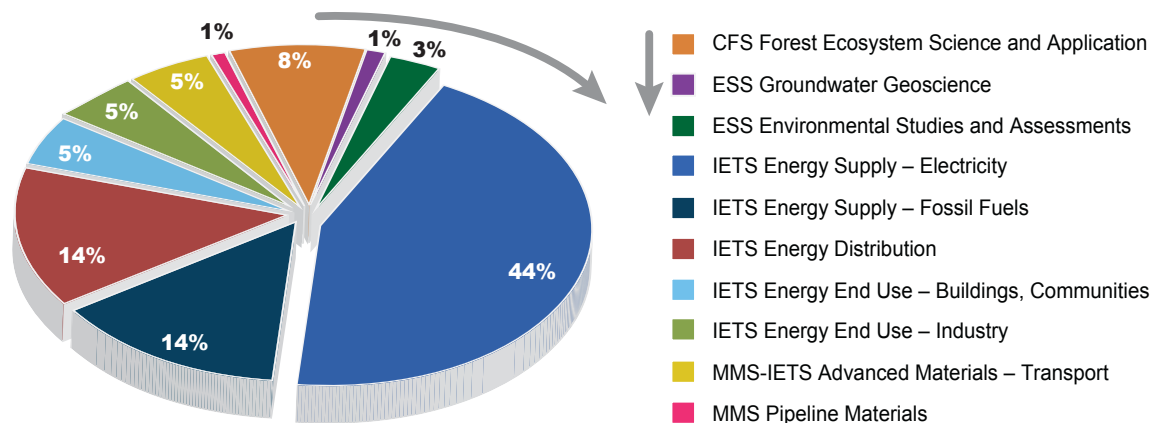
Two other earth sciences signature S&T projects work toward the competitiveness strategic outcome: the **Targeted Geoscience Initiative 4 (TGI-4)** and the **Geo-mapping for Energy and Minerals (GEM)** program. Both of these involve the gathering, analysis and dissemination of geological information. The **GEM** program is focussed on upgrading geological knowledge in northern Canada to modern standards. Using ground field observations as well as a customized array of modern geoscience techniques, NRCan provides state-of-the-art geological models for poorly known areas in the North. The GEM program provides evidence for resource investment and land-use planning, enabling northerners to make knowledgeable choices about their future prosperity and well-being. The **TGI-4**, the fourth in a series of such programs, undertakes fundamental research on the geological processes that lead to the deposit of ore systems deep inside Canada's geology. The program develops innovative methods, tools and techniques to improve detection of ore deposits and shares this knowledge with the mineral exploration industry to allow more effective discovery of new or deeply buried mineral deposits in Canada. NRCan releases national geological maps, surveys, mineral resource assessments and methodologies that help to attract mineral exploration investments.



## Strategic Outcome 2. Natural resource sectors and consumers are environmentally responsible.

Work under this strategic outcome includes 11 signature S&T projects in the fields of energy, forestry, environmental studies, ground water and earth observation. The pie chart below provides a breakdown of science and technology resources devoted to this outcome based on approximations for the 2012–2013 fiscal year.

### Improved Environmental Responsibility (\$276.9 million)



Canadian Forest Service (CFS); Earth Sciences sector (ESS); Innovation and Energy Technology sector (IETS); Minerals and Metals sector (MMS)

*Chart does not include Earth Observation project as it only started in 2013-2014.*

Seven of the 11 signature S&T projects deal with various aspects of energy supply and consumption. **Energy Supply – Fossil Fuels** supports research and development (R&D) into secure, affordable and cleaner fossil fuels. Canada's fossil fuel resources include oil sands, shale oil and gas, tight oil, gas hydrates, conventional and offshore oil, and clean coal. Technologies and methods developed by NRCan laboratories in cooperation with industry enable the Canadian unconventional oil and gas industry to improve its environmental performance as measured by impacts on air, water and land.

