Using S&T Foresight to Augment Organizational Tool Kits: A Canadian Institutional-Entrepreneurial Experiments

Jack E. Smith and the STFPP Team Members: Hassan Masum, Raymond Bouchard, Peter Kallai, Erik Lockeberg

jack.smith@nrc.ca; hmasum@ccs.carleton.ca; raymond@drachma-denarius.com; p.kallai@keystep.com; elockeberg@eisa.com

National Research Council Canada, 1200 Montreal Rd., Ottawa (Ontario), K1A 0R6, Canada

This paper will explore recent Canadian federal experience in developing S&T foresight and creating knowledge sharing networks aimed at creating integrative capacities and convergent domains that involve fusions of several disciplines. More specifically, the paper will report on the experience of the Office of Technology Foresight (OTF) at the National Research Council of Canada (NRC) and its federal partners (science based departments and agencies - SBDAs) as they carried out a major S&T Foresight Pilot Project (STFPP) to elaborate prospective R&D opportunities and challenges in preparation for contingencies that may have to be confronted in the 10-20 year time horizon of 2015-2025.

1. Introduction

As the knowledge-based economy's emerging requirements for innovation in a 21st century context are starting to become apparent, traditional R&D institutions are being expected to demonstrate more agility and acquire new anticipatory capacities to guide an increasingly demanding array of partners and clients who perceive speed, timing and future knowledge readiness as key competitive assets.

S&T foresight, which combines elements of societal and scientific foresight into a process of projecting forward future R&D challenges at least a decade, is being pilot tested in Canada as a cost-effective method of helping public institutions and their private sector partners jointly anticipate the substantial contingencies inherent in longer term R&D investments within a fast changing and globally competitive knowledge environment. Building new configurations and cross-disciplinary multi-stakeholder knowledge networks that blur the public-private boundaries is one method that is being applied to meet the new challenge.

In September 2002, the National Research Council of Canada embarked on an interdepartmental planning project designed to explore the long term future of technology as it relates to the planning and research activities of science based departments and agencies (SBDA) in the Canadian federal government.

The project, known as the Science and Technology Foresight Pilot Project, ran 10 workshops in November-December 2002. The workshops were evenly divided between two themes:

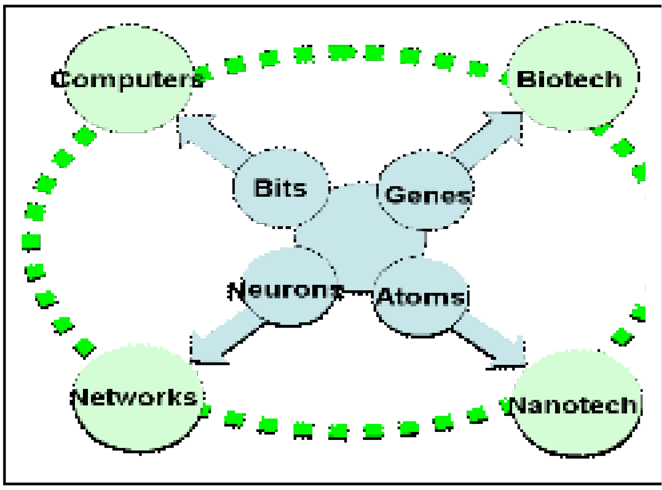
- **BioSystemics** - The convergence of nanotechnology, ecological science, biotechnology, information technology and cognitive sciences, and their prospective impacts on materials science, the management of complex public systems for bio-health, eco and food system integrity and disease mitigation.
- **GeoStrategics** - The future horizons and applications of geo-spatial data and related knowledge management technologies for decision support, including pattern recognition software, wireless communications infrastructure futures, and links to major new capacities in surveillance, ecological monitoring and resource management technologies.

2. STFPP: Summary of Principal Findings

Of the many findings uncovered in the STFPP, several stand out in significance:

1.Technology Dynamics – there are forces within the innovation process that are accelerating the pace of discovery: e.g. convergence, genomic health, military & security transformation, global S&T competitiveness, imagination of deeply connected sensor rich mesh computing networks. There are also many potentially disruptive technologies such as neural scanning, genetic therapies for regeneration and enhancement, quantum computing, nanotechnology, household robots, space-based power, and long life portable and fixed fuel cells, that could affect the direction of technology and societal infrastructure in unforeseen ways.

