Canadian Interdepartmental Science and Technology Foresight Pilot Project

Phase I. Synthesis Report Geostrategics

PRELIMINARY DRAFT

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Geostrategics Synthesis Report Ver 1.0 for Review.doc

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A Note from the Project Leader

Thank you for joining our Science and Technology Foresight Pilot Project (STFPP) team in the consideration of opportunities and challenges that could arise from the knowledge we have developed during the course of this Project to date. Our team has been impressed by the significant creativity demonstrated by the participants and is very encouraged in the results thus far as we begin to move toward the scenarios development phase of the Project.

As you will readily appreciate, the ideas, potential developments and prospective events envisioned in this report have been identified by participants as situations that ***could occur*** in the future. They do not purport to be predictive and as such they remain hypothetical and speculative, since we believe that no one can confidently predict the future of science and technology or global events. However, we also believe that these views can help us to better understand the possible range of challenges and opportunities that may arise and some of which we are quite likely to face as we attempt to be well prepared for the unfolding of the 21st century.

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 should be anticipated within a 10-25 time horizon.

This perspective then enables us to imagine sequences of technology or events that could align themselves so that possibilities envisioned in this report could evolve. This is the nature of foresight - creating a range of plausible future elements 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 it clearly does not represent the official views of the Government of Canada or any of its Departments and or Agencies.

On behalf of the National Research Council of Canada, this report is issued as a public document for research and discussion purposes only. We believe that this report offers a useful way to raise for discussion, the kinds of longer term intrinsic challenges and opportunities that Canadians should be thinking about as they and their organizations approach the many uncertainties which abound in these technology domains.

If this report helps readers to formulate research and technology innovations designed to provide new capacities for anticipating whatever future we are destined to experience, then a key objective of the STFPP will be realized.

On behalf of the Project Team, we look forward to your continued interest and contributions to this work as it proceeds to its conclusion in 2003.

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1 Introduction & Background

The Technology Foresight Pilot Project (TFPP) is a planning activity designed to explore the long-term future of science and technology as it relates to the scientific activities of science-based departments and agencies (SBDA) of the Canadian federal government.

The interest in undertaking this project comes from many sources. Through the foresight process, SBDAs aim to understand:

- What transformative and disruptive technologies could be potentially coming to fruition in the next decades and where Canada could play a role?
- What technologies and how they could shape common-good applications areas where governments play a lead role, such as the environment, national security etc.?
- Which are the key R&D priority areas where horizontal collaboration among SBDAs would be useful?
- How effective is “foresight” as a planning and analysis tool and methodology?

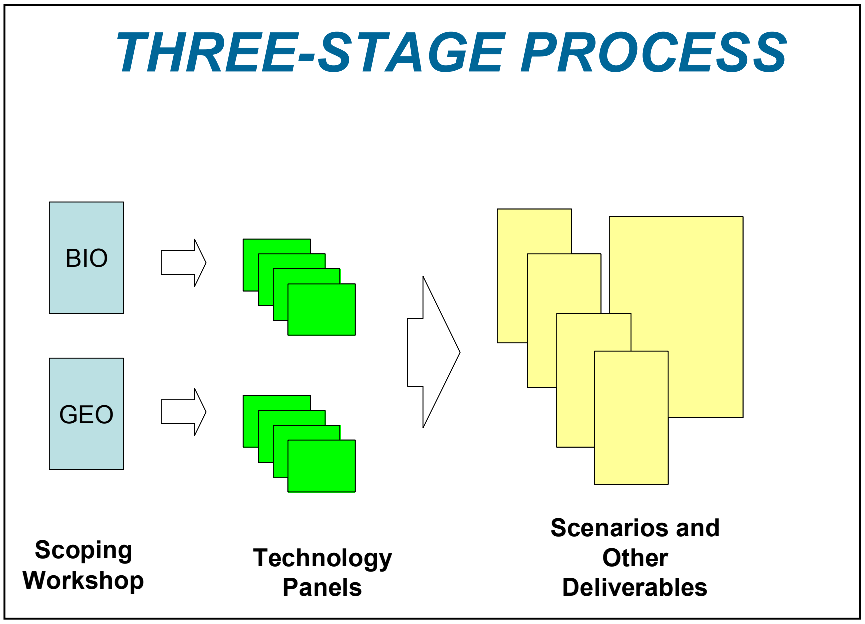
Within SBDA circles, there is a view that horizontal collaboration among the SBDAs will be more common (and necessary) as the government addresses more complex issues and in areas where the scientific and technology knowledge is spread across many departments and agencies. While in the past departments were able to operate in “silos”, many of tomorrow challenges will have to be addressed in a coordinated way. As an example, today challenges in national security includes the protection of the water or the food supply against biological or chemical terrorism or warfare. Clearly, this is such a great task that it requires the capabilities of several SBDAs.

1.1 Process and Methodology

Interest in building horizontal linkages among the SBDAs drove a number of design decisions for the project:

1. A working group of the participating SBDAs was created, with the mandate to oversee Foresight project activities.
2. A project team was established with participants from the working group as well as through the hiring of consultants to implement the Foresight project.
3. The TFPP through consultations with the SBDAs engaged a cross-departmental network of scientists and policy makers to obtain their views on future science and technology capabilities, which were then grouped into two broad topic areas: Biosystemics and Geostrategics (see the definition of Geostrategics in the following section of the report).
4. The TFPP then brought together a broad cross section of scientists from academia, government and industry from across Canada to examine in depth these two broad topics.

For each of the two topics, an initial scoping workshop was held in which key sub-topics were identified and the top 4-6 topics were explored. Participants were requested to describe their visions for 2025. The scoping workshop was followed by four technical panels, one for each topic, where participants were requested to probe much more deeply into the future. While the Geostrategics and the BioSystemics Foresight approaches were implemented in parallel, there were differences between the two approaches. This report covers the Geostrategics Foresight findings up to the completion of the technical panels. The next phase of the FTPP will be scenario development, where we intend to combine the findings in the two topics.



1.2 About This Report

This report is aimed at providing a synthesis of the findings of the scoping workshop and the four technical panels on Geostrategics Technology Foresight for the Canadian federal government. The scoping workshop and the technical panels were held between November 7, 2002 and December 12, 2002 at the West Carleton Meeting Centre in Kanata, Ontario.

The results of each of the events were recorded in individual event reports. These reports may be downloaded by following website: www.nrc.tomoye.com.

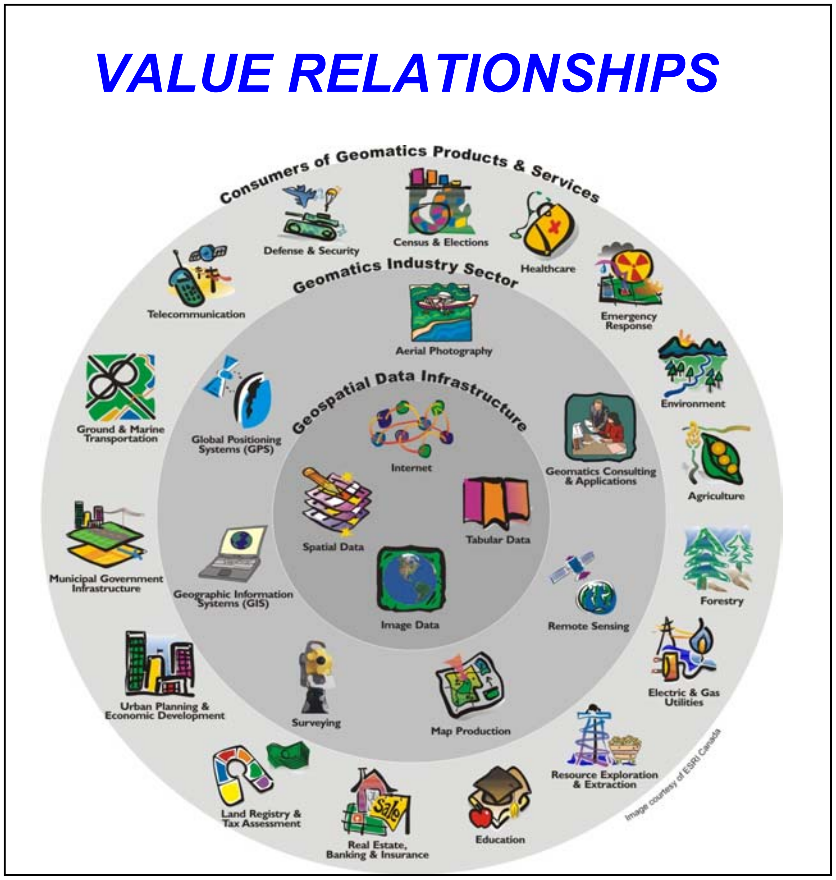
This report reflects the combined views of the participants, but it does not represent the official views of the Government of Canada or any of its departments or agencies.

It must be noted that this report is meant to provide a brief summary of the findings, but was not intended to capture all the contributions made by participants. In turn, this summary report will be provided to the participants of the following scenario planning events, as well as with participating departments to share with their internal staff.

The synthesis work was undertaken by the Geostrategics Knowledge Manager and was further refined by the Project Team and the interdepartmental Working Group.

Geostrategics is defined as "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.”



This project attempts to answer the following key question as defined in the terms of reference:

> **“How will geo-strategic knowledge, technology and prospective applications likely to be available in 2025 reshape our understanding of Canada, its land, sea and air/space resources, and provide new capabilities for national security, and the stewardship and sustainability of Canada’s resources?”**

Geostrategics impacts a diverse set of sectors, as can be seen in the following graph. The scoping workshop identified the six most important topic areas within Geostrategics, intowhich the subsequent technical panels were requested to probe deeply with respect to Canada’s needs for science knowledge and technologies by 2025. These topics are as follows:

1. National Security & Emergency
2. Environment & Resources
3. Oceans & In Land Water
4. Sustainable Cities & Settlements
5. Health Effects & Risk Factors
6. Transport

Many of these topics are interconnected. For example, one cannot seek to understand the environment without the study of the global oceans; we cannot build sustainable cities or settlements without understanding local environmental factors, such as pollution and air flow. It must be noted that many of these topics are also interconnected with the findings of the Biosystemics Foresight exercise, which was taking place in parallel with the Geostrategics Foresight exercise. The BioSystemics Foresight exercise was organized along the following four topics:

1. Biotechnology
2. Cognitive and Information Sciences
3. Nanotechnology
4. Systemics

At this point, while references have been made to these Geo-Bio inter-connections in the text, the report is organized strictly accrording to the six Geostrategics topics. The cross-topic synergies within the six Geostrategics topics are briefly illustrated in a separate chapter towards the end of this report. The last chapter is dedicated to horizontal collaboration opportunities, as identified by the participants.

1.3 Participants

The participants of the Geostrategics scoping workshop and the technical panels included representatives and nominated experts of the participating departments and invited experts from academia and industry. In total, over 110 experts from across Canada were consulted through this process, representing a wide range of science and technology areas within Geostrategics. The following is the list of experts consulted.