The paraffinic froth treatment technology, which improves product quality and energy efficiency in oil sands production, was developed relatively rapidly at CanmetENERGY, in less than 10 years from the fundamental research to the full-scale implementation by Shell at its Athabasca oil sands project and more recently by Imperial Oil. This made it possible to upgrade bitumen using less water and producing less waste, while increasing energy efficiency. NRCan laboratories have become the preferred locations for industry to test new oil sands-related technologies because these laboratories have developed unique facilities for this purpose and have long-term research programs related to oil sands. Most recently, state-run Japan Oil, Gas and Metals National Corporation and JGC Corporation have partnered

### Clean energy R&D program (examples)

- oil sands water and tailings management
- bitumen and heavy oil conversion
- emissions reduction and life cycle analysis
- unconventional gas resource mapping
- health and safety of off-shore and northern development



with CanmetENERGY to test their new oil sands Steam Assisted Gravity Drainage (SAGD) Supercritical Water Cracking Technology that, if proven and commercialized, will result in significantly reduced emissions and waste products of SAGD operations.

The **Energy Distribution** signature S&T project brings information and communications technologies (ICTs) to the energy transmission industry to support the creation of Smart Grids. This refers to links up and down the electricity supply chain from generation to transmission to distribution and ultimately to the meter. It includes customer-owned distributed energy resources to ensure reliability, adequacy and environmental performance. This signature S&T project has resulted in the creation of a Smart Grid Standards Roadmap for Canadian participation in North American smart grid standards and advanced smart grid standards development. The project also created the Smart Grid Project Repository to share results and knowledge from projects in Canada as well as from abroad.

The largest signature S&T project for this strategic outcome is **Energy Supply – Electricity**. This project supports the reduction of GHG emissions in electrical power generation. It involves several NRCan laboratories including CanmetENERGY and CanmetMATERIALS as well as Earth Sciences and the Canadian Forest Service. NRCan delivered 71 demonstration projects including award-winning renewable energy technology demonstrations in areas such as innovative hydrokinetic turbines, anaerobic digestion, biomass gasification, and thermal and electrical power production from solar energy. NRCan's role in clean fossil-fuel power generation is primarily as a performer of R&D. CanmetENERGY's world-class clean coal and carbon capture test facilities are also an important demonstrator and funder, notably, of carbon capture and storage technologies. This NRCan research establishment is an enabler in the design of technologies and systems for efficiency improvements in existing electricity generation and in proving new technologies at the pilot scale. This latter work helps to increase the confidence of electrical utilities and investors, which is important for market development. CanmetMATERIALS is also a performer of R&D, in collaboration with other government laboratories and academia to develop and test new materials for use in next generation nuclear energy systems. A recent achievement was the development of thermal insulation material for use in high-temperature and high-pressure environments such as the Canadian Generation-IV Supercritical Water-cooled Nuclear Reactor Concept.

The **Pipeline Materials** signature S&T project advances materials development and improves the integrity and reliability of pipelines for pipeline safety and reduced environmental impacts. As an example, NRCan has patented a bio-corrosion probe to monitor bacterial activity and corrosion simultaneously. The probe allows for early detection and prevention of corrosion induced by microbes in pipelines that can lead to oil leaks and spills.





Three other signature S&T projects deal with other aspects of energy supply and clean energy S&T.

**Energy End Use – Transportation** delivers clean energy technology R,D&D to the benefit of vehicle and parts manufacturers for reduced fuel consumption and emissions in Canada. Areas of R&D include advanced fuels, exhaust after-treatment, advanced materials and electric mobility. A Canada-China-U.S. collaborative project designed a vehicle front end solely from magnesium, the lightest structural metal in use, and achieved a 45 percent reduction in weight that improves fuel efficiency and also reduced the number of parts from 79 to 35, saving considerable manufacturing cost. CanmetMATERIALS was the Canadian participant in this project.

**Energy End Use – Buildings and Communities** develops energy-efficient technologies, processes and enhanced performance systems for market adoption in the Canadian residential and commercial building sector and communities. Areas of R&D include advanced heating, cooling and refrigeration, building controls and energy management, improved insulating systems, use of renewable energy technologies such as solar energy, high performance building design and integrated community energy systems.

**Energy End Use – Industry** is working to improve industrial processes by better integrating and operating existing equipment. Many industrial plants continue to use technology current at the time of their construction, typically more than 50 years ago. NRCan's Process Integration Incentive Program, for example, has had an impact of more than \$100 million in industry investments, energy savings of 6,600 terajoules in fuel energy annually and increased power generation capacity of 50 megawatts. This translates into total financial benefits of \$75 million annually and total GHG emission reductions of more than 400 kilotonnes per year.