2.Near Term Possibilities - many new and significant technologies could well appear in a fairly short time frame. The bio-health and nanotechnology environments in particular are advancing much more quickly than anticipated because of new instrumentation and bio-informatics. The Technical Panels identified extensive lists of bio, geo possibilities in this regard, which are summarized in the Synthesis Research Reports.



3.Governance – the Canadian federal S&T community is not currently well positioned to take advantage of the benefits of technology that requires horizontal approaches to optimize benefits. As well, the competing cultures of SBDAs often make it harder to deal with negatives. The STFPP again exposed some vulnerability in terms of alignments and commitment, but additional and more intensive application of foresight tools could strengthen horizontal governance and assist the federal system as a whole in demonstrating anticipatory capacities. The present transition time could be pivotal for activating such an alignment.

4.Scenarios – Canada faces significant uncertainties looking ahead to 2025 that suggest a variety of developmental pathways, S&T investment challenges and societal acceptance alternatives. These sometimes divergent and plausible future prospects can assist our thinking today in terms of preparatory strategies and policies for R&D.

5.R&D Collaborative Opportunities – the SBDA partners in the project all have their distinctive missions and operational styles and priorities, however there are several broad thematic areas of R&D that clearly have cross organizational implications, where horizontal joint efforts and investments to achieve critical mass and impacts for Canada's future agility should be considered. The STFPP has made a first step toward prompting a detailed discussion via its first approximation of a possible shared R&D agenda.

2.1 Technology Dynamics

There are two important dynamics at play: convergence and consilience. They occur as result of our expanding ability to observe and understand natural phenomena. This expansion takes place at both ends of the measurement scale, from the very small to the very large.

The standard disciplines (physics, chemistry and biology) occur at what could be called human scale. This is the directly observable world as it would have been observed by everyone and anyone until fairly recently. Developments in optics opened up the scale of what is observable, with telescopes letting us see larger more distant objects and microscopes letting us observe nature at the cellular level.

Figure 1.

We can now observe matter down to the atomic scale. The ability to observe and work with energy and materials at these smaller and smaller scales has resulted in an integration of sciences. At the nanoscale atoms, circuits, DNA code, neurons and bits become conceptually interchangeable. This unity of understanding at the material scale is known as convergence.

Similar advances have been made at the gigascale. The expansion of science has meant that we can observe not only local weather, but weather systems. The spread of influenza can in principal be traced and mapped. The tools of gigascale science are computers, databases, networks and satellites, which permit us to capture and analyze large amounts of data. The unity of understanding at the systems scale is called consilience.

At both the nano- and gigascale new disciplines are emerging that cross traditional boundaries. At the nanoscale level, technologies to build semiconductors can be adapted to build medicines. At the gigascale, graphical information systems designed to monitor weather can also be used to observe the spread of diseases.

What we are in fact observing is a convergence of diverse technologies based on material unity at the nanoscale and technology integration from that scale. At the nano level genes, bits, neurons, and atoms all started looking like the same thing.

Computer code operates in a base 2 (0,1) system, genetic codes are written in a base 4 (A,G,C,T) system, very similar from a mathematical perspective. With single electron transistors, atomic particles map on to computer codes. The technology of the semiconductor industry, scanning tunneling microscopes), can be used to observe and manipulate genetic structures. Ultra small circuitry and nano-scale interfaces make it possible to directly link logic chips with neurons.

As we work at the nano-scale the technology and methods developed in one area finds uses in the other, with a resultant increase of the pace of discovery in both areas.

Convergence is not limited to science and technology. The entire infrastructure that supports these technologies is now able to span separate markets. Bioinformatics, for example, has IT and pharmaceutical firms playing in the same markets – either as competitors or collaborators.

For S&T policy and R&D planning and agenda setting the blurring of scales and the convergence-consilience aspects of modern science present new challenges for how we should define R&D within the context of an ever-evolving innovation system. The consensus of the STFPP is that a useful starting point is that a dual exploration of imagined crises and agile opportunities can help us define boundary as well as potential conditions within which a range of now uncertain technologies can find their prospective applications.