Denis	Allard	Canadian Food Inspection Agency
Peter	Annan	Sensors & Software Inc.
Michael	Bailey	Navigation Technologies Corporation
Chris	Barnes	University of Victoria
Robert	Batterham	Ryerson, Batterham Associates Ltd.
Denis	Beaulieu	CARIS Québec/Ontario
Michel	Béland	Environment Canada - National Water Research Institute
David	Bell	York University
Martin	Bergmann	Department of Fisheries and Oceans
Pierre	Bernier	Canadian Forest Service
Johanne	Boisvert	Agriculture and Agri-food Canada
Ferdinand	Bonn	Centre d'applications et de recherches en télédection (CARTEL) - Université de Sherbrooke
John	Bonnett	National Research Council
Gary	Borstad	G. A. Borstad Associates Ltd
Raymond	Bouchard	Drachma-Denarius
Line	Brabant	LINE International
Carl	Brown	Environment Canada - Emergencies Science and Technology Division
Robert	Bukata	Environment Canada - National Water Research Institute
Philip	Byrne	Canadian Food Inspection Agency - Centre for Animal & Plant Health
Jack	Chambers	Canadian Space Agency
Allen	Chong	National Defence
Gérald	Chouinard	Communications Research Centre
Kevin	Cliffe	Natural Resources Canada
William	Coderre	Natural Sciences and Engineering Research Council of Canada
Catherine	Cote-Kirijian	Industry Canada
David	Crabtree	Defence R&D Canada
Tammy	Davies	Health Canada
John	Dawson	National Defense
Ron	DiLabio	Geological Survey of Canada, NRCan
Nicole	Dusyk	Environment Canada
Doreen	Dyck	Defence R&D Canada
Glen	Easton	Agriculture and Agri-food Canada
Susie	ElSaadany	Health Canada
George	Emery	National Research Council
Len	Exner	Exner Technology Concepts
Carol	Fairbrother	Natural Resources Canada
Stephen	Fanjoy	Vastor
Sara	Filbie	Industry Canada

Rich	Fleming	Canadian Forest Service - Great Lakes Forest Research Centre
Kathryn	Freemark	Environment Canada - Canadian Wildlife Service
Asoke Kumar	Ghosh	Canadian Space Agency
Randy	Gillespie	Canadian Centre for Marine Communications
Bernie	Gloyn	Statistics Canada
Michael	Goddard	Health Canada - Population and Public Health Branch
Barry	Goodison	Meteorological Service of Canada
Doug	Green	Health Canada
Maxine	Grier	Agriculture and Agri-Food Canada
Richard	Grieve	Earth Sciences Sector, Natural Resources Canada
Hugh	Gwyn	Université de Sherbrooke
David	Harries	National Research Council
Bill	Harron	Agriculture and Agri-Food Canada - PFRA
Leo	Hartman	Canadian Space Agency
Geoffrey	Holland	2WE Associates Consulting Ltd.
Jean	Hollebone	Canadian Food Inspection Agency
John	Jerome	Environment Canada - National Water Research Institute
Erle	Jones	Communications Research Centre - Industry Canada
Peter	Kallai	Keystep Growth & Finance
Terry	Kimmel	T.B. Kimmel & Associates
Neil	Knudsen	Technology Leadership Group
Kurt	Kyser	Queen's University
Keith	Langille	Texec Leadership Development Centre
John	Lawrence	National Water Research Institute
Peter	Leach	Leach Technologies Ltd
André	Lévesque	Agriculture and Agri-Food Canada
David	Liang	Defence R&D Canada
Chuck	Livingstone	Defence R&D Canada
Steve	MacPhee	International Hydrographic Management Consulting
Giulio	Maffini	A + i2 inc
Martin	Magne	Parks Canada
Ahmed	Mahmood	Canadian Space Agency
Dan	McGillivray	CRESTech - Centre for Research in Earth and Space Technology
Dave	McIlhagga	DM Solutions Group
Glen	Milne	Glen Milne & Associates
David	Minns	National Research Council
Ingar	Moen	National Defence
James	Moore	Health Canada
Steve	Moran	CRESTech
Catherine	Morrison	Morrison & Associates
Bob	Moses	PCI Geomatics
Fonda	Munroe	Canadian Food Inspection Agency
Dennis	Nazarenko	Marconi Wireless
Maria	Nazarowec-White	Canadian Food Inspection Agency
Paul	Nephin	Neptec Design Group Ltd.
Jim	Nicol	Telecom Internet
Udo	Nielsen	Dendron Resource Surveys Inc.
Olaf	Niemann	University of Victoria
Kevin	O'Neill	RADARSAT International
Jordan	Palmer	Youth Science Foundation Canada
Darko	Poletto	Spatial Knowledge Engineering Inc.

David	Pugh	Fisheries and Oceans Canada
Bill	Pugsley	Global Systems Centre, CACOR (Can. Assoc. for the Club of Rome)
Dianne	Richardson	Earth Sciences Sector, Natural Resources Canada
Erling	Rud	Health Canada
Peter	Schut	Agriculture and Agri-Food Canada
Jack	Smith	National Research Council -Technology Foresight Project Team Leader
Brian	Solheim	York University
Lynelle	Spring	SpringWorks
Roger	Stacey	Roger A. Stacey Consultants Ltd
David	Stanley	PCI Geomatics
Graham	Taylor	Precarn Incorporated
Phillipe	Teillet	Canada Centre for Remote Sensing
Stacy	Tesarro	Canadian Food Inspection Agency - Lethbridge Laboratory
Jacques	Trencia	Canadian Forest Service-Science Branch
Yves	van Chestein	DRDC
René	Voyer	Communications Research Centre
Doreen	Watler	Canadian Food Inspection Agency
David	Wells	University of New Brunswick
Kenneth	White	Acton White Associates
Norman	Willis	The Norm Willis Group
Richard	Worsfold	CRESTech
Harold	Zwick	MacDonald, Dettwiler & Associates Ltd.

2 Principle Findings

This section provides a high level summary of the findings cross-cutting the six Geostrategics topics and describing the sort of science knowledge and technologies that could be in use by 2025.

Ubiquitous Peer-to-Peer Sensor Webs

It is highly anticipated that by 2025 we will have a myriad of interconnected sensors monitoring various aspects of our world, including the environment, people and moving targets. Continuous monitoring of water resources, air quality, and disease threats will be widespread with the use of inexpensive, integrated, intelligent sensors. These sensors will be able to perform a variety of analytical tasks, including biological, genetic, chemical tests etc., by using highly integrated 'biochips'. Analyses that takes place today in labs will be done "in-situ", with all analytical and processing algorithms integrated within the sensors. It is expected that real time transmission of results will take place after validation of the results against peer sensors in events where key thresholds are surpassed. When monitoring people, security agencies will be able to identify and track the movement of individual suspects, similar to tracking the spread of invasive species, through matching against biometric databases.

Real-time Data, Information and Knowledge

There is increasing pressure to receive real-time data and information for a variety of critical public sector applications and decisions. As an example, national security applications such as border monitoring and, in emergency situations, real-time remotely-sensed data, is of very significant value for decision-makers. Current remote sensing systems (e.g. satellites and sensors) are unable to meet this demand. With the introduction of new micro and even nano satellites, should these become cost-effective, such limitations could be overcome by 2025. Inter-satellite communications, using advanced photonics technologies for data transmission, will enable the continuous coverage and receipt of data by the users, almost like we receive radio signals, in the form of an always-on "geo-utility".

Wireless Internet

Wireless communication is expected to maintain its growth momentum for the next two decades. Wireless will be the preferred choice for the implementation for Ubiquitous Peer-to-Peer Sensor Webs, including a strong micro-satellite constellation in space and expanded land-based wireless infrastructure. Much of the text, voice, data and image communication is expected to go through the next generation of the Internet. People or sensors will be equipped by universal software-defined radios, which will be able to communicate in any form (voice, image, text) with any peer and infrastructure around it, by simply uploading the right communication protocols and through multi-functional intelligent antennas. The high increase in wireless communication will require high capacity space and land based communications backbones, which will be supported by the next generation of nanophotonic communication devices and components

New Geo-Location Based Services

A whole new array of location-based services is expected to be in place within the next two decades. These new services will be based on the combination of providing the geolocation of something or someone and a status in one or more variables. For example, we expect to wear wireless health monitors by 2025, which will be connected to a central monitoring station and receive various health readings, such as vital signs. This specific service would be very important for high-risk patient populations, such as people with heart disease. Other examples include the geo-location and tracking of offenders after their release on parole, or tracking unmanned vehicles transporting goods.

Integrated, Shared Geostrategic Infrastructure

Ubiquitous Peer-to-Peer Sensor Webs will have to be built on or around massive infrastructures, considering the size of Canada and the wide variety of desired data, but these infrastructures could be shared among the various departments interested in implementing such webs. As an example, schools or other government-owned buildings in urban areas may be equipped with integrated sensors to track air quality and microorganisms that cause disease. Measurements can be processed at the sensor level and results may be sent to databases integrated with climate (historical) and weather forecasts (future) to allow for the storing, analysis and accurate prediction of air quality and potential disease threats. The same integrated infrastructure could be utilized by health and the environment agencies and departments to maximize benefits to Canada. Another use for this infrastructure might be the monitoring of water, air and fish indicators in the environment.

Intelligent Knowledge Systems for Common Good Applications

It is expected that future generations will be much more reliant on technology to make operational and policy decisions. The future lies in the development of systems that are capable of synthesizing data and information into knowledge, in a way that effectively supports decisions. Such systems could also become autonomous learning systems, once they produce new knowledge through analysis of decisions and decision impacts. The highest form of these systems will be allowed to make simple decisions, without major human intervention or interaction and command, and to communicate and control robots that can implement such decisions. One can imagine a host applications for such systems in the area of national security, such as the sensing and elimination of attacking missiles, vehicles, etc.

Virtual Reality Worlds

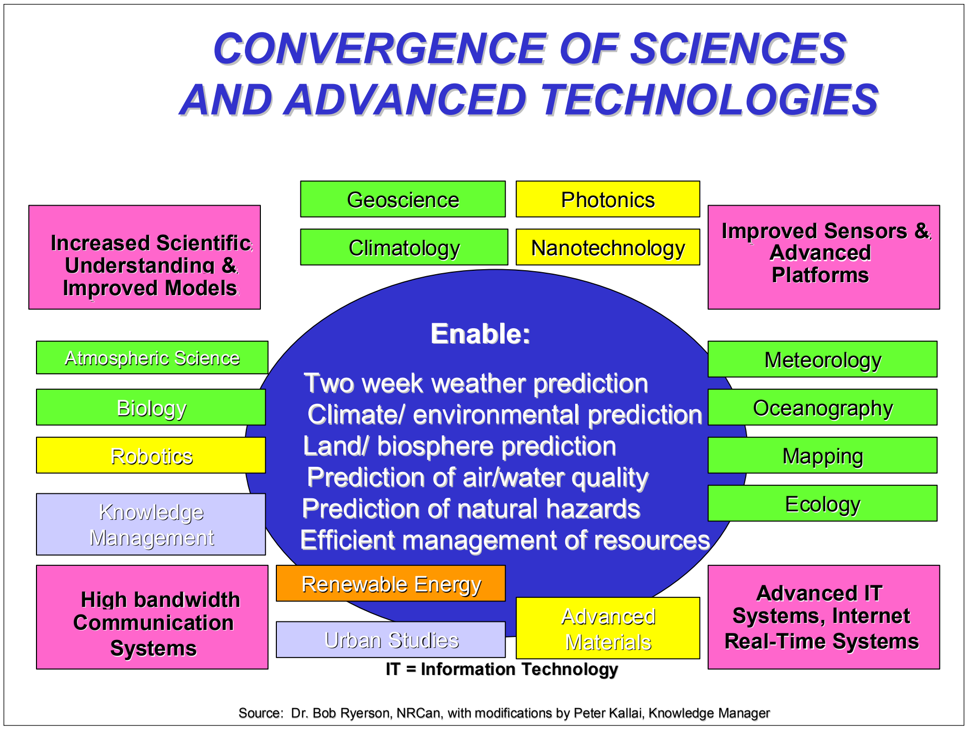
In order for technologies and scientific knowledge to be accepted by Canadians, scientists must communicate and popularize their discoveries. By 2025, we may expect the wide proliferation of virtual reality and interactive tools used to create complex models – for example models of local, regional environment – that will allow people to interact with these models and see the impact of certain decisions. Current virtual reality-based, interactive games could provide the base capability and technologies. Such virtual reality worlds could be of use to communities sharing interest in certain decisions. Examples for such virtual reality worlds could include the modeling of oceans, environment, urban transport, national security, spread of invasive species, etc., just to name a few.