The **Forest Ecosystem Science and Application** signature S&T project generates knowledge about forest ecosystems and develops technology transfer tools for use in forest management policies and practices. This knowledge is essential for tracking Canada's progress in addressing climate change and to fulfil national and international reporting requirements for forest-related carbon and GHG estimates. The forest industry's competitiveness benefits from this initiative as a result of better understanding of the environmental and the socio-economic factors affecting forest health that is needed to promote sustainable forests.

### A cool solution for buildings and communities

CanmetENERGY has contributed to the transformation of commercial refrigeration in Canada by developing CoolSolution®, a technology that reduces energy consumption and GHG emissions by 30 to 50 percent. The technology is based on increasing the use of natural refrigerants and includes heat recovery from the refrigeration system to provide building heating requirements, and adaptation of the operation to the Canadian climate.

### Canada's national forest carbon monitoring, accounting and reporting system

This system was developed to improve the forest carbon and GHG estimate for use in analysis and international reporting. This includes refinement of the Carbon Budget Model of the Canadian Forest Sector and the development of a national deforestation monitoring program.

## Understanding contaminants in groundwater

A study in the Athabasca oil sands region developed new methods for detecting and differentiating the source of contaminants as naturally occurring or mining-related. Researchers have investigated contaminants in lake sediment and tree ring cores to obtain a time perspective pre- and post-oil sands activity, to be able to determine the impact of development of this resource on the environment. The study's results are used in environmental management decisions and help to improve the design of controls and monitoring programs.



Also targeting environmental responsibility is the **Environmental Studies and Assessments** signature S&T project. This involves the conduct of environmentally oriented geoscience research activities and provides expertise on potential environmental impacts of new or proposed projects, as well as resource assessments for crown lands where federal protected areas are to be defined. Among these, the Mineral and Energy Resource Assessment results made a significant contribution to support the federal decision on boundaries for Nahanni National Park and the announced Nááts'ihch'oh National Park Reserve. The assessment allowed for an effective balance between natural resource extraction and the protection of biodiversity. The boundary decision allowed for 47 percent of strategic mineral potential – tungsten – to be excluded from the park while protecting 95 percent of the Upper Nahanni Caribou herd. In another example from this signature S&T project, NRCan's technical expertise has led to the improved protection of Sydney Harbour in Nova Scotia during the Sydney Tar Ponds clean-up. Reviews of the environmental impact statement, monitoring plans and annual reports for the clean-up have led to changes in the design of the sampling plans, field methods and data analysis to better protect the harbour during remediation.

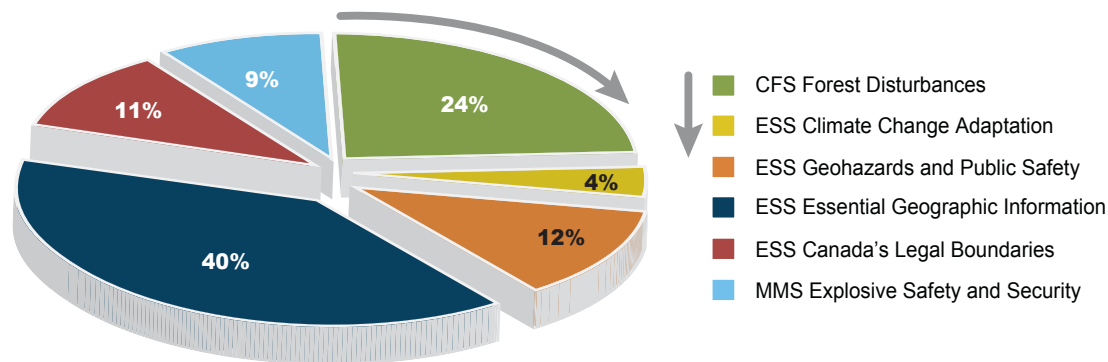
The **Groundwater Geoscience** signature S&T project applies NRCan's expertise in hydrogeology, mapping and remote sensing to raise understanding of groundwater issues across regions and at a national scale. NRCan maintains an inventory of waters with data about the quality and quantity as well as distribution and use of those waters. Provinces and territories, as managers of water resources, have direct access to NRCan's groundwater S&T through the Groundwater Information Network (GIN). GIN partners coordinate activities, standardize and share data for the purpose of knowledge transfer.