2.2 Near Term Possibilities

One of the most important observations to come from the STFPP is that many impressive technical advancements could happen relatively soon. It is also important to note at this point that because this information is derived from a foresight research exercise, as distinct from scientific and technological validations, some caution should be exercised by the reader in the context of the following disclaimer:

Government Disclaimer

The ideas, potential developments and prospective events envisioned in this report have been identified by participants as <u>situations that could occur in the future</u>. They

do not purport to be predictive. The approach we are taking relies upon consulting a wide range of expertise, with the expectation that through our collective experience, imaginative abilities and interactive knowledge of technological development pathways, we can begin to construct a coherent view of some of the major developments that can be anticipated within a 10-25 year time horizon. This is the nature of foresight - <u>creating a range of plausible future elements</u> that in their diversity should alert readers to the kinds of issues and perspectives they may not have initially considered in longer term research planning and contingency thinking. Accordingly, this report reflects the combined views of the participants, and the best wisdom and creative thinking that we could stimulate with the tools of foresight, but <u>it clearly does not represent an official view of the Government of Canada or any of its Departments and or Agencies.</u>

The following tables and text list some sample bio-health and related technologies that are technologically possible, along with prospective, or plausible early arrival dates. (Note: Forecasts were made based on information in 2001 – 2002. Similar tables exist for other topic sub areas that space restrictions preclude being featured here)

Horizon	**Prospective Technology Event**
2004	Biosensors available to monitor and measure *in situ* bioremediation. They will be applied to pollutants that are difficult to measure or are in hard to reach locations.
2004	Manufacture of high temperature carbon nano tube (CNT) composites
2004	Low power CNT electronic components
2004	New materials based on SiC, GaN
2005	Gene Chip available that will include markers for all human genes and will test for over 100,000 conditions. It will be used by professionals in selected applications.
2005	Many new and older drugs will be prescribed after screening a patient’s genetic profile to estimate safety and efficacy. New drug prescriptions will include a screening kit.
2005	Birth of first human cloned baby
2005	Therapeutic cloning of embryonic stem cells an accepted practice.
2005	Bioengineered microorganisms available as biocatalysts for industrial use. E.g. produce lysine from sugar for use in animal feed.
2005	Design and fabrication of self-healing nano materials
2005	Development of multifunctional CNT structures
2005	Devices using quantum dots
2005	Some deployment of super micro-electro mechanical systems (MEMS)
2005	Testing of nano sensors
2005	Testing and use of nano coating and materials
2005	Tech transfer of information from Human Genome Project to create biological approaches to nanotechnology
2006	“Green” genetically modified plants used altered genes from the original plant, rather than the introduction of foreign materials.
2006	Early use of genetically modified organisms, GMOs to remove difficult-to-degrade materials.
2007	Quantum navigation sensors
2007	Quantum computing
2010	Drugs designed for specific genotypes and phenotypes will begin appearing on the market. Pharmacogenomics accelerates both the discovery and the approval process. Drug economics will shift from the production of ‘blockbuster’ drugs to specific target drugs.
2010	Comprehensive genetic, behavioral and environmental screening will be capable of predicting degree of disposition of most major chronic diseases.
2010	Gene therapy will be commonly used to treat some genetic diseases.
2010	Stem cell will be matured in cells producing dopamine to treat patients with Parkinson’s disease.
2010	GM crops valued at over $30 billion annually.
2010	Global environmental technology worth $@ trillion. 20% is bioremediation.
2010	Consumer pressure and environmental concerns accelerate transition to environmentally sustainable bio-manufacturing in the chemical, textile, paper, food, and industry sectors.
2010	Bio-fuel represents 5% of automotive fuel in Europe.
2010	Self assembling, multi-functional materials
2010	Micro-opto-electro mechanical systems (MOEMS) assemblies
2010	Multiple sensors on single chip with integrated logic functionality
2010	Highest paid celebrity is synthetic
2010	Nano (chemical + direct) mood control
2011	Computer model of “virtual plant” can be used to understand plant physiology and selected genetic modifications.
2011	Molecular computing
2012	Single chip real time translation
2013	Biomarkers will be used by most individuals with cancer or at risk of getting cancer. They will monitor early development, identify tumor subtype, pinpoint treatments, monitor responses, and estimate prognosis.
2013	First preventative vaccine for a specific cancer