Increased Complexity of Knowledge and Decision-Making

Our desire to make the best possible decisions prompt us to explore many interactions that are present in complex natural systems, such as the oceans and/or the environment. As an example, in order to make the best possible decisions about coastal zone areas, one must explore over 20 interdependent factors, such as land use, economic activity on shore, the fishery, climate, weather, vegetation, salination, coastal erosion, etc. This creates tremendous complexity in decision analysis and decision making. In ideal conditions, scientists would collect all required data on all factors and interdependencies to create a complex model to simulate decision(s) and decision impacts. The conditions are, however, rarely ideal. Decisions must be made in a timely fashion, without complete data sets or information. In such cases, we could take advantage of decision-support technologies such as soft computing, or chaos and complexity theories.

Convergence and Complexity of Systems

Many of the Geostrategic applications identified above will require the convergence of various technologies and science areas. This will add a very significant complexity at the systems level. As an example, the creation of Ubiquitous Peer-to-Peer Sensor Webs with integrated, intelligent sensors could require the convergence of such scientific knowledge and technologies as genomics to identify species, where these genomic tests would be “burnt into” integrated circuits designed for advanced plastic materials, instead of silicon, which in turn is being manufactured through nanotechnologies to allow for large scale integration and miniaturization.


CONVERGENCE OF SCIENCES AND ADVANCED TECHNOLOGIES

Enable:

Two week weather prediction
Climate/ environmental prediction
Land/ biosphere prediction
Prediction of air/water quality
Prediction of natural hazards
Efficient management of resources

IT = Information Technology

Source: Dr. Bob Ryerson, NRCan, with modifications by Peter Kallai, Knowledge Manager

Once the sensors are put in place, information will be shared and validated in a peer-to-peer environment, which will require that the sensor not just collect, but perform data processing functions. Information is in turn transmitted through high bandwidth wireless infrastructure, using terrestrial or space infrastructure and stored in multiple interconnected databases; this will allow seamless data integration based on international data standards and allow for real-time analysis.

More Disruptive and Enabling Technologies Are In The Pipeline

A host of new enabling technologies that will make the various technology visions a reality are in the pipeline. A few of these,include:

- Nanotechnology that promises large scale integration and miniaturization;
- New designer materials; engineered for their desired characteristics;
- Ever increasing processing power of microcircuits (in line with Moore's Law);
- The internet, which is a great tool for information, resource sharing and for the creation of knowledge networks;
- Smart systems and agents that can understand the meaning of words (semantics) in order to implement meaningful queries of databases and the Internet and synthesize data into information;
- Autonomic software that is capable of self-repair and automatic code generation;
- Wireless communication that will revolutionize social organization and interaction;
- Fuel cells that can power remote sensors for extended periods;
- Robotics and nanorobotics that will help action decisions;
- Organic sensors that will enable us to use plants and other life forms to act as alert mechanisms;
- New virtual reality-based visioning tools that allow citizens to participate widely in consultations and the decision-making process;
- New human-machine interfaces that allow for more effective interaction. e.g. direct link between systems and the brain; and,

- Telepresence that mimics the look and the feel of humans being in a meeting or perform activities such as diagnosis and surgery remotely.

The following sections of the report organizes the results of the Foresight exercise by topic areas.

3 National Security & Emergency

3.1 2025 Vision

Participants expect a more secure and safe Canada in 2025, but there are a number of challenges. How do we predict new methods of attack? How do we protect priority areas, such as food, water and computing infrastructure? Given that Canada is a northern country, how do we respond to disasters, if they happen in winter? How do we protect against or respond to warfare using natural resources (tainted water)?

By 2025, security will be understood by decision makers and the public to include economic, environmental and health issues as well as physical security. Resources will be assigned to develop measures for addressing them.

In order for national security organizations to fulfill their responsibilities, we need more and better information related to our country, potential security risks and their potential impacts. Foresight participants expected that by 2025, security organizations will need to be able to observe and identify everything and everyone remotely in a non-intrusive way, including individuals, vehicles, boats etc. Such observations and identifications will provide the basis for a well-synthesized flow to decision-makers of comprehensive national security information about the level of security threats. Some of the other key characteristics of security management will include the following:

- Security planning will be done using an integrated, multi-disciplinary, team-based approach;
- Integrated security systems will be required to monitor the various aspects of security;
- All aspects of homeland and international security issues will be subject to responsible and integrated management;
- Non-linear thinking will be applied, as we can not effectively predict the future based on the past;
- Comprehensive emergency environmental response will be possible with all impacts completely mitigated; and
- Balance will be reached between individual privacy and national security.

Much of the security information required has “geostrategic elements” and therefore, spatial mapping can be used to organize such information – using multi-dimensional web space. Given that integrated security systems will be needed, when multiple organizations have information and data, security becomes everyone’s business. This adds an element of openness to the system and creates both privacy problems and a counterbalance.

It is expected that Canada and the world will evolve through a number of eras of security management. The following table shows two dimensions to identify these eras:

Cosmological/Global	Management Approach
Era of Regional Security; alliances among regional economies and civilizations	New world order, clash of civilizations, big brother watching ▪ Awareness ▪ Detection ▪ Defense
Era of global security for water, food etc.	Reactive, fill known gaps, defensive
Era of security against artificial life forms	Proactive, anticipate potential threats, prepared, pre-emptive measures ▪ Problem definition ▪ Data capture

	▪ Info and knowledge ▪ Understanding problems, threats ▪ Automation of data, information and knowledge chain
Era of cosmological security – cosmological threats, alien species, microbes from Mars	Self-directed, knowledge-based, intelligent, automated interventions

It can be speculated that by 2050, we will reach global peace on earth and therefore, all security decisions will be governed globally.

We expect that with respect to the information-based society, Moore's law will continue to be valid for the next 23 years – doubling computing power every 18 months – thus the computing power will be approximately 16,000 times greater in 2025 than it is today. Data storage density will also be increased several thousand times within the same time horizon. With the pervasive use of optical communications and with its advance in capacity, we will have the capability to operate a global sensor web and receive real-time information. By 2025 the key question will be how to translate all this data into useful information and then into knowledge real-time.

3.2 Key Questions and Decisions

The following are some of the key questions and decisions that we should be able to respond to in order to implement the vision outlined above:

- A new definition of national safety and security to reflect the new era that we live in
- Rights/safety tradeoffs
- Individual and collective rights tradeoffs
- Recognition that national security is now facing non-traditional threats and asymmetrical situations that require a different world view
- Recognition that new threats emerge from sources antagonistic to our values that are not easily understood
- Combative situations lead to problems with access and organization of information
- Issues regarding security and data require fundamental questions about democracy and governance
- Data volume leads to issues of data value
- Data value can only be derived through the development of semantics and standards
- Issues regarding ownership of and access to data
- Need to develop conflict management models to structure the information
- Use history as a source of knowledge
- Food source security
- Global identifiers
- Micro data
- Ways to reduce the cost of building and launching space based sensors
- 3-D modeling and systems for urban warfare
- Detection, sensing in real time
- Artificial Intelligence and other software to process data, support decisions
- Improvements in response time to situations where real time data is available
- Deal with the issues of the role of government – who is the steward of information?
- Human behavior relative to technology – we need better information on this
- Critical to develop knowledge and people, use collaborative teams
- Human resource issues, critical in terms of skills development and behavioral sciences

3.3 Science Knowledge and Technologies Needed

Science Knowledge
2005 – dynamic modelling of fate/behaviour and impact of chemical and microbial attacks on water/ecosystem and air √
2005 – better knowledge to correlate and integrate existing and future databases
2005-2010 – development of neutralizing agents for chemical and germ warfare
2010 – multi-spectral/hyper spectral sensors and automated algorithms to classify and ID “targets”
2015 – lower cost observation platforms (Unmanned autonomous vehicles (UAV) sub-sea, ground-based and space craft)
2020 – genomic technology available to correct genetic damage dispersed geo-spatially
Sensors
2005 – global inventory and understanding of early threats +
2010 – cheap in situ sensor, undetectable by others, continuous operating mode √ +
2010 – cooperative robotic systems patrol Canada’s sea floor to apprehend intruders +
2020 – defences or countermeasures against cruise and ballistic missiles, nuclear and terrorist attack
2025 – low cost space-based surveillance sensors
2025 – utilization – near continuous coverage (vehicle level), vehicle identification is possible from space
Data Transmission
2005 – compression technology to allow fast transmission and recovery of data
Data Capture and Warehousing
2005 – web-based countermeasures to detect and neutralize cyber attacks against the financial industry
2010 – searchable information catalogues +
2015 – mass data storage on personal computing devices
2025 – data recovery of national and global data sets
Data Processing
2010 – interpretation of real-time data to enable accurate trending and forecasting √
2010 – psychoanalysis to identify potential terrorists and mass murderers
2015 – full use of peer to peer processing of data and information
2025 – photonic computing
Visualization, Dissemination
2007 – virtual reality tool integrated into personal vision
2015 – intelligent technology; what is the public able to access and when
2020 – tools/services that can automatically synthesize data into information √
2020 – 4D interactive, holographic modelling of datasets
Information /Knowledge Systems, Modeling
2005 – data information conversion to preserve knowledge/memory despite technological advances √ +
2007 – next version of Web
2007 – educational tools
2010 – emergency measures integrated databases (atmospheric, watershed) to predict fate of chemical and germ warfare releases
2015 – AI agents within advanced Integrated Earth Observation (IEO) systems capable of generating actionable intelligence in real time for emergency measures
2020 – Web-based, interconnected sensors for weather, terrain analysis, CBRN (chemical, biological, radioactive and nuclear) threat, tactical and strategic uses
2020 – accurate predictive models for CBRN threats and impacts
2025 – real time situational assessment: economy, agricultural, border control, military tactical and strategic √
2025 – models reduce global data to useful form/volume
Infrastructure
2005 – comprehensive, integrated product: data sets
2010-2025 – smart (sensor reactive) deployment systems to counteract chemical and germ warfare

Symbol key: Where Canada has a role (+) and technologies have to be developed quickly (√):

3.4 Enabling Technologies

Enabling Technologies

- Increased deployment of cheap, integrated and intelligent sensors that can identify and analyze people and moving objects
- Image processing algorithms for the intelligent detection, classification, identification of people and objects
- In-situ mobile tracking systems
- Low cost micro, nano, pico satellite systems that enable cheap sensor deployment
- Integration engineering to fully exploit nanotech in robotic systems
- Software to fully exploit computational technology at the limit of Moore's Law
- Automatic systems generate software code for complex systems development
- Molecular engineering leads to creation of first Von Neuman machine
- Virtual reality becomes a pervasive substitute for reality
- Industry de facto technology standards
- Calibration technologies easy, consistent, implemented everywhere
- Real time, world wide, 24/7 remote sensing systems
- Smart systems and technologies e.g. crossing a border at an airport triggers an artificial intelligence system that tracks you while in the country and shuts off when you leave
- Data fusion & artificial intelligence to make information usable
- Advanced wireless communications through the implementation of software defined radio systems
- Advanced manufacturing – especially in advanced electronics – to miniaturize electronic components and products
- Nanotechnology to provide small, integrated devices

3.5 Key Drivers, Wild Cards, Disruptive Technologies

Drivers

- Canada remains a sovereign nation
- No major climate change (may require a change in the R & D agenda)
- U.S. remains a hegemony
- R&D must increase to stem downward spiral
- Kyoto obligations do not have a major negative economic impact
- New generation; new expectations
- Government surplus to support innovation
- Innovation agenda and trade globalization
- Public confidence in technologies
- Counter-innovation: privacy vs. accessibility; control of knowledge
- Rising education levels and standards
- Multidisciplinary solutions needed for more complex security issues

Wildcards

- No acceptance by society of technology; e.g. Canadians do not want "big brother watching"
- Cold fusion becomes a significant source of energy, oil reserves are depleted; this results in a global shift in economic and political power
- Intense solar flares over a prolonged time crash all communities and systems
- Pickering bombed; Toronto under massive radiation cloud
- Collapse of US economy due to repeated terrorist attacks
- Crop diseases cause massive failure of harvests world wide; disastrous food shortages

- Spread of massive epidemics such as foot and mouth disease
- China becomes dominant world economic power, surpassing US, Japan and Europe; progressive change to new world order
- Commercial espionage of systems and products
- Genetically modified plague
- A major hack of the Web that disables it for weeks and corrupts data bases
- Fossil fuels are depleted; no viable replacement; pervasive security impact
- Predator nations are able to siphon off Canada's oil resources and we have no means of detection
- Rogue state attacks Canada with airborne psycho-narcotic agent that induces widespread sociopathic behavior
- Rogue states develop countermeasures to defeat Canada's CBRN technologies
- Other kinds of unusual attacks, like a time series attack where the impact is not felt for a number of years
- Silico-phagocites to destroy silicon-based technology as a defence against advanced robots

Disruptive Technologies

- Cheap fuel cells which can change the geopolitical agenda
- Age reversal pills, which would result in population explosion
- Advanced intelligent systems prompted by advances in molecular and nanotechnology
- Computational power that approaches the quantum limit
- Molecular engineering becomes a reality; robotic systems become new life forms with multiple impacts on society

4 Environment & Resources

4.1 2025 Vision

According to Foresight participants, Canada should root its science and technology development in an understanding of itself as a northern and maritime nation that believes in taking care of "mother earth".