The **Earth Observation (EO) for Responsible Development of Natural Resources** signature S&T project, new in 2013–2014, conducts R&D that leverages the power of satellite data to support regulatory compliance monitoring and environmental impact assessment; work is currently focussed on the Alberta oil sands region. The project uses radar and optical satellite data, including NRCan's long-term satellite data records with more than 30 years of daily national coverage. Several activities are underway with provincial/territorial, federal and academic partners. These include detecting changes in infrastructure (e.g. buildings, roads, tailings ponds) to monitor expansion of industrial activity and complying with regulatory approvals. The project is also identifying changes in vegetation type and productivity; assessing elements of regional hydrology to understand regional baselines and changes; and detecting ground deformation linked to steam-assisted extraction techniques to improve the understanding of the impacts and risks of these approaches in varied geological circumstances.

## Strategic Outcome 3. Canadians have information to manage lands and are protected from related risks.

In working to achieve the third strategic outcome through six signature S&T projects, NRCan gathers and disseminates information for the management of lands and natural resources and for helping to protect Canadians and Canadian resources from risks ranging from those anticipated and those yet to be encountered. The pie chart below provides a breakdown of S&T resources devoted to this outcome based on approximations for the 2012–2013 fiscal year.

### Information to Manage Lands (\$113.9 million)



Canadian Forest Service (CFS); Earth Sciences sector (ESS); Minerals and Metals sector (MMS)

The **Forest Disturbances Science and Application** signature S&T project supports federal regulations and policies to prevent, manage and control natural and human-caused disturbances in Canada's forests. This includes disturbances caused by native and exotic forest pests, climate change and wildfire. This improves emergency response thus improving the public safety of Canadians. It also strengthens the competitiveness of Canada's forest sector by putting into practice climate change adaptation knowledge and tools. Pathogens are expected to increase as a result of changing climate and increased trade. A genomics tool has been developed to detect a fungus that causes sudden oak death that could pose a threat to hardwood forests. The use of this tool enables Canadian nurseries to certify that their products are free of the disease through phytosanitary<sup>7</sup> certification and regulatory compliance.

### Asian long-horned beetle – The long and winding road

NRCan science, conducted in cooperation with the Canadian Food Inspection Agency (CFIA), Health Canada, municipalities and the province of Ontario, resulted in the eradication of the Asian long-horned beetle from Canada (formally announced April 5, 2013). The economic return on forest pest S&T investments is conservatively estimated to be 2:1 in avoided costs. However, there was a new detection of the Asian long-horned beetle in mid-August 2013 in Mississauga, Ontario. It is localized, and as reported in the *Toronto Star* October 2, "... this invasion is likely new and not a continuation of the old one, said Gregory Wolff, the CFIA's chief plant health officer." Efforts to delineate the infestation and eradicate this pest will continue.

<sup>7</sup> These are measures to control plant diseases as in agricultural crops.

Four earth sciences signature S&T projects contribute to achieving this strategic outcome. Activities under **Climate Change Adaptation** include scientific analysis on climate change issues affecting Canada north of 60° latitude as well as partnership development work to integrate practical adaptation planning into community management strategies. Science and information products are provided to governments (territorial, provincial, other federal departments and agencies), decision makers and project collaborators to improve land and natural resources management and reduce risks to infrastructure caused by climate change.

**Geo-hazards and Public Safety** researches and monitors natural, geological hazards such as earthquakes, volcanic eruptions, landslides, geomagnetic storms and tsunamis to understand their underlying causes and impacts and the probability of their occurrence. The Department's Canadian Hazards Information Service (CHIS) provides real-time information to emergency response organizations and critical infrastructure operators to help them manage and respond to hazardous events more effectively. NRCan's research has contributed to hazard mitigation plans for northern pipelines, for power generation with B.C. Hydro for seismic hazards related to dams, for power systems with Ontario's Hydro One and Manitoba Hydro, and for air navigation and airlines, among other industries. Critical infrastructure operators have used alerts and warnings developed by NRCan to protect infrastructure from the impact of natural hazard events, reducing the costs and the time required for business resumption.

### Geomagnetic effects on pipelines

The proposed Alaska Highway pipeline, which would, if built, cut across Yukon and northeast British Columbia to meet up with the Alberta system, is vulnerable to geomagnetic effects because of its position in the zone that is subject to the precipitation of particles from the sun, the same ones that cause the aurora borealis (northern lights). NRCan made a comprehensive assessment of the geomagnetic effects, including construction of Earth models to calculate electric fields and use of these as inputs to a pipeline model. This was combined with statistical analysis of geomagnetic activity to provide an overall assessment of geomagnetic impact for use in the design of the proposed pipeline.