2013	Transgenic pig organs that reduce human rejection used for heart, kidney and liver transplants.
2013	Low-power PCs run for one year on batteries
2014	50% of all new drugs based on genomics. They are specifically designed for a target subset of the population.
2015	Pharmacogenomic tools will reduce the cost of drug development and approval by 30%. The time from discovery to regulatory approval will be cut by 50%.
2015	Comprehensive legislation in Europe and North America will define protections against 'discrimination' based on predictive medicine.
2015	Molecular nanotechnology will be used in the manufacture of molecular compounds for use in bio-engineered medications.
2015	First major chronic disease is prevented at the molecular level by a genetically engineered drug.
2015	Bio-based economy begins with agriculture producing significant sources of energy and natural resources.
2015	Commercial production of hydrogen from water using genetically modified algae is used for fuel cells producing electricity.
2015	Biomimetic material systems
2015	Biological computing
2015	Nano-electro-mecahnical systems (NEMS) flight systems
2015	Many super-MEMS products tested and in use
2015	Entirely new classes of materials and processes are in everyday use.
2015	Nano diagnostic products enter commercial marketplace
2015	Early communicating and/or programmable nano-systems
2015	Very early work on nanobots
2015	Biochips – 1012 bits/cm^2
2015	Sensory chips – taste, smell, sound
2015	Photonics replaces electronics
2015	Ethical computer
2017	Tele-presence (primitive halodeck)
2020	Availability of communicating and/or programmable nanosystems
2020	Nanobots are working in labs and being tested, evaluated, and fielded for various specific applications
2020	Nanomedicine is replacing older forms of medicine such as surgery, traditional pharmaceuticals, rational drug design
2020	Universal assemblers still not available
2020	Cyberspace covers 75% of populated world
2020	Functional mind-machine interface
2030	Robots mentally, physically superior to humans

Figure 2

Whether or not these technologies happen, and happen on these schedules, remains to be seen. There are already indications that economic conditions are slowing down commercial R&D, particularly in the biotech area.

The key point is that these technologies could happen and they could happen soon. There is a sense, at least in scientific circles, that leading laboratories are on the verge of discovering many new transformative, and for some disruptive, technologies. While the public at large may be acclimatized to the relentless pace of innovation, technology watchers are of the belief that the rate of innovation of the past three decades pales in comparison to what is coming down the road. *In this kind of environment, it pays to look ahead.*

Biotechnology is not the only driver of change in the health sector. There is a "slipstream" of scientific discovery and technological progress that is directing and giving energy to new discoveries. It can be described in terms of 6 components.

1. <u>The IT juggernaut</u>. Amazingly, the progress of computer technology has not slowed down since the 50s. Indeed it shows signs of continuing at a more furious pace. The digitization and virtualization of the world has extended our ability to communicate, visualize and control beyond any natural human ability. Visualization technologies enable us to 'see' diseases in bodies, and detect the spread of them through society.
2. <u>Biotechnology</u>. Our expanding ability to study cell, organisms, and their relation to their environment continues to bring success in an area of great complexity. This new understanding of self-organizing, self-replicating objects is creating knowledge in the unrelated areas of IT and nanotechnology. We have created the potential to engineer life forms, something that touches on the very meaning of existence.
3. <u>Nanotechnology</u>. We are on the threshold of building structures at the atomic and molecular level, structures that we cannot see, feel or smell. Yet these structures can have amazingly useful properties. It is expected that this field will enable us to devise instruments of exceptional sensitivity which will greatly expand our ability to view and understand the biological world.
4. <u>Medical Science</u> will be revolutionized by these new technologies through the use of non-invasive monitoring techniques, highly directed drugs, and much more effective prosthetics.
5. <u>Cognitive Sciences</u>. The ability to understand neural functions may well have profound effects on human performance and well being. There will likely be a cross-fertilization with the IT sector as we train computers to think like humans.

6. Systems Science. An understanding of fundamental material process, combined with new mathematical work in the area of chaos theory, cellular automata, small world networks, and game theory will likely enable us to understand and better manage a wide range of complex systems.

2.3 Governance

The third finding of the STFPP suggests that Canada may not be approaching S&T strategically enough. Scientific knowledge and technological capability are powerful forces in the shaping of modern economies and societies. Without them, we would be operating at a much more primitive level.

Within Canada's governance system there exist both communities of purpose, commonly known as Departmental or Agency missions and communities of practice which horizontally cross all or most missions. Communities of purpose focus on what must be done. The activities of these communities gravitate into clusters in which a common interest and expertise is shared, be that environmental protection or security. Their goals and requirements may at times conflict, strategically and tactically/financially, but their issues eventually get negotiated and resolved, via the communities of practice.

Communities of practice reflect the *way* in which issues are resolved and problems solved. They are domains of expertise that sort out priorities, although they may not do it in a totally disinterested fashion. These communities also drive their own definition of what success looks like. In Canada's governance model, political direction and government agenda management is a community of practice characterized by political and social values, i.e. what is socially or politically important. Decisions in this community are made within Cabinet and executive levels of the government. The economics and finance community of practice views the world in fiscal terms. Treasury Board and the Department of Finance as central agencies make allocative decisions; lower levels of the bureaucracy execute them.

