Diane A. ISABELLE  
National Research Council of Canada

TECHNOLOGY FORESIGHT AT THE NATIONAL RESEARCH COUNCIL OF CANADA: METHODOLOGY AND IMPLEMENTATION

Key words  
Foresight, strategic planning, science and technology.

Abstract  
The article presents a technology foresight exercise carried out at the National Research Council (NRC) – the Government of Canada’s premier organisation for research and development. The actions undertaken were focused on a technology foresight exercise with a time horizon of 2020 to initiate planning for its strategic and organisational renewal. The exercise provided a global perspective and critical insights on the future and impact of Science and Technology (S&T) globally and in Canada, and on opportunities for the NRC to address national challenges as part of the Canadian National System of Innovation. This paper first summarizes the scope, extent and methodology of the technology foresight exercise. Then, the implementation of the foresight exercise as well as an assessment of the implementation and outcomes are examined. Finally, the paper concludes with general observations and recommendations for science-based organisations embarking on similar foresight exercises.
Introduction

Technology foresight has emerged as a prominent instrument of technology policy since at least the early 1990s. The definition of technology foresight used here is that of Georghiou (1996): “A systematic means of assessing those scientific and technological development which could have a strong impact on industrial competitiveness, wealth creation and quality of life” [1].

Since its creation in 1916, The NRC has been the Government of Canada’s premier national science and technology institution, working with governments, universities and industry to tackle vital issues [2]. In 2005, the NRC undertook a foresight exercise with a time horizon of 2020 to initiate planning for its strategic and organisational renewal. The exercise provided a global perspective and critical insights on the future and impact of S&T in Canada, and on opportunities for the NRC to address national challenges as part of the Canadian National System of Innovation. The resulting strategy was implemented over the subsequent years and assessed in 2009.

1. Scope and Methodology

The renewal project intended to identify opportunities to enhance the impact of NRC activities on Canadian socio-economic well-being and stimulate transformative changes within the National System of Innovation. This required NRC to re-assess its key roles and further align NRC resources and investments with Federal Government priorities.

The ‘Renewal Project’ was composed of four distinct phases:
- Phase I: Environmental Scan;
- Phase II: Strategic Direction;
- Phase III: Strategy Development;
- Phase IV: Strategy Implementation.

2. Environmental Scan

The environmental scan involved identifying global issues that were societal, economic or scientific in nature, industry needs and government priorities as well as S&T trends that would shape research and science in Canada over the coming years. It included an assessment of NRC core competencies, an analysis of the Canadian national system of innovation, and interviews with selected Canadian and foreign government S&T organisations on organisational capabilities for S&T organisations and change management practices. A variety of techniques were used, such as extensive literature search, brainstorming and consultations, surveys, interviews, S&T foresight workshops and scenario-building exercises.
2.1. Key Social and Demographic Findings from the Environmental Scan

The key findings related to social and demographic trends from the environmental scan are as follows [3]:

- **Changes in Cultural Identity**: By 2025 it is expected that roughly 22% of the Canadian population will be aged 65 and over. By then Canada’s population is expected to be around 35 million with visible minorities accounting for 19% to 23% of the total. Between 6.3 and 8.5 million citizens will reflect cultures, values and religions that are quite different from those upon which the country was founded. Demographic changes will have economic and social impact in terms of smaller workforce, lower productivity, pension payment liability, and changing consumer expectations.

- **Worldwide Decline of the Nation State**: Although democracy is on the rise there is also a growing number of failed nation-states. The nation-state is seen to be losing ground to trade and religious groupings as the primary source of identity and Canada’s place in the world will decline.

- **Loss of Leadership by Western Society**: In the 20th century it was widely assumed that the future would be owned and defined by western industrial cultures, technologies, economies and world views. Shifts in the way we think about the world contribute to a loss of confidence in institutions and leadership in western society.

- **Demand for Greater Security**: Rapidly increasing global interdependence brings new threats and vulnerabilities. To some extent ‘security’ drives how we perceive the world and how we react within it.