One group of participants suggested that by 2025, we would achieve zero waste (full recycling). We will have clean air and water. In order to achieve this, we will have to become pro-active managers of the environment with the capability to provide accurate models of our environment and with the capability to repair damages to the eco-system.

Another group suggested that we would have a more dynamic hydrologic cycle with more extreme events. It must be recognized that ecosystems will therefore be unable to adapt in currently predictable timeframes or in a sustainable manner. We can expect increased toxic loading in air, water, land, and ocean systems globally and a warmer Arctic. In order to counter increased toxic loadings, we need to develop the ability to repair ecosystems by technological or other means (legal, regulatory actions). In terms of interventions, we will need to be able to impact different environments with predictable effects and side effects.

By 2025 we expect to have emission-free portable energy sources as the next generation battery replacements and sustainable energy from wastewater (hydrogen, geothermal). We might even be able to harness thermonuclear fusion energy as an alternative.

In order to better manage the environment and resources, both groups agreed that there is a need for better geo-information. We need reliable indicators for geo-eco systems health assessment, which may be offered through programs developed in the European Union, under Global Monitoring of the Environment and Security (GMES). In order to build accurate models for Canada, we need global access to satellite earth observation data, a standard approach to data catalogues and a standard approach to calibration/validation and data assimilation. In case we do not have all data and information available for decision-making, we must take advantage of such decision knowledge as soft computing (decision making with incomplete information) or the chaos and complexity theories.

It is expected that we will go through several eras of development to get to a self-healing eco-system. These eras could include the following:

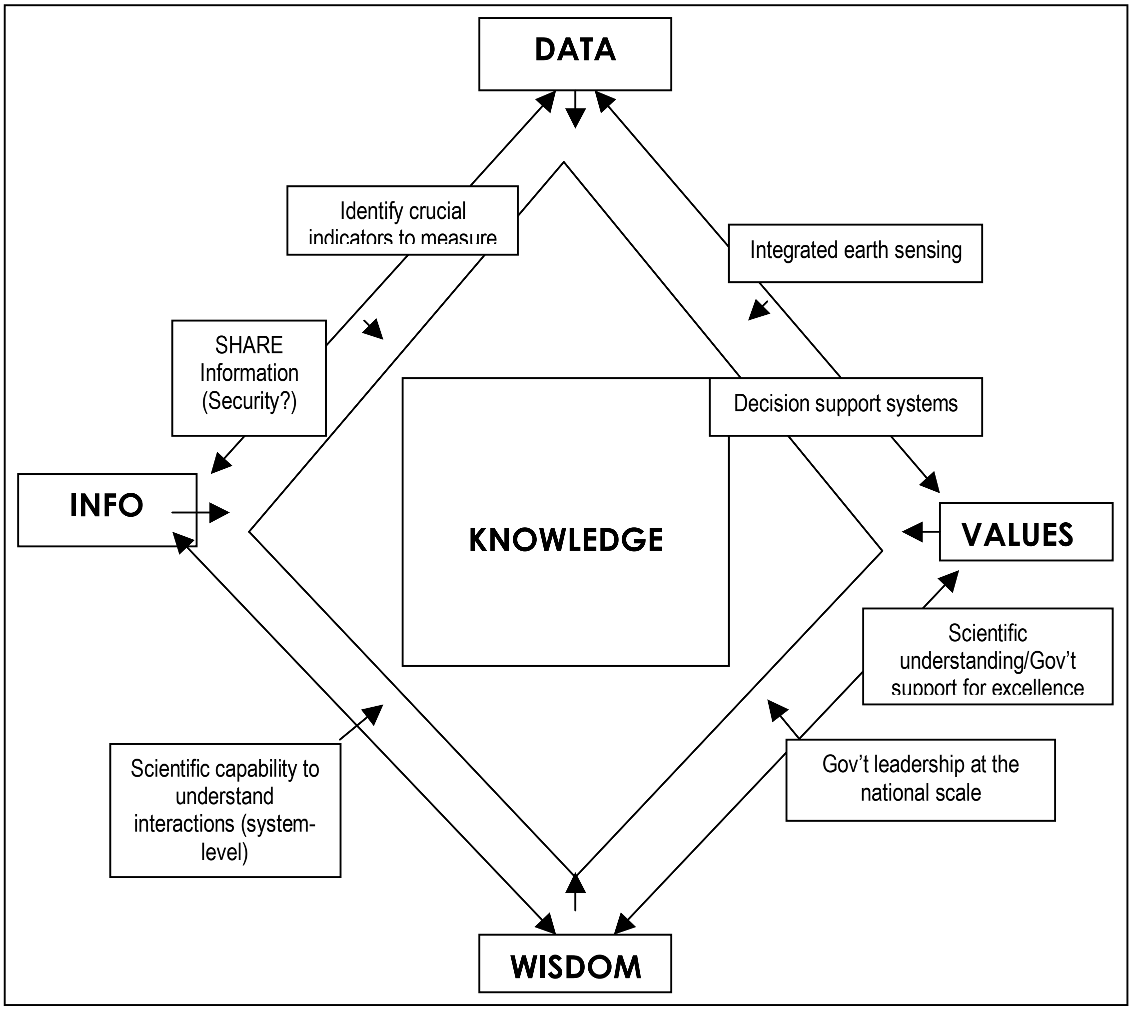
- 2002-2005 – Connectivity of data bases, sensors and people;
- 2005-2015 – Information processing: good data for good information, including calibration and validation, internetworking between data sources and data stores;
- 2015-2025 – Knowledge processing: modelling, analysis, self-learning systems for effective solutions;
- 2025-2050 – Self-healing eco-system.

The Canadian strategy for achieving this vision could include the following elements:

- The use of our unique niche as a northern, maritime nation to be a global leader in climate change. This incorporates specialization in management of renewable and non-renewable resources
- Integration of traditional First Nations knowledge with science knowledge
- Developing greater efficiencies in sector cooperation
- Understanding the cost of inaction
- Making available free, usable information to citizens to assist in policy and decision-making

- The need to create linkages between data and knowledge
- The need for "communication out" of the system, with technologies adding value and supporting public utility of knowledge
- Overall assessment and management of eco-system health of supply, quality and distribution of land, air, water, flora & fauna (Canada linked to global eco-systems)
- Canada's strategy must be set into a framework linking global environments, socio-economic factors and natural resource conservation and extraction.

With respect to environment and resource information management, participants expect the integration of data and information systems. Such systems should reflect the complexity of the earth's systems and provide real time data for smart synthesis. Such smart systems should be capable of creating knowledge through receiving current data, mining data archives and integrating values, information and wisdom to suggest smart decisions.



4.2 Key Questions and Decisions

The following are some of the key questions and decisions that we should be able to respond to:

- What is the current inventory of Canada's resources? What is the rate of depletion of these resources?
- What is the scope and nature of global climate change and what are the impacts on Canada?
- How can we ensure and monitor fresh water quality and supply?
- How can we protect Canada's unique biodiversity and habitat?
- What will be the social values of Canadians with respect to the environment and resources?
- What technologies are required to effectively monitor the environment and resources (e.g. green house gas emissions for Kyoto)?
- Can current technology be leveraged to provide new solutions?
- What incremental improvements of technology vs. breakthroughs are required?
- How can we make better of use of current environmental and resource data?
- How can we ensure that our knowledge does not lag behind new technologies and that their impact on the environment and resources are well understood?
- How can we connect people for effective collaboration between departments, governments, universities and the private sector; also, given the global nature of environmental issues, between Canada's scientists, its institutes and other countries?

4.3 Science Knowledge and Technologies Needed

Science Knowledge
2005 – photonic bandgap +, meta materials, micro electro-mechanical systems (MEMS), micro electro-optical-mechanical systems (MOEMS) 2007 – source/sink of carbon – all Canadian ecosystems 2007 – land surface process parameterization and modeling – must be an ongoing effort 2010 – complex modeling including bio-geo-physical processes and their interactions 2010 – real-time environmental modeling of diseases based on in-situ sensors 2025 – science integration: physics and biology; nanotech and other sciences; new fabrication processes, new materials; math
Sensors
2002 – 2025 – need continuous long-term measurement and observation to create environmental and climate time series √√ 2002 – 2025 – continued development and miniaturization of lidars for aerial sensing applications such as coastal zone environments √; 2005 – real-time in-situ sensor web for Canada for monitoring soil, water and air quality 2005 – satellite sensors for ongoing, all-weather sensing of atmosphere and surface 2005 – toxicity bio-sensors in fish cells, as opposed to whole fish 2005 – millimeter wave sensors (radar, radiometer) 2010 – portable PCR: multi-species identification data stored within intelligent sensors to able to monitor dangerous/alien species or for biodiversity; can be applied for both animals and plants. 2010 – IR, FIR spectroscopy 2010 – Hadamard transform spectroscopy + 2015 – small, integrated, inexpensive wireless bio and geo markers for gauging and tracking eco systems√, interfaced to central monitoring systems√ 2015 – precision forest pest control 2015 – 2020 –microsat →picosat→formation flying for inexpensive launch of earth observation sensor and data transmission for real-time and continuous monitoring

2020 – distributed Synthetic Aperture Radar systems for monitoring the environment and resources in any weather conditions
2020 – inexpensive multi-purpose mobile wireless sensors – on vehicles, airplanes etc. to provide a continuous flow of environmental data
2025 – integrated and cost-effective remote environment sensors and remote in-situ sensors with long operating power replacement cycle (hydrogen cells) with better satellite coverage to pick up the signals
2025 – space based detectors/sensors for alien species “Immune System”

Data Transmission

2010 – high data rate link > 10 Gb/s optical data links
2018 – we need better data compression algorithms for data transmission and storage to avoid bandwidth saturation
2025 – selective (processed) wireless transmission from remote sensors (selective means dropping redundant – not changed data)
2025 – direct information link to brain (!)