There is a continuous tension between social priorities and financial ones, so these two communities of practice are constantly negotiating what may be practical.
The S&T community of practice however lacks the coherence and legal and procedural structures of the first two. It is based on knowledge. Outside the policy decision-making space it forms an integrated, well structured body of knowledge (at least compared to other bodies of knowledge), but inside policy space it is used on an 'as required' basis, usually in the most rudimentary, technical and fragmented way.

One challenge for foresight is to build bridges between areas of S&T expertise in order to obtain or leverage the knowledge and learning of S&T toward a greater contribution to overall public sector innovation as well as to public policy choices generally.

2.4 Prospective Scenarios

In March 2003, as the final exploration of foresight tools for the STFPP, a major scenarios workshop was convened involving close to 100 skilled participants working for two days to define prospective scenarios for Canada in 2025.

The intent of these scenarios (listed below in Figure 7) was not so much to try to predict the future as to define plausible sets of technological and societal conditions representing major uncertainties that ***if they were to become realized would require new or adjusted S&T capabilities and policy preparedness to enable Canada to contend with, benefit from or be capable of adapting to them.***

The primary methods used include therefore not only scenario construction but also backcasting for R&D and policy implications under the assumption that understanding how one got to this world and what technical capacities would have had to have been operative is important context information for current and future policy development, especially for those concerned with ensuring the adaptive or contingent capacity of government.

What was also instructive about this workshop is that it represented close to 200 days of professionally donated time. This evokes one of the themes of this paper – that by involving stakeholders directly in future casting activities, R&D institutions can extend their normal S&T capabilities significantly and in a catalytic manner into the key innovation receptor domains of economy and political choice. This process can demonstrate public value via increased societal flexibility and it contributes to ongoing capabilities that can become entrepreneurial knowledge networks.

One of the first tasks for a scenarios planning exercise is to develop a list of the anticipated key drivers of change. The following tables indicate some of the elements that the Office of Technology Foresight assembled with the assistance of its volunteers.

Although Canada has not had a regular forum for societal or S&T focused foresight, using it to increase the resilience of Canada's S&T readiness and to learn how to better anticipate the unexpected is a logical and cost-effective investment, given the inevitability of major surprises resident in a complex globalized world. S&T Foresight relies on correctly interpreting S&T change drivers, and the causal and temporal factors involved with change when it comes to Canada's future social, economic, and political realities. It is therefore, a highly analytical and speculative exercise that incorporates imagination and creativity to a large degree.

Figure 3; Sample Macro-Trends and Uncertainties for Teams Assigned to Scenarios Development

Macro Shaping Trends	*Uncertainties Surround*
• Integration, Miniaturization of Technology • Globalization of Trade, Capital, Terror • Harmonization of Standards, Protocols • Migration, Multi-Culturalism of Populations • Intensification, Differentiation, of Wealth • Bi-polarization of Religious Values and Secular Evolution • Transformation of Infrastructure Systems • Virtualization, Digitization & Integration of Business Models, Communications, Entertainment, Education • Automation and Customization of Production • Acceleration of Knowledge Services as Economic Driver • Proliferation, Adaptation, Rapid Circulation of Disease	• Individualism versus community • Sustainable development dynamics • Outward-looking communities versus isolationism • Financial market consistency and performance • New diseases, viral spread, containment • Access and use of weapons of mass destruction • Consequences of global warming • Impact of changing fertility rates

Teams were asked to consider these lists of factors in developing the scenarios 2025. As well they were given some templates developed specifically for the purpose of ensuring some consistency of scenarios elaboration.

These and the scenarios developed are summarized below in the Steps 1-6 that describe how participants were tasked and in related Figures 4 - 6.

Step 1 – Building Your World

Each participant will be assigned to a team with a scenario. The first step is to get acquainted with other members and get a common understanding of how you would further describe the world you have been assigned. These have been very loosely defined to give you latitude to enhance it.

Try to define some basic characteristics. Is the scenario good or bad? Does it overly rely on new technology or a transformation of social attitudes? Is it managed from the top, or organized from the bottom up? Later we will be considering policy implications. Ask yourself what issues society might need to address in your scenario.

Step 2 – Change Drivers

Once you have an idea of what your world looks like, identify the drivers that will push us into your world.