**Essential Geographic Information** involves the collection, analysis and dissemination of information and data products to support social, environmental and economic decision making by governments and others. NRCan coordinates federal government activities and complements work by provincial and territorial mapping agencies under the Geomatics Accord. NRCan directs its efforts and funding to areas where provinces and territories are not actively providing data to ensure Canada's vast geography is covered. NRCan works with them to ensure efficient data collection, data sharing and standards development to ensure that datasets from different sources can work together.

**Canada's Legal Boundaries** applies S&T to deliver an integrated and modernized survey system to support sovereignty and the administration and management of real property in the North and on Aboriginal Lands. This project is creating a framework to identify, document, register and protect boundaries and property rights. For example, from 2009 to 2013, NRCan provided 77 land descriptions for First Nation reserves and managed 210 surveys of boundaries for those reserves and adjoining provincial lands. NRCan's activities included collection of data and conduct of analysis to determine the extent of Canada's continental shelf for the country's technical submission under the United Nations Convention on the Law of the Sea.



The **Explosives and Materials Safety and Security** signature S&T project supports achievement of this strategic outcome and is undertaken by CanmetEXPLOSIVES and CanmetMATERIALS. This initiative involves explosives research and technology development to improve the safety and security of mining and infrastructure as well as for personnel protection and armoured vehicles. Explosives testing for Canada is conducted to determine whether an explosive is safe to be used. Research on blast effects on buildings is also undertaken to improve the resistance of federal infrastructure to attack using explosives. Research on defence materials supports Canadian manufacturers in producing defence products comprising ships, submarines, light military vehicles and weapons systems for the Department of National Defence.

## Going to more accurate heights

Traditional surveying techniques relied on accessing the nearest of 80,000 fixed monuments to get a measurement of relative height. These physical sites required regular maintenance by ground crews, adding to the costs of keeping the reference system useful. NRCan took the decision to move to a new height reference system that more accurately accounts for the dynamic movement of the Earth's crust, a system that uses Global Navigation Satellite Systems and approximately 250 federal survey stations. Use of this model gives more accurate and consistent height values, reduces surveying costs in the North and puts the country at the forefront of implementing this approach.

## Testing of new armour

New ceramic armour materials fabricated at CanmetMATERIALS were found to have equivalent or better mechanical properties than those commercially available. Composite armour plates and new steels are being tested for protection against increasingly powerful explosive devices while also reducing the weight of personnel armour.



## 3. Future Directions – Implementing Blueprint 2020

### Present Realities and Future Challenges

NRCan is positioned uniquely as the only *national* S&T organization in Canada with networks of research establishments across the country able to work with partners in industry and the research community to increase the competitiveness of Canada's resource industries. This is also true for the many goods and services provided by NRCan S&T activities that address the public good responsibility of the Department. Increasingly the Department has a role in "knitting together" the innovation ecosystem as seen in the growing need for research endeavours that involve many partners in both the private and public sectors. Serving the public good and having industries that are competitive are the best ways to protect and grow employment and to create wealth. (See diagram, page 2.)

It is a formula in which science and technology drives innovation and NRCan facilitates and catalyses S&T across the innovation ecosystem.

#### Blueprint 2020

In his *Twentieth Report to the Prime Minister on the Public Service*, the Clerk of the Privy Council called for a clear and shared vision of what Canada's Public Service should be and for an action plan on how we will achieve it to be developed. He asked deputies to broaden the conversation so that public servants across the country can join in and invited all public servants to take part in this important dialogue about our shared future.

The Blueprint 2020 vision sets out four guiding principles to help examine how work is done in the federal Public Service:

- an open and networked environment that engages citizens and partners for the public good
- a whole-of-government approach that enhances service delivery and value for money
- a modern workplace that makes smart use of new technologies to improve networking, access to data and customer service
- a capable, confident and high-performing workforce that embraces new ways of working and mobilizing the diversity of talent to serve the country's evolving needs

NRCan has been providing S&T related to Canada's resource sectors for a long time. Over the years it has reinvented itself under different names and with varying mandates. The first decade of the twenty-first century is already history; how should NRCan deploy its science and technology in the second decade and beyond? The current "Blueprint 2020" initiative affords the opportunity to look into the future and to consider how government scientific establishments like those of NRCan should be organized to deliver on the needs of Canadians into the twenty-first century.