Data Capture and Warehousing

2005 – integrated data archive including government, industry and academia for sharing and the accelerated processing of data into information and then into knowledge
2005 – raster/vector data fusion
2005 – dynamic validation and calibration of data bases (!), protocols for accepting/rejecting data
2010 – spatial resolution fusion – ability to fuse data with different spatial resolution
2010 – improved field data capture

Data Processing

2005 – smart sensors process data at the edge of the sensor web to reduce communication requirements
2005 – need validation of feature extraction from images and data +
2010 – web-enabled real-time geospatial analysis in distributed environment
2010 – data acquisition ahead of applications; data processing automated to provide information
2015 – from data to reliable information (calibration and validation and more)
2020 – massive parallel computing (SETI model) √ and data storage with resource allocation and attribution, meshed networks, background, low-level operating systems
2020 – optical signal processing +√
2025 – fully automated feature extraction, classification and analysis of observations of the environment
2025 > – optical computing

Visualization, Dissemination

2005 – community-based science and monitoring via web
2007 – easy to understand, easy to manipulate data visualization tools required for 3D and 4D data and information representation
2008 – real-time access to real-time data via web
2025 – easy access to validated information in real-time, for a wide range of uses (e.g. water quality), in a quality visual format with intelligence in the background

Information /Knowledge Systems, Modeling

2002-2005 – create virtual information networks; link databases, e.g. Canadian Cryosphere Info Net
2002 - 2025 – knowledge of cold climate systems in a changing climate system
2005 – analytical tools to integrate multi-scale RS data
2005 – modeling alien and pests using primary data
2005 – design damage control systems (!)
2005 – data processed into useful information in real time, made widely available (climate, toxics) √ +
2005-2010 – full integration of GIS with sophisticated 4D models √ +
2007 – plug & play ecological modeling environments/systems similar to the gaming environment that exist today
2010 – simulation modeling systems – keystroke & verbal commands
2010 – modeling chaotic and random systems
2015 – Canada’s environmental model “commercialization” and popularization
2015 – clean resource extraction
2015 – intelligent data/info systems facilitate accurate resource inventories – oceans; terra
2020 – artificial intelligence based systems capable of inferring new knowledge beyond data mining and cluster information systems
2020 – intelligent information systems agents to support decision making proactively for new policy and in real time for emergencies

2020 – more robust models for change prediction (from global to local and reverse) √√
2025 – ubiquitous access to self-defined data that allows artificial intelligence driven analytical models to identify and solve problems
2025 – Information/knowledge available wirelessly to purchaser at point of purchase
2025 – scalable electronic governance, “electronic government”
2025 – real time, intelligent, self-adapting and auto calibrating environmental models, fed by wise, in situ indicators
2025 – user friendly – visual; popular

Infrastructure

2005 – data continuity partnership to ensure that we have long time series for climate change prediction
2005 -2025 – validation of remote sensing and model output products
2005 -2025 – maximizing access to data, given commercial interests √√
2010 – free data access; facilitate data integration
2010 – establish confined “eco-labs”; legislation, containment, public opinion √
2010 – intelligent systems on satellites autonomously adjust observation strategies to suit environmental conditions – e.g. weather
2015 – integrated earth monitoring systems permit effective regulation of resource extraction and its consequences
2015 – monitoring network to validate-calibrate remote sensing data
2015 – light-weight long-life portable power supplies (small scale)
2015 – cooperative, intelligent autonomous systems explore harsh environments and perform other tasks
2020 – self-healing eco-systems→plant-based systems
2020 – static and spatial dynamic monitoring network
2025 – self-ordering networks
2025 – direct networked human brains
2025 – an intelligent inquiry and warning system for environmental change at all scales √
2025 > bridge the digital gap in access to information for the poorest societies (developing countries)

Symbol key: Where does Canada have to have a role (+) and what technologies have to be developed quickly (√)?

4.4 Enabling Technologies

- Integrated products with data from in-situ, satellite, models (data fusion)
- 4D data – incorporating time series data from many sources in forecast models (in situ and remote sensed)
- Open GIS Consortium standards
- Semantic web technology
- Network computing
- Variable range wireless; high efficiency, high data rate, SDR (software defined radio), single architecture
- New materials and technology: radiation-resistant components to promote miniaturization, reliability and self-healing
- Integrated optics
- MEMs/MOEMs
- Terrahertz technology
- Neural networks
- Optical logic, fuzzy logic
- Photonic bandgap
- Plant biotechnology (e.g. earth healing plants)
- Computing technology: optical, nano, pico
- Real time systems
- Sensor miniaturization

4.5 Key Drivers and Wild Cards

Drivers

- Energy crunch
- Organic product demand
- Pollution
- Bandwidth saturation
- Demand for broadband, high speed, high accuracy, real time, low power consumption, miniaturized technology
- Increasing demands on resources by increasing populations with higher expectations (e.g., energy)
- Urban brownfield development – R&D focused on releasing the money held in escrow for clean-up
- International cooperation: Canada, as a small country needs to cooperate on large projects, e.g., space projects
- Water scarcity and quality degradation as an emergency driver accelerator (also air, soil)
- Regional response to pressures may be different because of economic drivers (resources vs. manufacturing), culture, geographic location (e.g., Kyoto)
- Government policy and regulations
- Market response to new environmental technologies
- Climate change
- Arctic warming leading to the opening of the North West Passage – sovereignty issues

Wild Cards

- 9/11 Two
- Accelerated climate change
- New cold/hot military conflicts; space assets vulnerable
- Religious wars delay technological advances
- Repeated satellite failures and/or ground infrastructures
- Decreased coordination of monitoring networks
- Space elevators – changes the pricing structure of satellite, space travel
- Middle East oil shortage; increased restrictions on access to data
- Global change linked to climate change; population change, bio-reactors
- Development of a low-cost, handheld, local gravity suppressor
- Collapse of financial system and markets; no support for technological development
- Offshore resource extraction results in catastrophic decline in biodiversity
- User acceptance is key for technology adoption

5 Oceans & In Land Water

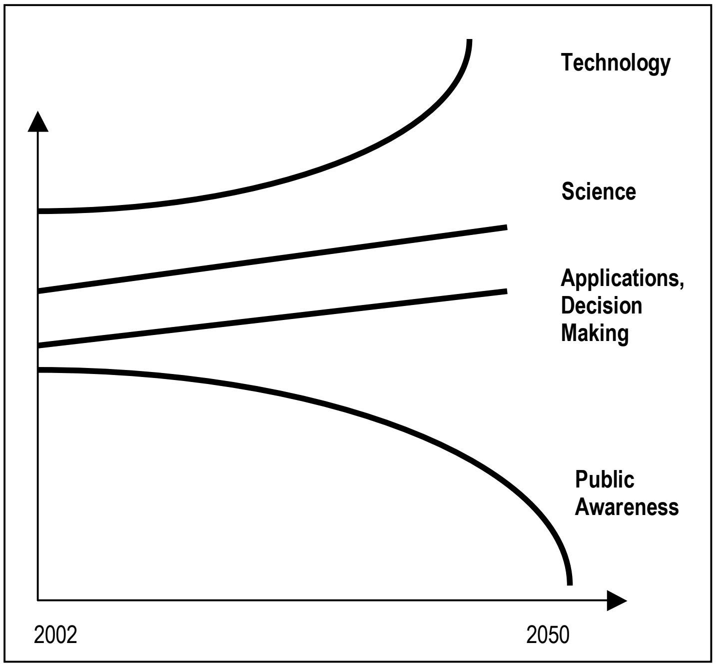
5.1 2025 Vision

As mentioned in the introduction, our understanding of the environment and resources must include the understanding of the oceans and in-land water resources. As an example, the global warming of the oceans and in-land waters is directly impacting the hydrological cycle and global atmospheric movements. As such, winds and rains can carry significant pollution from urban or industrial areas to the wilderness. Given the understanding of this integration, we have chosen to show the oceans and in-land water topic under its own section to reflect its importance within this context.

In-land water
Canada, one of the richest countries in in-land water, will need to continue to provide high quality and safe water well into the 21st century. In order to achieve this by 2025, we will need to be able to monitor, in real time, water dynamics across Canada and provide reliable prediction for the amount, quality and waste content of ground water. Water yield should be known and sustainable; droughts should be resolvable; and groundwater salination understood. Mechanisms of transporting water between regions that don't have it and regions that do will be in place.

Oceans
By 2025 Canada will manage its oceans in a sustainable and profitable manner. By 2025, for example, all key fish stock management variables will need to be understood; we will need to develop good knowledge of our oceans and the atmosphere to be able to make climate and weather forecasting available in real time with reliable predictions for up to six months in advance.

It was pointed out by Foresight participants that one of the key steps to achieving the vision is the complete mapping of the hydrological cycle. Given the global nature of oceans and the hydrological cycle, Canada will have to work cooperatively with other nations (which includes access to free geospatial data). To achieve this goal, large investment will be required .



Participants suggested that Canada could use its unique niche as a northern, maritime nation to be a global leader in ocean and in-land water resource management; however, this would require a pro-active stance from the government. Among others the government will have to make better use of science and scientific research to make evidence-based decisions with respect to oceans and in-land waters. This will require better integration (closing the gap) between scientific research, operational management and decision-making and public awareness (see chart).

Some partipants pointed out that the existing gaps between technology, science, applications, decision-making and public awareness are and will be increasing over the next 25-50 years.

Therefore, critical elements of future directions could include the popularization of oceans and in-land water technology and science results and it is important to improve communications with citizens on the pro-active management of oceans and in-land water. This approach would require scientists who collect data to turn that data into information and knowledge in a way that could be easily understood by the public.

It is expected that we will go through several "eras" between 2002 and 2025 in achieving the vision as Canada increases its technological, scientific and political maturity. Some of the variations for these eras are shown in the table below.

Option 1	Option 2	Option 3
2002-2007 Sensor & Data Collection	2005 – 2015 Improved communications within and between sectors, sharing best practices	2010 – 2020 United Nations Convention on Free Data Availability and Common Standards, Web-based.
2008-2015 Science Knowledge, Visualization, Dissemination	2015 – 2025 Ecosystems mechanics, understanding aquatic health - acceptance of concept. Long-term natural systems monitoring	2015 – 2025 Widespread sensor deployment, Inexpensive standard sensors, Linked ocean, space, land sensors.
2015-2025 Integration of Information and Knowledge Systems	2025 – Onwards – Free information; borderless society. Global information on oceans and waters. Understanding real time the climate.	2022 – Onwards Real time predictive representation Development of new models and applications, Visualization technologies Customizable applications by end users.

Participants' suggested that evolving technologies must reflect the complexity of earth's systems; that data and information must be available real-time to decision-makers and scientists that greater emphasis be place on mining the data and developing information from it and on applying "smart synthesis technologies" to enable the mining of available data.

5.2 Key Questions and Decisions

The following are some of the key questions and decisions that need answers over the next 20 years if improved geostrategic information is to be made available:

In-land water

- What is the supply and quality of water in and around cities and settlements?
- How can we be warned in case of supply or quality problems in advance?
- How can we make water supply and quality sustainable in and around cities and settlements?
- What are the real costs of maintaining water quality and supply?
- How can we rehabilitate in-land water sources?
- How can we monitor and control water salination for coastal waters?

Oceans

- How can provide reliable, accurate climate and weather forecasts?
- How can we anticipate coastal management issues stemming from the multi-use of coastal zones?
- How can we protect coastal waters and habitat from toxic substances dumped by ships?
- How can we assist ship transport by showing in real-time the under-keel clearance and other navigational hazards in coastal environments?
- How can we effectively harvest fish stock in a sustainable manner?
- How can we protect our natural coastal borders from intruders?

- How can we ensure that we maintain our unique ocean biodiversity, including the protection of marine mammals and seals?
- How can we learn about new invasive species in oceans and coastal waters?
- How can we protect our coasts from coastal, seabed deformations?
- How can ensure the safe use of our oceans and in-land waters for transport and recreation?
- How can we influence weather conditions or move water where it is needed for agriculture?
- How can we accurately measure climate change and understand its wide-ranging impacts?