What's a driver? In a world of cause and effect, it is the cause. Drivers can be characterized as trends and dynamics which have momentum (such as population growth). They may also be 'tipping points' which, once passed, release a latent trend (such as climate change or environmental degradation). Drivers may have momentum themselves, such as population growth. The whole discussion about the nature of drivers can get complicated. We will keep it simple. Use Post-it notes to capture your thoughts about drivers. Then, lay them out in the familiar STEEP categories used in environmental scanning.

Make the following distinction between your drivers:

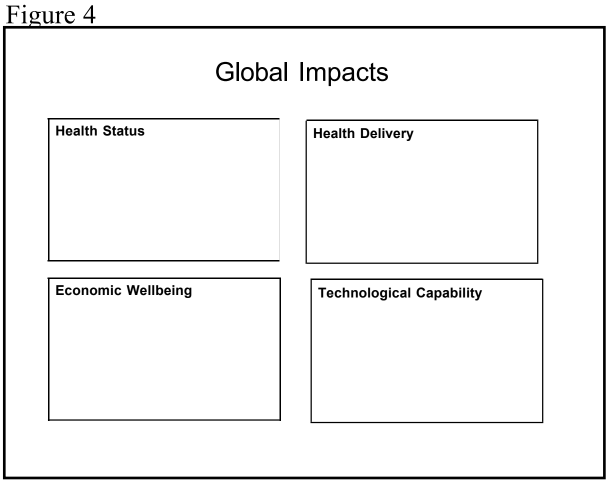
- Are they baseline assumptions? These describe the context of your world that is 'pretty sure' to occur. They can include ideas about population size, likely technological progress, form of government, and social attitudes.

- Scenario 'What If?' assumptions are the wild cards or deviation from the norm that make your scenario unique. These can be things like the release of a man-made virus, or the rapid progress of a new technology.

Keep track of relationships between drivers. Some may be valid in an international, but not domestic, context. Some may operate in a virtuous circle.

Step 3 – Global Impacts

Figure 4



As a next step, consider the implications and impacts of the drivers you have identified.

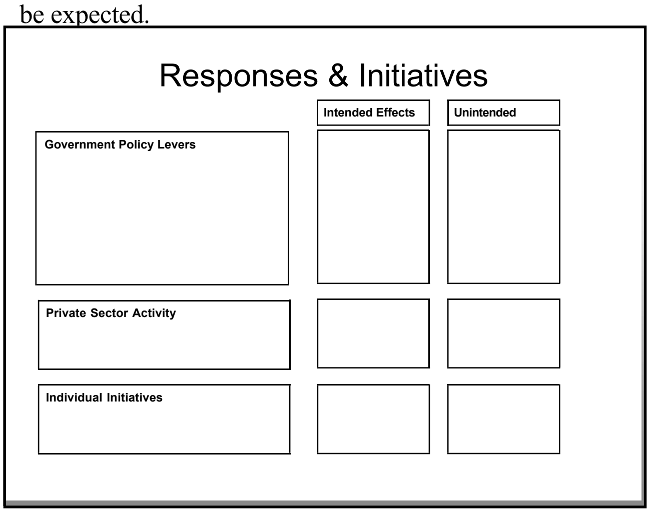
The template suggests looking for impacts on four variables:

- Health Status – just how healthy are we?
- Health Delivery – by what means do we deliver health care?
- Economic wellbeing – are we better off? Does are health system contribute to economic wellbeing or is it just too expensive?
- Technological Capability – is technology helping us out or is it just a diversion away from real health issues, such as a quality environment?
- You may want to add a further category covering social cohesion: are the drivers strengthening social harmony or creating social difference and discord?

Note that these are just suggested impact categories. You may, as a group, wish to define other categories, such as ethics or the implications for risk management. If so, go ahead, but try to keep it in the realm of Bio-Health innovation. Look at the big picture. Look at Canadian issues in the context of a global health environment.

Step 4 – Responses & Initiatives

In this step, take a look at some of the possible human interventions that will either amplify or attenuate the effects of the drivers. Nothing happens in a vacuum and over the space of 15-20 years a lot of human tinkering can be expected.



In some scenarios they may be major vehicles of health care delivery. Individuals may also play a role, particularly when it comes to 'wellness' strategies. Certainly, a composite of Individual Initiatives produces a public *reaction* which may be positive, neutral or negative to the intended initiative. You should be considering big instruments here, not system tinkering such as R&D, Regulatory, Health system uptake and Health industry commercialization, public confidence, etc.

When you have a reasonable list of actions, take a look at possible consequences of the actions, staying within the context of the scenario. Look for both intended consequences and any interesting unintended consequences.