Following the conclusion of the Blueprint 2020 initiative, the S&T Board will be the main catalyst for NRCan's response through the development of an action plan. In anticipation, this chapter provides a vision of how the principles of Blueprint 2020 could see application to the future of S&T at NRCan.

## A Whole-of-Government Approach

Blueprint 2020 calls for a **whole-of-government approach**, **enterprise-wide solutions** and consolidated operations. These ideas can and should be adapted to and applied to what is called here, **Government Science 2020**. More and more, it is recognized that the organization of government science, exclusively within separate vertical hierarchies, directed at fulfilling specific departmental missions, is not the most effective way to address complex challenges posed by horizontal issues such as climate change, sustainable development and public security.



Consistent with other Westminster-based systems, Canada's Public Service will likely retain the current structure in which science capacity is distributed across line departments and agencies and where individual ministers are responsible for the science required to meet their mandates. However, it does raise the question of how best to support horizontal coordination of complex science-based files.

Various components, for whole-of-government S&T are in place already, including a well-functioning Assistant Deputy Minister S&T Integration Board with representation from all S&T-performing departments and agencies. More recently, the Deputy Minister Committee on S&T was revitalized. However, the governance system is suboptimal as it is Public Service-specific so that any coordination across the entire science and innovation ecosystem takes a special effort on the part of officials and only occurs in the context of a single issue or program.

The implementation of complex, adaptive research networks is one way to overcome the challenge. This would allow for Canadian experts in appropriate disciplines who are necessary to address a given issue, to work together and to combine their resources, regardless of their employer of record, inside or outside the federal Public Service.

## An Open and Networked Environment

The concept of a national innovation system, alluded to throughout this paper with reference to the innovation ecosystem, is a useful way to think about the role of government S&T. Rather than addressing separately the needs of individual companies or government science agencies, it suggests establishing and strengthening broad links between many entities involved in S&T. It requires, moreover, a high degree of networking between *many* S&T agents, on a local or regional basis, especially given the huge size and diversity of the country.

S&T at NRCan has been moving in this direction, from the traditional silos of sector and laboratory to broader engagement throughout the innovation ecosystem. One example is the creation of FPIInnovations, which represents a bringing together of forest and pulp and paper industry research organizations with NRCan and provincial governments. Another example was the relocation of the CanmetMATERIALS laboratory from Ottawa to Hamilton, Ontario, so that the facility would be close to the industries that it serves – automotive, steel and other materials – to make it easier to build networks with these partners.

An important consideration in achieving a more open and networked environment is for government agencies to join their industrial partners in the shift to Open Innovation; this is creating new requirements and opportunities for government science.

Open Innovation drives results in collaborative or networked settings, rather than within the confines of single companies or organizations. Much of the discussion of Open Innovation includes discussion of how to manage intellectual property (IP) as seen in the changing way companies create value and organize themselves and their innovation activities. Open Innovation suggests the need for a paradigm shift in government science from the *management of technology transfer* to the *management of IP* or, where appropriate, to the *management of innovation impact*, and that is indeed the approach of NRCan's recent improvements to its IP policy.

### A clarification of “Open”

It would be misleading to equate Open Data and Open Access to Open Science.

**Open Access** refers to providing increased access to government publications.

**Open Data** refers to providing access to datasets of a specific nature. This includes data that are of a non-experimental nature such as the reporting of earth observations. Data that support published government R&D could also be included. However, access to data sets resulting from experimental research and development will be limited until the publication of results, including the full experimental approach so as to provide the full context to ensure proper use and interpretation of the data.

**Open Science** means wider collaboration in the funding of and participation in the undertaking of science, whereby the collaborators themselves decide the level and timing of “openness” such as whether or when the results will be published in Open Data fora or through Open Access publications or whether the results will be commercialized for profit.

Government Science 2020 encourages all three of these as potentially beneficial models for Canada.