5.3 Science Knowledge and Technologies Needed

Science Knowledge
2002 – monitoring protocols to assess climate change and possible impacts
2004-2005 – modular sensors in autonomous operating vehicles with fuel cell propulsion devices
2005 – reliable monitoring of inland/coastal water quality from space
2005 – interferometric Synthetic Aperture Radar (InSAR) refinement for land surface changes of hydrographic causes (!)
2005 – self contained modules attached to all (hulls) vessels working in Canadian waters – module: sensor pack for physical properties; acoustic bottom (!!)
2010 – integration of global atmospheric and ocean systems, biology/chemistry/physics
2010 – integration on inland water and terrestrial bio-productivity changes
2010 – perfect top-of-atmosphere routine correction of remote sensing of data
2010 – water quality "remediation systems" (!)
2015 – precipitation forecasting: by watershed, hours (2005), days (2015), weeks (2025)
2020 – integration of "book learning" and Aboriginal knowledge
2025 – getting to the point where all local knowledge, rural and urban, can be integrated
2025 – achieve a 95% accuracy in the mapping of hydrological variables (!!)
2025 – water ionization units – no harmful ballast waters from ship bilges
Sensors
2003 – real time sensing of animal/bird movement
2005 – remote-controlled platforms with micro-sensors
2005 – security systems for the protection of off-shore energy resources
2005 – 2020 – Spatial sampling of water quality (+)
2010 – ID of invasive species
2010 – continuous monitoring of water quality by stand-alone devices (+++)
2010 – in-home water quality detection systems
2010 – sensors/knowledge real time – monitoring snow pack (continuous) and snow melt over large areas (+!!)
2010 – technology to identify point sources of pollution from remote sensing
2015 – teal time monitoring of coastal dynamics: erosion; bathymetry, on-shore currents (sensors: Synthetic Aperture Radar (SAR), LIDAR, SONAR)
2015 – sensors for toxins, bacteria, viruses in drinking water
2020 – more satellites with higher resolution (on more wavelengths; more frequent coverage)
2020 – embedded sensors everywhere, instrumented dust, e-coli sensors
2020 – miniature microchip implants for aquatic species with multiple-year power packs (then is absorbed within biological structure) (+!)
2025 – sensors in ubiquitous micro-organisms
2025 – 4D acoustic optical radio remote sensor fusion technology to geo locate structures and objects on sea surface, water column, seabed, sub-seabed
2025 – fleet of UAV (Unmanned, autonomous vehicles) continuously monitor world oceans (++!)
Data Transmission
2002-2005 – cheap high-speed transmission (fixed + wireless) to link remote sensors
2002 – 2015 – multi-nation small satellites: local real time data reception, real time data processing/distribution of high

resolution data and images 2020 – no-fee global broad band infrastructure includes sub sea nodes (++) 2025 – data transmission technologies that harness the Northern Lights (already done with meteorites) 2025 – no data transmission necessary for bulk of the data; smart sensors process data locally; exception reporting
Data Capture and Warehousing
2005 – development of integrated data-collection 2005 – government purchase of satellite images/data for cheap/free access by all departments 2020 – link from remote sensors to various databases 2015 – technology for permanent and continuous monitoring over space, over time. Automatic recording – cheap technology; automatic processing – integration, detecting of issues 2005 (technology)/2025 (political will) – Global real time interactive, distributed geo-spatial, freely available, earth monitoring database network with comprehensive information
Data Processing
2005 – distributed parallel processing 2010 – new spatial data models 2015 – 2025 – Data processing linking in real time information from different spatial and temporal scales 2015 – enhanced GIS or data base systems: data capture & manipulation is easier (computers/storage), data processing algorithms more accurate; date integration is easy 2025 – mapping of coastal water and the Northwest Passage (climate change) 2025 – better algorithms and models to extract satellite information
Visualization, Dissemination
2005 – 4D visualization tools for groundwater discharge 2005 – on-line queriable maps of geological formations, oceans, sea floor, etc. (+) 2005 – standardized Coastal Zone GIS maps: hydrographic, land use; seabed fauna, fish habitat; all data finds 2010 – www.waterquality.gc.ca - water quality simultaneous and continuous for all of Canada 2010 – 4D visualization of features/objects on ocean surface/water column/seabed/sub-seabed (in real time – 2015) 2015 – ocean/water "weather man" on TV for public; link between those who know and those who need to know 2025 – globally available 2D or 3D visualized satellite data available through the cellular/wireless network. Two-way transmission. (+)
Information /Knowledge Systems, Modeling
2015 – all controls on fish stocks are understood and manageable 2015 – six month weather forecasting worldwide (modeling) ocean/atmosphere coupled (+++!!) 2015 – better long-range forecasts, by area 2015 – tools/ methods to add onsite user data to regional/global models for water use 2020 – integrated oceans and in-land water policy models that consider spatial data 2020 – drought areas are mitigated against as well as inundation areas; water available for irrigation; implies knowledge and technologies for resource management are available 2025 – up-to-date public knowledge, understanding and awareness of water use, pollution 2025 – technology for integration of multi-source, multi-scale, multi-temporal information 2025 – real time response (ocean health) reaction to information or stimuli 2025 – hydrologic modeling complete
Infrastructure
2002 – free geospatial data 2002 – sampling strategy for sensor perception and implementation 2005 – fata standards (e.g. ISO) 2010 – fnfrastructure for the real time under keel clearance monitoring for all ships 2015 – access to terrestrial databases to evaluate land management impacts on water quality 2015 – in-home water treatment commonplace 2015 – integrated earth observation (EO) data system = Met data systems (e.g. World Meteorological Organization (WMO)) (+) 2015 – "super-computer" to coordinate all global aquatic information; linking nodes through standardized QA/QC's 2020 – trans-border water quantity and quality issue diffused 2025 – self-sustaining oceans and cities

symbol key: (+) = most innovative (!) = Canadian advantage

5.4 Enabling Technologies

- More robust, more secure data linkages, firewalls, software
- Software to sort, analyze and manage information
- Pattern recognition software
- Faster processors
- Ocean technologies (sub sea vehicles, smart sonars, acoustic drums)
- Wireless broadband communications everywhere
- Portable hand-held computing devices including power supply
- Organic sensors (genetically modified plants or organisms)
- Smaller, cheaper, more integrated function sensors, measurement instruments
- Information extraction and data fusion
- Cabled observatories
- (Internet) communications
- Robotics technologies
- Intelligent systems
- Smart vehicle/systems
- Smart agents – actionable intelligence
- Solar panels 10x more efficient at 10 x lower cost (+) to operate remote sensors
- Portable energy sources – essential to many sensors
- Skin-powered battery
- Micro-Electro-Mechanical Sensors (MEMS), molecular assemblers nano-technology for miniaturization of sensors, satellites and components
- Nano robotics – autonomous data collection

5.5 Key Drivers and Wild Cards

Drivers

- Population density
- Urbanization
- Ecosystem health and decay
- Abdication of individual responsibility in favour of self-interest
- Awareness: vision achievement not necessarily proportional to awareness
- Human health
- Regulatory environment
- Self sufficiency vs. need for collective action
- Political inattentiveness to science
- Employment, economic arguments vs. environment
- Global warming leading to the opening of the North West Passage – sovereignty issues
- Economic competition – access to resources, marine farming, marine transportation routes
- Environmental: waste management, coastal erosion, nutrient run-off, trace drug run-off
- Political: International/sovereignty, International law, Security/defense
- Policy/program funding allocations

Wild Cards

- Terrestrial and extra-terrestrial aliens (friendly or not) invade
- Silicon viruses destroy all chips

- Which way will climate change drive other changes?
- Communications with other species
- Changes in political order at national and international levels
- Separation (Canada)
- Shutting down of the Gulf Stream
- Extreme environmental events (flood, drought, hurricanes)
- Coastal flooding (Global warming)
- Sinking of ice-age bow wave south of great lakes: lakes then drain into Mississippi, not St. Lawrence River.
- Chernobyl revisited
- Oil spills/accidents
- Collapse of U.N.
- Massive human migration
- WW III
- 9/11 – type major terrorism event
- Water terrorism

6 Sustainable Cities & Settlements

6.1 2025 Vision

The vision of sustainable cities and settlements is dependent on values, which are in turn dependent on, for example, immigration, infrastructure etc. Therefore, instead of a vision, Foresight participants looking at this issue chose to define a series of “desirable states” for sustainable cities and settlements.

The range of alternative value options could lead to “cowboy” vs. “spaceship” type cities and settlements. Sustainability is relative, depending on culture, industrial base and geographic area. Sustainable cities must be agile, dynamic, based on a variety of economic units, and require critical mass. Sustainable values stress the need to exercise increased discipline at the environmental level.

Some participants argued that Regina is better sized than Toronto, while some participants appreciated the larger urban environment offered by Toronto. One can also imagine the cities of 2025 as specialized interdependent villages. According to some participants, Canada does not understand “urbanization” in a global context. Therefore, collectively we are unable to imagine human settlement the way heavily populated countries do.

Participants offered some views on the “Design Specifications for the Sustainable City”, including the following concepts:

- Minimal eco-footprint
- Reducing large cities, building smaller ones
- Land, energy, resources optimized
- Green cities, attractive and compact
- Maximum quality of life
- Social capital – resources
- Social cohesion – minimize crime
- Social inclusion – tackle poverty, inequality
- Human capital – innovative, wise, knowledgeable
- Sustainability-based economy –minimize carbon use, service orientated, closed loop economy
- Sustainability-based governance – infrastructure for wise decisions, involve citizens, long-term views
- Bio-regional – focus on local area for needs/markets

Participants expect urban development leading to better cities to live in. It will focus on quality of life. It will result in Canadian cities that are healthy and nurturing places.

Achieving the vision requires both technology strategies and policy strategies. One group of participants acknowledged that a number of issues are important to the urban environment, but some of these had been covered by other participant groups or may even be outside the scope of Geostrategics. These might include transportation, energy, greener buildings, zero waste/packaging take back and health care.

With respect to technology needs for future cities, participants suggested that geostrategic technologies could assist in:

- Monitoring air quality, transportation density, population density, water quality, waste management, energy use, social well being and crime
- To help understand and model the inter-relationships of these variables in static and dynamic models.

Such static and dynamic models will help city planners, city operations, permits, emergency response and routing logistics personnel, just to name a few groups of decision-makers.

Models, on a high level, would require planned data acquisition, wide ranging sensors, data and information infrastructure, interoperability and common standards. The following sections show some of the key questions and decisions city personnel will have to face over the next 20-25 years.

6.2 Key Questions and Decisions

- What is the anticipated immigration to Canada and its impact over the next 20-25 years on the growth of our cities?
- How can we optimize service delivery to and inside large cities like Toronto or Vancouver?
- How can we inform our citizens about the "health" of our cities (human health, eco-health etc.)?
- How can we improve the sustainability of our cities, for example, reduce energy consumption in them?
- What will be the values of our city populations and how should/could we influence that?
- How can we improve city transport including the public transportation system?
- How can we ensure and monitor the safety of the citizens? How can we plan for a safer city?
- How can we ensure that quality drinking water is available to all city residents? How can we minimize the risk of tainted drinking water?
- What new risks, hazards and emergencies should we prepare for and what would be their anticipated impact?
- How can we model decision-options for public consultation and input?

6.3 Science Knowledge and Technologies Needed

It must be noted here that one of the two groups of participants decided to re-define the Geostrategics categories and present a new structure. These new categories and appropriate vision statements are presented in the first half of the table, while the second half of the table shows the results from the other group of participants.