Step 5 – Backcasting the Trajectory

Step 5 is a reality check. Take the previous work on drivers, impacts and responses. Try to build a path between the present and the future. What events have to happen between now and the future in order to bring about your scenario. Consider the full range of government responses – funding of R&D, applying tax or procurement levers, regulations, assessment of technologies, and health technology assessment or uptake practices.

Line up events in chronological sequence and see if they 'make sense' -- are plausible.

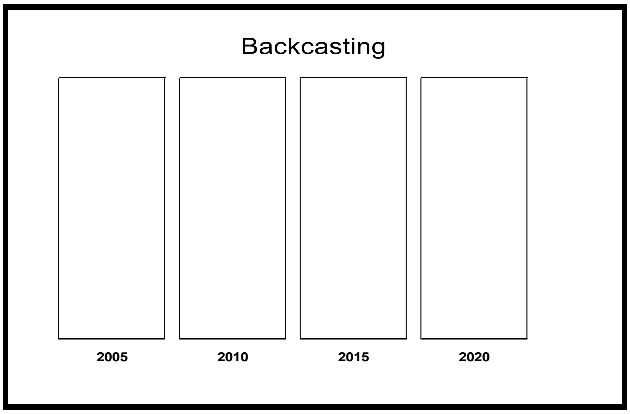


Figure 6

Step 6 – Write a Draft Scenario for 2025

Pull all of the elements together into a story line dated sixteen years into the future. Try putting it in the format of a press release announcing some new policy or initiative. Describe:

- The current situation (as of 2025)
- How we arrived at that situation
- The challenge faced by government, business, or ordinary Canadians
- The decisions taken
- The program undertaken
- The huge benefits Canadians can expect

Do this in a bulleted list format. We will have the opportunity to draft the scenario in narrative format later. As for the unintended consequences, hide them, but do not forget about them.

Scenarios Context:

"The only relevant discussions about the future are those where we succeed in shifting the question from whether something will happen to what would we do if it did happen" - Arie de Geus

Goal: The STFPP team synthesized a set of 10 scenarios to stimulate a sampling across the space of technological, social, environmental drivers:

1. Gaia Strikes Back - Ecosystems on the brink.
2. Agility Canada - Economic success story, private-public model for the world.
3. Insecure Cocoon - Terrorism, crime, and global military instability.
4. Muddling Along - Competent but reactive "status quo".
5. O Say Can You C - De facto U.S. protectorate.
6. Techno-Ban - Techno-disasters prompt neo-luddite backlash.
7. Techno-Ethics - Sustainable economies, life in balance, slower growth.
8. Techno-Mania - Anything goes (as long as you can pay for it).
9. Virtual Avatar - Living in cyberspace with cyber bots full-time.
10. You Are What You Invent - Skunk works group, necessarily inventive & adaptive

Figure 7

2.5 R&D Collaborative Priorities

A key goal of the project was to derive some horizontal, collaborative R&D agenda items that could be applied as priorities for government funding using a networks-of-excellence model similar to that used for funding some strategic groupings of university R&D where several domains, disciplines or different mission organizations could combine their talents.

The project was designed with this intent in mind and the following lists provide a glimpse into the preliminary findings in this regard. Clearly more work needs to be done to bring together the diverse agencies, including both R&D performers and funders to determine how useful this initial pass over future collaborative possibilities will be for their various missions and for the needs of the federal government as a whole.

The Project team evaluated candidates for potential horizontal R&D in terms of the following criteria:

1. Richness & potential for important discoveries or useful applications
2. Innovative approach or technology related to the foresight topics and challenges;
3. Cross- Departmental or Agency implications and prospective collaborations
4. Ability to add value to core functions of government and its role to lead and perform excellent S&T for public or longer term strategic business purposes;
5. Connection with the development of a knowledge based economy

Potential Horizontal –Collaborative R&D Opportunities for Federal S&T

1. **Biological Survey of Canada: The National Bio-Inventory**
2. **Subterranean Bioscience of Northern Regions: The Unknown Below**
3. **Proteomics: Health and Food Applications**
4. **Complex Modeling: Networks, Self-Organization and Emergence**
5. **The Mesh: Pervasive Computing and the Semantic Web**
6. **Bio-Photonic & Sentient Sensors: Distributed, Autonomous, Ubiquitous**
7. **Neuroscience of Learning: Opening the Cognitive Toolbox**
8. **Total System Costing: Accounting for Sustainability**
9. **Bioremediation: Repairing the Environment**
10. **Pharming: Agricultural Drug Production**
11. **Eco-Aquaculture: Fish and Seafood Protein Systems**
12. **Bio-Economy: Bio-Energy and Green Chemistry**
13. **Sentient Habitats: Buildings That Serve**
14. **Personalized Health Care: Doctor on Board**
15. **Remote Health Care: Telemedicine and Telepresence**
16. **Organizations That Work: Functional and Emotional Adaptation to Innovation**
17. **Wireless Power: Microwave Distribution and Solar Satellites**
18. **Permanent Airborne Platforms: Cheaper and Closer Than Geosynchronous Satellites**