## A Modern Workplace With Smart Use of Technology

Consistent with and building on the main planks of the Open Government initiative, Government Science 2020 will ensure advancement of

- Open Access, to government science publications
- Open Data, by providing easy access to government datasets for innovative re-use by Canadians
- Open Collaboration, including the use of social media and other emerging networked technologies to reduce inter-institutional barriers and to facilitate communication for interdisciplinary and international collaboration among academic, industry, citizens and research institutions at all government levels

The *open government* conversation that has dealt with Open Access and Open Data efforts addresses only the outputs or products of government science such as publications and data. Far greater potential for innovation and synergy exists through collaborative co-production of knowledge, crowdsourcing, innovation prizes and citizen science. Open discovery could be a real game-changer for government science.

NRCan has already taken the first steps with the updating of its IP policy and the central coordination of IP through the Office of the Chief Scientist. The introduction of a new Publications Policy, similarly, will improve access to NRCan science, for the technical community as well as for policy analysts and the general reader. Being smart about using technology as well as having ready access to it, are critical to being able to take advantage of these opportunities.

## A High-performing Workforce

The integration of science and policy is a key element of Government Science 2020. In particular, what is needed is a shift from a *science communications* paradigm to a *knowledge mobilization* paradigm. It is not enough for Public Service research scientists to produce excellent science and publish it in the scientific literature. Neither is it suitable for NRCan policy analysts to go to external sources because internal S&T is not readily accessible in plain language form. The responsibility for science and policy integration rests with both science and policy communities. Government stands to benefit from approaches that facilitate a better utilization of up-to-date S&T in policy products. NRCan initiatives such as the Policy and Science Integration Community of Practice (PSICoP) are working in this direction but more is needed.

Implementation of effective knowledge mobilization strategies, applied across the Department and the government at the science-policy interface, will help to achieve better returns for research investment and improvements in the relevance, quality and impact of government science.

## The Rise of Social Science

Developing a truly network-based approach to Government Science 2020 is a long-term effort, as the name suggests. This will involve overcoming barriers and the creation of new connections and working relationships.

Historically, the Public Service has tended to form networks that are more like hierarchies. There is a preference for formal, well-defined *public-private partnerships*. Further, these should be stable, well-structured networks in which all the players are known. IP rights are negotiated up front and full financial tracking and accountability are dominating aspects of the relationship. In addressing Government Science 2020, there will be no avoiding the Cloud, which will enable informal, mass collaboration and social production where contribution is voluntary, transient and less amenable to traditional planning or hierarchies.



The proliferation of social media and Web 2.0 technologies (soon to evolve into Web 3.0)<sup>8</sup> is ushering in a *new digital age* and *social economy* that provide the capability for organizing without organizations. For government science to continue to retain relevance, achieve excellence and deliver impact into the first half of the twenty-first century and beyond, NRCan and other SBDAs will have to respond to and be part of this change in technology and culture.

<sup>8</sup> These refer to increasing degrees of interactivity which marked the evolution of Web 1.0 to Web 2.0, the growth in user-generated content (Web 2.0 to Web 3.0) and the dispersal of the Web from the desktop computer to many other, networked devices combined with increasing use of artificial intelligence (Web 3.0). This has been summarized as Web 1 as the static Web, Web 2 the writing and participating Web and Web 3 the semantic, executing Web.

## 4. Conclusion

NRCan's S&T activity extends across the vast land mass of Canada, addressing innovation and public science needs in energy, mining and minerals, forestry, and earth sciences. The historical drivers for S&T in these fields continue to shape the Canadian economy: resource sectors account for a large proportion of exports, of capital investment and a great deal of employment. NRCan addresses these and related needs through its 23 signature S&T projects that support the achievement of the Department's three strategic outcomes.

These outcomes will see the strengthening of economic competitiveness and the safeguarding of the public good. Accountability for the Department's S&T through the S&T Board is assured by reporting on signature S&T projects and using financial management tools that enable the tracking of spending on S&T.

Canada will continue to look to NRCan for S&T leadership in dealing with natural resources challenges on the horizon as well as those currently unforeseen. Some concerns that are already known and will likely become more significant include the opening of the North as a result of melting of the ice pack and permafrost, global imperatives to significantly reduce carbon dioxide output, access to energy that is clean and secure, and reduction of the environmental footprint of resource industries.

Technology and economic realities are changing rapidly throughout the world. Companies, organizations and government agencies must respond by adapting or risk becoming irrelevant. The Blueprint 2020 initiative is an opportunity for the federal government, including NRCan, to consider future directions and the innovation in organization and governance that will be necessary to continue to meet the needs of Canadians. The federal government's S&T will see greater networking of research activity, blurring of roles in the conduct of research and dispersion of responsibilities amongst many players. This opening up of science will pose challenges for NRCan, which is already investing effort in new ways of working that will lead to more efficient and effective science.