From this backdrop several challenges of critical importance for Canada and the world have been identified:

- **Chronic Diseases and an Ageing Population**: Chronic disease is the most common and costly health problem worldwide. Opportunities exist in the area of early diagnosis, monitoring and cures for many of these diseases based on Canadian strengths in genomics, proteomics, biosensors, biomaterials and nanotechnology areas.

- **Pandemics and Infectious Diseases**: Bacteria and viruses are able to develop resistance to essentially all antimicrobial and antiviral agents marketed to date. With population movement at an all-time high, conditions are ideal for the global transmission of infection. There is need for quick identification of infectious agents, for the creation of a robust, innovative production capacity for vaccines. Traditionally the vaccine market was unattractive to investors but the economics of vaccines may be improving, particularly with countries now scrambling to stockpile vaccines.

- **Connected Communities** both from a physical and virtual perspective will create new opportunities for many sectors of society, including transportation, trade, education, research, healthcare as well as security and
government services. Connecting communities requires physical infrastructure for transportation, transportation technologies, network infrastructure, computational power, bandwidth, as well as software and hardware technologies to address the challenge and to support the new knowledge economy.

2.2. Key Energy and Environment Findings from the Environmental Scan

The key findings related to energy and environment from the environmental scan are as follows [3]:

- **Natural Resource R&D:** The Canadian resource sectors, including agri-food, forests, energy, minerals and metals, as well as related industries are some of the largest contributors to Canada’s GDP. There is clearly an urgent need for R&D, particularly in innovative value-added opportunities such as Agrifood. In the area of Forestry Canada has proven its ability to be innovative and with the right combination of R&D and policy frameworks it should not only maintain its global position but improve upon it. The Mining and Minerals industry is well positioned to transform S&T advances into commercial activity and it fully recognizes both the commercial and environmental imperatives for its leadership role in sustainable development. Canada is rich in fresh water resources whereas freshwater is becoming increasingly scarce around the world. Opportunities include purification, desalination, transportation of water; and safe water management through the application of technology.

- **Environmentally Sound Technologies:** The emerging global market for environmental technologies presents a significant economic opportunity. This refers to all technologies to manage pollution through control, remediation, avoidance and monitoring. According to OECD findings bio-based technologies will provide both economic and environmental benefits that include cost savings of 10–50%, a reduction of CO2 emissions by 10–80%, water savings of 20–50% and a significant reduction in pollution and toxic substances. In Canada, a combination of abundant biomass resources, a strong science base for industrial bioproducts and bioenergy, and federal priorities in favour of biotechnology, are creating a favourable climate for the development of a new bioproducts and bioprocessing industry.

- **Sustainable Energy and Economic Growth:** Access to adequate supplies of energy is both an opportunity and a prerequisite for growth. Although the potential benefits of hydrogen and fuel cells are significant, many challenges remain before they will offer a competitive energy alternative. Solar and wind are renewable energy sources that create new opportunities for economic growth and that will accelerate the transition to reliance upon...
domestically available clean energy technologies. There is a renewed interest in **nuclear power** as an emission-free energy source and as a natural hedge against the environmental costs of fossil fuels. Uranium is one of the world’s most important energy minerals, but is notable for its very low energy efficiency. Less than 1% of the resource is extracted as energy and the rest is stored as “waste”. At this rate, Canadian uranium resources, about 14% of world total, will be exhausted within 50 years. R&D is required to make that technology 10 to 50 times more efficient. The **oceans** contain a huge amount of power that can be exploited for generating useful energy. Developed conversion systems concern tidal energy, thermal energy, marine currents and ocean waves. Canada is particularly rich in tidal current and wave energy resources.