Social Organization
2002 – at home workforce 2005 – 3 levels of government establish a "framework agreement" on urban governance 2010 – diffuse uncontrolled forces of change 2010 – ubiquitous wireless communications network 2020 – city state – drastic change in human social organization does away with cities/civilization 2025 – rats and cockroaches rule 2030 – population growth continues to compete with natural eco-system balance
Food
2002 – restaurants with tailored menus (based on health profile) 2007 – rocal food production – non-monoculture food production 2010 – technically tailored food sources – positive modifications 2010 – genetically modified organisms 2015 – non-destructive animal husbandry food production 2015 – bar coding gives total product labeling - knowing food history can drive industry to improve through supply 2020 – hit tipping point with pollution - food; lack of quality leads to significant health problems – reaching epidemic levels 2025 – totally encapsulated city; build into a mountain; energy self-sufficient for pure food, water & heat (space ship

mentality) 2030 – under ocean (water) closed environment 2030 – limits to growth: water, land, capital
Energy
2007 – clean transport 2010 – fuel cells sourced by hydrogen 2015 – alternative energy sources in common use 2020 – lean logistics supply technologies 2025 – -use of water and barges for goods transport
Water
2005 – use-re-use economics and regulation 2010 – sensing systems built into water systems – tracking quality of water, zero waste 2015 – water rationing 2020 – clean water cycle design 2025 – zero water consumption technologies – industrial grade
Materials
2005 – smart homes and buildings 2012 – ultra light weight construction materials 2015 – intelligent buildings systems and materials 2020 – sun protectors throughout 2020 – regulated chemical production 2025 – nano-structural materials 2030 – geonome copyrighted 2030 – emphasis on designing environmental friendly systems at inception rather than cleaning up – lean manufacturing, clean production
Land Use
2002 – sustainable development is in conflict with design and artistic impression – where wide-open spaces are embraced in human values (cowboy mentality) 2005 – organic farming validation 2005 – mega-structures/small-cities – e.g. 1 km^3 in/near shanghai 2005 – personal transportation units 2005 – optimized sustainable infrastructure 2010 – failure of mega-farms 2010 – localized produce gardens 2010 – limited city size – less than 5000 people 2015 – culturally isolated city-states linked by a loosely-structured political networks 2015 – intelligent traffic systems within and to the outskirts 2020 – “new age” colonies – separate from “business”, “recreation” and “political” centres 2025 – multi-use of space – agricultural/manufacturing co-exist 2025 – downtown is now in suburbia
Sensors
2005 – real-time monitoring of city services – sewage, water, waste, utilities 2005 – intelligent routing based sensor web 2010 – programmable and wide variety broader range sensors 2015 – intelligent sensor monitor bio, eco health
Data Transmission
2005 – crime surveillance 24 hours on demand – difficulties with privacy 2005 – better use of existing data 2015 – full “telepresence” – video conferencing; broadband data 2025 – mesh networked wireless sensors
Data Processing, Visualization, Dissemination
2005 – open access to information easy to digest format 2005 – issue based 3-voting through web 2008 – community/citizen input and visualization output to models 2010 – data management/aggregation (updatable) 2010 – inter-connected info system through web

2010 – accessible data bases across Canada on city governance – real-time data access and data fusion 2010 – data security – multiple storage, secure, current, access convenient 2010 – infinite data storage for all incoming data 2015 – community dialogue Tools allow informed conversations about the future, better decision-making 2015 – community visioning tools help citizens and decision-makers plan more wisely 2025 – data processing and presentation to people in house & city
Information /Knowledge Systems, Modeling
2005 – accurate, dynamic models 2007 – networked "Centers of Excellence" in major cities, family, business, civil, education sector and labour to manage sustainable development 2010 – monitoring energy consumption 2010 – education for sustainability widespread in school system 2020 – modeling city development to keep quality of life – size, household facilities 2020 – central command control system for sustainability 2025 – governments practice sustainability-based decision-making (integrated, long & medium term) 2025 – economy based on sustainability principles – "closed loop", service-oriented, sustainable energy and transportation 2025 – data integration to information to knowledge

6.4 Enabling Technologies

- Sensor webs to track health, monitor services, air/water quality
- In situ sensors
- Deployable sensors
- Remote sensors
- Systems integration
- Data integration
- Geographic Information Systems (GIS)
- Modeling
- Enabling Technologies:
- Telepresence to minimize requirements to move people
- Surveillance to reduce crime
- Visioning tools to assist people in envisioning a sustainable future
- Communications/dialogue models to get people involved in decision-making

6.5 Key Drivers and Wild Cards

Drivers

- Kyoto
- Immigration/Aging Population….baby boomers reincarnate
- Urbanization
- Teleworking
- Decaying infrastructure
- Area & growth
- Sprawl vs. density
- Resource protection
- Development and renewal
- Transportation
- Crime & other issues related to congestion & density
- Scarcity or amplitude of resources
- Education about world conditions
- Understanding that doing it right is cheaper than current methods

- Cities are base for terrorist activity

Wild Cards

- More Walkerton water crises
- USA annexes Canada for water supply
- “Minimal Life” centres due to asteroid earth impact ten years ago
- Outer space colonization
- Agility (dynamics of synergy)
- Terrorist attack on water supply
- High tech anarchy
- Teleporting
- Canadian values vs. world urban values
- Putting values into practice

7 Health Effects & Risk Factors

7.1 2025 Vision

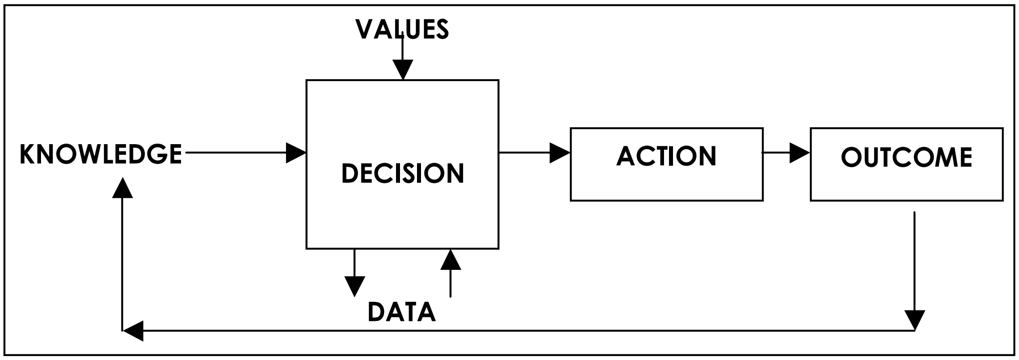
Participants envision healthy Canadians living in a healthy environment in 2025. While the main focus was Canada, participants acknowledged that we must view Canada in the global health context of humans, the flora and the fauna. Participants expect a significant enhancement in the health status of Canadians and the Canadian environment by capitalizing on new, improved geo-spatial technologies by 2025:

- Protection, knowledge, predictive capacity
- Ecological integrity
- Balance
- Environmental sustainability
- Restorative

It must be noted that within this topic participants were asked to look at health effects and risk factors on national level (population scale) as opposed to the clinical level.

The universal characteristics of Canadian and global health would include, among other things, the ability to predict and map epidemics in real time – both infectious and chronic diseases, meeting the demand side of management (need) of food production, security & safety, preventing disease, encompassing social, emotional, psychological, economic, physical, ethical, spiritual well-being as well as addressing stress-related hazards.

It is expected that the development and effective adoption of geo-spatial smart technologies will support evidence-based decision-making in risk analysis, audits and evaluation. The chart below was used to illustrate this capability at the personal level through the decision making process used by the physician in patient care, a model which could be adopted at the national level.



In order to achieve the above vision participants suggested that Canada needs new geostrategic capabilities to monitor levels of risk factors (e.g. air, water, food, soil, radiation) and their health effects. This could be achieved by creating sensor webs with “lab on the chip” sensors, which can identify a wide variety of risk factors and measure effects in real time (which means a very significant reduction in lab processing time through full automation). Smart monitoring would allow the reporting of risk events as opposed to a constant flow of measurements. Smart synthesis will process the data into useful information – actionable intelligence – to enable decision-making. At the same time,this information will create opportunities for complex modelling of risk factors and the health environment in support of better operational decisions that would be used in such cases as preventing the spread of the West Nile Virus.

Canada will need to have advanced risk research capabilities, especially research into mixtures of risk factors and their interaction within a complex environment. To achieve these technological capabilities Canada will need to develop and nurture much stronger strategic alliances, relationships and partnerships within the country. As an example, current public assets – e.g. schools – could be used as "nodes" in a distributed fashion for data acquisition for a wide variety of needs. This would require an agreement and partnership between the various levels of governments. Citizen mobilization and involvement is another key ingredient for success – as an example, volunteers could put up air quality sensors on their rooftops, which could be connected to central monitoring stations to provide citywide air quality monitoring.

Strong partnerships are required to address very significant infrastructure issues, such as standards & methods, legislative barriers, privacy, business processes, data sharing etc. A shared infrastructure, however, will have the capability to deliver different information for different uses or clients.

It is expected that Canada will go through several "eras" of managing health risk factors and effects to achieve the vision. The following table shows two options for these eras.

Option 1	Option 2
Era of "strategic and collaborative cross-discipline networks"	Data Collection Era (now)
Focus on deliverable, multi-disciplinary, "community of interest" era	Data & Information Management Era
"Fluid, proactive, risk-taking, innovative, think-tank" era	Science and evidence based decision making
	Individual, Customized Health Care Information Era

The following section highlights some of the key questions and decisions that government could be facing over the next 25 years.

7.2 Key Questions and Decisions

- How could we provide a "health weather map" for Canadians?
- How could we improve the early detection and prevention of known and unknown diseases (humans, flora and fauna)?
- How and what can we learn about critical factors such as the environment, industrial waste etc. that cause health effects over such a large territory as Canada? What factors can we monitor effectively through remote sensing?
- How could we build effective predictive models to help preventive actions?
- How can we monitor the food supply for risk factors, track and then prevent the spread of health hazards?
- How could we get integrated information real-time from physicians/veterinarians across the country on risk occurrences, for example contagious diseases?

7.3 Science Knowledge and Technologies Needed

Science Knowledge
2005 – range of technologies for food sterilization
2005 – geo sampling techniques: probability and statistics
2010 - monitoring climate change and impact on health
2010 – information about biodiversity
2015 – measuring biodiversity
2017 – implantable GPS sensors – regulations to allow
2020 – physiological markers to environmental stresses
2025 – measuring ecological resilience and integrity
2025 – age related disease minimization
2025 – food is disease-free
Sensors
2005– applications: monitor and alert to bioterrorism, natural disease outbreaks, invasive species, genetically modified species and pathogens, trade, population health/heard/individual health evaluation
2005 – global environmental template matching by satellite with percentage similarity (predictive)
2005 – 2003 Imbedded TX/RX chips
2005 – biological air filters – plants to remove toxins
2010 – remote and rapid detection of animal and plant pathogens
2015 – soil probe sensors for organisms (on seeders, harvesters, manure spreaders)
2015 – small, implantable disease sensor with transmission capability to satellite
2015 – remote sensing emerging diseases (global)
2015 – sensors for environmental microsystem change
2020 – sensing underground ecological dynamics
2020 – embedded sensors in humans for tracking disease
2020 – genome mutation sensors (all known) diseases
2020 – grid of wireless remote sensors for airborne organisms – insects, spores, pollen, etc.
2025 – health sensors on modes of transportation e.g. airplanes
2025 – psychosocial impact sensors - land and space sensors
Data Transmission
2003 – GByte Data Rate; Terra Byte Store
2005 – Terrabyte Data Rate; PetaByte Store
2010 – remote diagnosis, Remote robotic surgery is feasible in real time
2015 – Peta Byte Data Rate; YottaByte Store
2015 – human wireless transmission
Data Capture and Warehousing
2005 – digitization of historical data for GIS (this is not a technology advance, but a necessary project).
2005 – common geo-spatial reference system applied to science; data collected in this reference system with identified attributes
2005 – exposure databases for risk assessment
2010 – use of sound, statistically valid techniques for the enhancement of historical data
2020 – global health without individual ID compromise
2020 – real-time tracking and monitoring for risk exposure
Data Processing
2005 – user-friendly analysis of complex spatio-temporal data to deal properly with auto correlation issues
2010 – harmonizing data collection and evaluation among federal departments and international partners
2010 – Predictors of insect vectors distribution
2025 – develop a network-centric infrastructure with web-alarms to trigger responses
Visualization, Dissemination
2005 – mapping of health, social, environmental and other factors predicting disease outbreaks in a visual manner
2005 – mapping weather, climate, watershed factors in real time with overlay of desired health risk parameters
2007 – virtual reality visualization techniques
2010 – AI and knowledge-based systems to allow better visualization of current data to enable discovery and decision-making