The traditional hierarchical organization of government departments will continue. The challenge will be how to blend this structure with the new realities that are emerging and will emerge in the future. A start has been made in this direction at NRCan with the increased capacity to manage and govern S&T as described in this report.

New tools and policies have been created – not least being the establishment of the S&T Board – and more will be instituted in the future. These are essential steps for ensuring that Canada is positioned to compete well into the twenty-first century. Whether working with industry to improve competitiveness or undertaking the surveys and data gathering that are essential public goods, NRCan will continue to mobilize its science and technology for the benefit of Canadians and with an eye to the future.



## 5. Appendix: Summary of NRCan Expenditures for S&T

First six months of 2013–2014: April 1, 2013–September 30, 2013 (Actual 2013 dollars)						
Sector Lead	Signature S&T project	Signature S&T Project Name	Vote 1	Vote 5	Vote 10	Grand Total
			Operating	Capital	G&Cs	
<b>CFS</b>	2	Forest Sector Innovation	11,169,617	-	12,609,348	23,778,965
	14	Forest Ecosystem Science and Application	8,035,563		765,160	8,800,723
	19	Forest Disturbances Science and Application	14,244,217			14,244,217
<b>CFS Total</b>			<b>33,449,397</b>	<b>-</b>	<b>13,374,508</b>	<b>46,823,905</b>
<b>ESS</b>	3	Geomatics Innovation	4,742,268		118,780	4,861,048
	4	Targeted Geoscience Initiative	4,853,040			4,853,040
	5	Geo-mapping for Energy and Minerals	10,470,545			10,470,545
	6	New Energy Supply Geoscience	3,613,617			3,613,617
	15	Groundwater Geoscience	2,370,511			2,370,511
	16	Environmental Studies and Assessments	4,516,609			4,516,609
	17	Earth Observation	1,016,224			1,016,224
	20	Climate Change Adaptation (Geoscience)	2,282,407		158,043	2,440,450
	21	Geohazards and Public Safety	9,141,952	-		9,141,952
	22	Essential Geographic Information	16,551,812	3,078,626		19,630,438
	23	Canada's Legal Boundaries	7,554,986			7,554,986
<b>ESS Total</b>			<b>67,113,972</b>	<b>3,078,626</b>	<b>276,823</b>	<b>70,469,421</b>

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First six months of 2013–2014: April 1, 2013–September 30, 2013 (Actual 2013 dollars)						
Sector Lead	Signature S&T project	Signature S&T Project Name	Vote 1	Vote 5	Vote 10	Grand Total
			Operating	Capital	G&Cs	
<b>IETS</b>	9	Clean Energy S&T - Energy Supply (Electricity) + materials for Energy Supply	5,116,720		566,225	5,682,945
	10	Clean Energy S&T - Energy Supply (Fossil Fuels - Oil & Gas)	11,276,021		1,261,853	12,537,874
	11	Clean Energy S&T - Energy Distribution (Transmission and Smart Grids)	1,058,155		1,465,814	2,523,970
	12	Clean Energy S&T - Energy End Use (Buildings and Communities)	9,404,163		980,990	10,385,153
	13	Clean Energy S&T - Energy End Use (Industry)	2,648,038			2,648,038
<b>IETS Total</b>			<b>29,503,097</b>		<b>4,274,882</b>	<b>33,777,979</b>
<b>MMS</b>	1	Green Mining Innovation	4,882,385	947,960		5,830,346
	7	Advanced Materials for Energy - Transportation + Clean Energy S&T - End Use (Transportation)	5,599,647		166,602	5,766,249
	8	Materials for Energy - Pipelines + Clean Energy S&T Distribution (Pipelines)	295,431			295,431
	18	Explosives and Materials Safety and Security	2,567,753			2,567,753
<b>MMS Total</b>			<b>13,345,215</b>	<b>947,960</b>	<b>166,602</b>	<b>14,459,778</b>
<b>OCS</b>		Office of the Chief Scientist	860,323		423,831	1,284,154
<b>OCS Total</b>			860,323		423,831	1,284,154
<b>Grand Total</b>			<b>144,272,004</b>	<b>4,026,587</b>	<b>18,516,647</b>	<b>166,815,237</b>