3. Strategic Direction

Armed with the consolidated findings and insights from the environmental scan several activities took place in Phase II, the establishment of a strategic direction. A series of 26 workshops was held with NRC staff across the country. Staff were asked for input on the key opportunities and challenges identified. The objective of these consultations was to build a shared understanding of the S&T opportunities and challenges for Canada from the perspective of the year 2020, and assess whether a strong role can be played by NRC. Opportunities highlighted by staff were consistent with those identified in the foresight phase as key national issues: energy, natural resources, and health.

| Governance                          | – Link National S&T policy to the economy  
|                                   | – Align Government priorities  
|                                   | – Improve collaboration between Government, Academia and Industry  
|                                   | – Demonstrate leadership  
| Infrastructure                     | – Focus on regional strengths  
|                                   | – Increase private sector research and absorptive capacity  
|                                   | – Become more adaptive, agile and responsive  
| Knowledge & Intellectual Property (IP) Management| – Support knowledge sharing, management and dissemination  
|                                   | – Access international knowledge  
|                                   | – Add value to products before export  
|                                   | – Protect IP for Canada  
| Education                          | – Develop and improve cross-disciplinary education  
|                                   | – Engage Aboriginal youth  
|                                   | – Hire professors with industry experience  
|                                   | – Immigration policy linked to education needs  
| HQP                                | – Attract & retain top talent  
|                                   | – Grow internal talent  
|                                   | – Improve industry receptor capacity  
|                                   | – Link immigration policies to employment opportunities  

Table 1. Challenges Identified by Key External Stakeholders
Subsequently, 7 cross-country workshops were conducted with close to 300 key external stakeholders from industry and universities as well as from provincial and municipal government organisations to validate the strategic direction and identify challenges. The challenges are summarised in the Table 1.

The consultation process was critical because the selection of strategic directions for the NRC rests in a large part on its ability to engage its key stakeholders. On the basis of these results a vision of potential future roles for NRC was derived.

Later, in 2005 over 40 scientists from across the NRC got together for a unique brainstorming session – a disruptive-technologies workshop. The goal was to explore anticipated S&T challenges from now until 2020 and identify areas likely to be transformed by breakthroughs in the next generation and in which NRC should consider investing and developing new competencies. The results are summarised in Table 2.

Table 2. Results of the Disruptive-Technologies Workshop

<table>
<thead>
<tr>
<th>Human health</th>
<th>ICT</th>
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<td>Diagnostics</td>
<td>Mathematical theory of computation</td>
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<td>Therapeutics</td>
<td>Programming languages</td>
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<td>Bio-systems interfaces</td>
<td>Software engineering</td>
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<td>Food</td>
<td>Breakthrough applications</td>
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<td>Transportation</td>
<td>New software authoring communities</td>
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<td>Autonomous vehicles</td>
<td>Sustainable energy and environment</td>
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<td>Micro-vehicles</td>
<td>Generation</td>
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<td>Sub-orbital vehicles</td>
<td>Storage and distribution</td>
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<td>Intelligent systems</td>
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<td>Manufacturing</td>
<td>Quantum technologies</td>
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<tr>
<td>Monitoring environments</td>
<td>Cryptography and computing</td>
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<tr>
<td>Infrastructure</td>
<td>Photonics, spintronics and molecular electronics</td>
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<td>Extreme measurement and control</td>
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4. Strategy Development and Implementation

Following this extensive foresight exercise, NRC coalesced the input from the broad range of stakeholders to derive its new 2006–2011 strategic plan “Science at Work for Canada”, focused on the following three strategic goals [4]:

1. Contribute to the competitiveness of Canadian industry in key sectors
2. Make significant contribution to national priority areas critical to Canada’s future, namely health and wellness, sustainable energy, and the environment.
3. Strengthen Canada’s innovation system.
This paper focuses on the first two strategic goals. A critical consideration for NRC was the convergence of enabling technologies such as biotechnology, information technology and nanotechnology with disciplines such as manufacturing, transportation, advanced materials and construction, to enable the development of new technologies that allow more sustainable economic growth and development. The new strategy therefore built on NRC’s multidisciplinary nature, its collaborative approach and its international networks enabling the development of solutions to complex national problems.