Figure 8

3.0 From Institutional R&D Toward Entrepreneurial Knowledge Networks

Since 1994, under the leadership of Dr. Arthur Carty, the National Research Council of Canada has been gradually developing new and quite innovative methods for ensuring that its functions provide added value to Canada and to its business enterprises. This evolution has been described in previous papers for this Journal. (Smith: R&D Management Volume 30, #4 and Volume 33, #2)

The STFPP as described above represents another step or an additional tool in the innovation and knowledge enterprise tool bag of approaches to building an improved horizontal governance capacity through foresight. In this instance it is the agility of a more forward aimed R&D management portfolio that is policy linked that creates the potential for new value and adaptive capacity for federal strategists.

The development of networks has been a key objective for the STFPP. To date over 250 persons have contributed time and knowledge to the pilot project representing most federal Departments and Agencies as well as universities, provincial centres of excellence and private enterprises. These networks of awareness, knowledge sharing and prospective influence across a broad range of policy functions have been built using an entrepreneurial leverage model, which is innovative in the following ways:

- The Office is a virtual one, consisting of two NRC professionals, public service team members from partner departments and agencies and consultants who are recruited according to the tasks and challenges associated with varied client groups;

- These teams are both public and private sector depending upon stakeholder interests;
- For the S&T Foresight Pilot Project 13 Departments and Agencies were enlisted as sponsors and participants, some of whom allocated just funding, while others contributed part time expertise
- The leverage formula that was applied and required by NRC as the catalyst-organizer of the STFPP resulted in the commitment of $7 of partner funds for every $1 of NRC input. These funds enabled the Office of Technology Foresight (OTF) to engage the consultants and post docs necessary to carry out the main organizational work, and to build the network through multiple events and presentations to interested groups since the OTF remains at only two full time professionals.
- In addition to the financial leverage, there were substantial in-kind professional time contributions, in the form of participation, which as previously indicated involved close to 500 person days - this could be valued at $ 500,000, since that is approximately what would be required to compensate for professionals at the level of expertise we were able to attract.
- The use of foresight scoping and scenarios tools and related technical approaches looking ahead 10-25 years as best we could was fairly novel for government, which normally tends to operate within a time frame of five years or less - at least the broad scope and diverse involvements and two high level topics addressed made this approach quite novel in the horizontal-collaborative sense
- So in summary, the total value of this initiative could be seen as approaching a million dollars derived from the seeded resources of $25 K and two professional staff.

The OTF will be building upon the success of this pilot project to develop additional clients and new projects starting in April 2003.

4.0 Conclusion

This paper has elaborated some of the findings and approaches that NRC has used to develop a model for exploring and building foresight capacity within the federal government of Canada. This has included the tools adapted by the STFPP and social capital management methods for exploiting the private-public networks that have been attracted to the project to prospect for future-relevant ideas.

The draw has been both the intriguing nature of foresight, as well as a motivation for shared insights and team based learning and being part of a unique opportunity to potentially influence the direction of Canadian S&T as it confronts the broad issues areas that have been at the fore of the foresight challenge.

As Canada begins to prepare for its next major change of government leadership and major demographic shifts in its federal workforce looking ahead 5-10 years, the challenges and opportunities for foresight should grow in magnitude and relevance. Ultimately the test of this approach will be how Canada can best apply its federal S&T expertise and institutional capabilities to prepare for a variety of plausible futures and significant uncertainties for which collaborative R&D involving several federal partners would logically be a source of new or strengthened capacity.

In summary, the STFPP has demonstrated a model for collaborative foresight and research and policy anticipation. This model is characterized by significant leverage, extensive cross-disciplinary interchange, mutual networks development and extensive brainstorming. The STFPP demonstrates new approaches and solutions to technological, social and governance issues that Canada may have to become better prepared for as it looks ahead to the prospective forces and determinants of change that could shape the policy environment of 2025.