Through significant quantitative and qualitative analysis as well as consultations with stakeholders, eight industry sectors were identified as knowledge-intensive where R&D was critical to their success and where NRC could make a significant contribution to support the competitiveness of Canadian industry, within a relatively short timeframe. In partnership with industry, governments and universities, NRC set up the following key industry sectors: aerospace, agriculture, automotive, biopharma, construction, ICT, manufacturing and materials, and medical devices. NRC was already active in most of these areas. However, the strategy enabled a concerted multi-disciplinary, cross-institute effort.

To address two of the national priorities identified in the NRC strategy, namely sustainable energy and the environment, two national programmes were launched in late 2006: A national bioproduct programme and a fuel cell and hydrogen national programme. A cross-NRC initiative in nanotechnology was also launched in 2007. The overriding objectives of these initiatives were to leverage council-wide research activities and dedicate resources to strategically important and excellent longer-term research activities. In keeping with one of the strategy’s core principles – partnerships – NRC pursued these initiatives in collaboration with other federal departments and agencies, and with universities, industry and the non-profit sector.

A Central Business Support group was established to facilitate the flow of high-value technology from NRC while providing business-focused support to NRC executives, Institutes and programmes.

5. Assessment of Implementation

In 2009, halfway through its strategy implementation efforts, the senior executives of NRC assessed the implementation efforts and progress. The assessment methodology included interviews, discussion groups case studies and document reviews. The assessment was organized around critical enablers for and potential barriers to strategy execution, namely: vision, people, management, and resources. Generally, it was found that the new strategy enabled NRC R&D efforts to be better aligned to more effectively address enduring issues of the nation. It was also found that new initiatives such as the
key industry sectors, increased the flow of technologies into high-impact secors of the economy. However, the strategy was not understood in a consistent manner by staff and middle management. Progress with the strategy implementation was perceived as slowing down due to resource constraints, barriers to change and external factors, as well as gaps in business and leadership skills. Key positive impacts of the strategy implementation on people were identified as: more cross-collaboration, more awareness and opportunities to contribute to new areas. However, activity/process “overload” was identified as having a negative impact on middle management in particular. As is typical of research organisations, NRC was perceived as a multitude of sub-cultures requiring a variety of change management techniques in support of the strategy implementation.

The mid-term implementation of the strategy enabled strategic decisions and a revision of some of the key commitments. Under the leadership of a new president since early 2010, NRC is currently building on its foresight expertise and this assessment to develop its next strategic plan.

6. General Observations and Recommendations

NRC has been involved in technology foresight since the early 2000s and lessons learned have been incorporated in subsequent exercises [5]. A general observation is that it is very important to involve as many people as possible in foresight activities and to challenge people past their comfort level. Therefore, the active involvement of NRC scientists, along with external consultants, proved invaluable. Not only were the scientists able to cast a scientific eye on future S&T, they also benefited from participating and learning about foresight. Further, it helped ensure a buy-in to the new strategic directions. In terms of recommendations, the exercise should involve youthful participants in addition to senior persons to enable exchange of views across age groups. In the same way, cross-validation of technical findings with diverse groups of experts adds credibility to the findings and the strategic decisions. Well articulated communication throughout the exercise is vital to ensure a common understanding of expectations among participants. In order to maintain momentum, it is important to keep a close timeframe between the various components of the foresight exercise. Finally, advocating the purpose of the foresight with key stakeholders is crucial to ensure that the outcomes of the foresight are neither lost nor ignored.

Conclusion

Canada, as many other countries, cannot afford to be reactive to major events and trends. S&T organisations involved in foresight activities can more
easily create opportunities backed by S&T knowledge when external factors, including not only S&T trends but economic, regulatory, social and competitive factors, are continually monitored. Therefore, the establishment of a foresight competency in-house is becoming increasingly vital for any R&D organisations.

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Reviewer: 
Julita JABLECKA

Foresight technologiczny w Krajowej Radzie Badawczej w Kanadzie: realizacja i wdrożenie

Słowa kluczowe
Foresight, planowanie strategiczne, nauka i technologia.

Streszczenie