2010 – holographic chambers
Information /Knowledge Systems, Modeling
2005 – self-integrating epidemiology/GIS database 2005 – evidence based decision making 2007 – individual health status while you sleep (+) 2010 – integrated symptom data collection 2010 – develop modeling to predict disease spread in order to identify best defence 2010 – predictive systems aid health emergency operatives in controlling outbreaks of infectious disease 2010 – targetable sensor delivery system (salt-lick) with data transmitter 2010 – smart sensors that produce information at source rather than data 2014 – cure sick building syndrome (linked to bio filters) 2015 – real time outbreak monitoring 2020 – real time decisions based on real time data 2020 – smart buildings that sense sensitivities to environment 2020 – integration of below-ground with above-ground knowledge of ecological system dynamics 2020 - environmentally dependent, statistically sound techniques for developing spatio-temporal models of complete, complex ecosystems 2025 – all-encompassing computer model with all the necessary inputs to predict your personal health so you can take corrective action 2025 – AI to link cause and effect 2025 – global disease vector monitoring system
Infrastructure
2005 – space-based system monitors for geographic spread of ecological niches that favor epidemiological vectors (+) 2015 – public health protection legislation enabling real time monitoring 2015 – electronic health records 2018 – mature humanized organ transplant technology from surrogate animal donors 2020 – World Health Organization with teeth 2020 – Medicare is universal (preventive and predictive)

Symbol key: (+) = most innovative (!) = Canadian advantage

7.4 Enabling Technologies

- Genetic engineering
- Information highway, network-centric society
- Modelling technology that can cross-correlate temporal and spatial data and perform auto-correlation
- Amplification techniques for metabolites and proteins
- Nanotechnology and its applications to sensors, diagnostics, therapeutics, communications, data storage, computing
- Autonomous, integrated biological systems
- Molecular computers
- Quantum computers
- Sensors developed for human health have applications in food production
- In-situ sensors “smart dust”
- Distributed processing
- Biomemetics

7.5 Key Drivers, Wild Cards and Disruptive Technologies

Drivers

- Bio terrorism, bio security
- Accidental, unintentional, natural events

- Global change (climate, land use, el Nino)
- Political choice, actions
- Population density – if, high,may lead to increased disease spread
- Urban decay
- Investment in Health Care Systems
- Demographics
    - Birth rate and migration = population growth rate
    - Cultural shifts within migration – leading to changing values
- Transmigration (large movement of refugees), movement of disease, ghettoization
- Accumulation of toxins in food chain
- Greater access to data, collaboration at multi-level, collaborative knowledge management
- Quality data (standards)
- Energy costs
- Energy source, if dirty – pollution and health risks, if cleaner – clean up pollution
- Extended life span, recreation needs. If lifespan increases, but disease remains, health care system will have to adapt
- Redistribution of world resources e.g., AIDS/Africa, access to education, technology, financial assets, more conflict, disruption of social fabric, more epidemics, “lifeboat mentality”
- Regulation/Legislation
    - Must enable (e.g. patent on Harvard Mouse)
    - Need a balance between privacy and the public good
- Education and Access to Information
    - Makes information available and helps make the right choices
    - Information overload
    - Need appropriate, timely information with knowledgeable interpretation
- Credibility of Science:
    - e.g., Vaccination
    - Genetically Modified Organisms (GMO)
    - Drives policy
    - Has impact on public health
    - Re-emergence of disease (with reductions in vaccinations)
    - Impacts of regulations – too strict or too lax
- Economics/Resources
- Public vs. private health care delivery
- Food supply-demand reach… point at which demand exceeds supply…
    - May lead to increased and more balanced lifestyle
    - Malnutrition
    - Population crash
- Conflict (war)
    - Application of military health technologies
    - Destruction of monitoring framework
    - Disinclination to share information
    - Redirection of resources
- Generic Conflict (e.g.) Greenpeace vs. economic interests
    - Degradation of environment
    - Reduced investment in development of vision and technologies
- Lack a mechanism to resolve conflicts
- Privacy values at risk
- Natural evolution of pathogens (natural selection) and hosts

Wild Cards

- Sudden rapid change in any of the drivers

- Genetic accident, e.g., escape of a pathogen knocks out mitochondria
- Radical changes in world political scene or within Canada
- Separation (West or Quebec)
- Advanced R&D in military that can be adopted for non-military use
- Return to the dark ages
- Ecological catastrophes
- Interstellar object hits earth
- Vaccine cure-all
- Pandemic (e.g. flu HIV/AIDS)
- Extra-terrestrial pathogen comes to Earth – breakdown of social structure – global chaos
- Bioterrorist attack
- California sinks into Pacific Ocean
- Generic treatment for all disease "magic bullet"

Divergent and/or Disruptive Technologies:

- Ubiquitous wireless networks
- Sensor webs
- Drug for telomeric restoration/preservation – slows aging
- Retrovirus technology allows genetic regeneration, rejuvenation (gene therapy) (+)
- Agents to offset environment induced immune deficiency – e.g. treatment for immune-compromised astronauts returning from interplanetary missions – spin-offs, e.g, 20th century sensors; HIV and other immunodeficiency type disease
- Ability to correct genetic damage from radiation etc. through convergence of genomic technology and synthetic viral agent technologies

8 Transport

8.1 2025 Vision

Participants envisaged a “smarter” transportation era by 2025. An integrated, non-location-based society that is sustainable, where a distinction is made between transport and travel. No traffic jams and using high-speed aircraft and trains might characterize this era. Virtual interactions, such as in the workplace, will be a distinguishing feature. The “smarter transportation” vision covers two aspects of transport:

“Telepresence” or non-transportation of people

The premise is that transportation, unlike travel, is not a value added activity; getting things done without moving people is a worthwhile objective. As an example, being able to have national meetings, like the Science and Technology Foresight Technical Panels, in virtual reality could be of real value. Using communications technology to eliminate moving people, e.g., e-bay, e-commerce, virtual reality, is expected to reduce the demand for people transport by 2025, allowing more resources for the movement of goods, etc. Some of the required technologies exist today – e.g. adequate bandwidth, virtual interactivity tools. Some technologies, however, are needed to make this a reality by 2010: directory technologies and addressing systems, holographic display and capture technologies, touch and feel simulation technologies, among others. Other requirements include cultural comfort with communications technology, clear economic motivation and cost-effectiveness.

Movement of goods

What could movement of goods mean in 2025? Are there possibilities for the economic manufacture of low quantities, “quantity of one” or direct transport from source to consumer? Some of the requirements to make this a reality in 2025 would include new energy sources, such as hydrogen/solar, advances in GPS technology, increased load security and tracking, advanced roll-on/roll-off vehicles, magnetic levitation, commercialization of light-than-air craft and new types of products that could be manufactured on a nano-scale based on pre-defined manufacturing (software) programs. The non-technology requirements include clear economic motivation, cost-effectiveness, fully-costed transportation, national security, etc.

There are many challenges and options for the next 25 years for both the movement of goods and of people. For the long-term, teleportation is a real possibility, but it will probably be beyond 2025 before this is viable. Magnetic levitation of vehicles is real today, but implementation costs need to be brought down in order to use it in a practical way.

Another option would be to move goods and people in miniaturized transport modules that are self-propelled and can be integrally linked together for moving groups of people and clusters of goods, so that other infrastructures are used more effectively. Fuel cells could be considered to propel such vehicles. Given Canada’s leadership in fuel cell R&D, this area is seen as a particular opportunity for Canada. Pilot-less transport – a system of intelligent highways using sensors, information, artificial intelligence, coordination, system modeling – could become a reality in the 21st century.

It is widely expected (among the participants) that the location of factories will be mostly in developing countries, which introduces issues of how goods are to be brought to Canada and then moved around. This probably means that the need for transportation of goods would increase. Some of the participants expected that we would have to deal with probable energy shortages, which would prompt us to search for more efficient and intelligent movement or goods and people or the complete elimination of distance.

More flexible business paradigms would allow for more co-operation, lessen duplication and encourage shared capabilities and use of intermodal transportation. This would require an open systems architecture for stores and fleets (by 2015) and for people by (2020). Such an open system architecture could take advantage of wireless, personal/product geo-location and identification systems and the identification of available transport capacity. Intelligent systems/ agents could do the matching of demand and supply for transportation services.

8.2 Key Questions and Decisions

The following are some of the key questions and decisions that we expect to face within the next 20-25 years with respect to transportation.

- How can we avoid gridlocks in suburban and urban areas?
- How can we improve the transport of people and goods? How can we reduce the transportation of people by means of new technology advancements?
- How can we reduce toxic emissions from vehicles?
- Would a system based on the "milkman analogy" provide for a more efficient transportation system? (In the old days milkmen delivered the milk to everyone; now everyone individually drives to the store for milk.)
- Would the full costing of goods (including environmental, transport) trigger a case for distributed manufacturing?
- Could we make local manufacture efficient enough (low cost) to reduce the need for transportation?
- Question of urban meltdown and its effect on transportation?

8.3 Science Knowledge and Technologies Needed

Science Knowledge
2005 – HQP! (Highly qualified people) 2010 – formal solution to "travelling salesman" or "milkman" problem 2025 – cognitive solutions to speed of light delays in planetary telepresence systems (telerobotics)
Sensors
2010 – navigation aids for drivers 2015 – monitoring and accounting of the true cost of transportation 2020 – wide use of GPS and sensors that allow automated vehicle, traffic movements
Data Transmission
2003 – continual vehicle tracking 2005 – optimized teleshopping 2005 – information transport via satellite (!) 2007 – mobile probes create and update map information 2010 – most vehicles give and receive traffic data 2010 – on-line, real time communication, teleconferencing through high bandwidth 2015 – unlimited bandwidth
Data Capture and Warehousing
2005 – open source spatial data 2005 – information aggregation and validation systems 2007 – user-controlled privacy 2015 – database for transport paths;
Data Processing
2005 – real time context and location-based info 2010 – vastly distributed geo-spatial processing 2015 – mobility effectiveness indicator 2030 – demonstration of molecular deconstruction and assembly technology – first step toward teleportation
Visualization, Dissemination

2005 – thematic data broadcast
2008 – automated macro navigation to micro navigation; can you navigate to the closest parking spot?
2010 – non-distracting information delivery
2010 – 3D display navigation systems
2015 – teleprescence systems for exploration of hostile environments (e.g., sea floor)
Information /Knowledge Systems, Modeling
2002 – integration of environmental and everyday transportation information
2005 – fleet management technologies (!)
2005 – interdisciplinary systems management
2010 – geo-spatial data and individual source destination information permit “best solution” transportation
2010 – expert systems for goods transport, routing decisions, two-way transport
2011 – integrated systems for decision-support on a planning level
2015 – map driver interaction
2015 – smarter transport to deal with restricted energy
2015 – real time traffic/traffic light optimizer
2015 – path of least resistance navigation (time, cost, environmental, scenic)
2015 – improved climate control – systems that can replicate a preferred climate, to reduce seasonal travel
2025 – advanced roll on, roll off vehicle technologies (intermodal transport)
Infrastructure
2015 – broad data access leading to development of innovative transport management tools
2005 – 2025 – standardized, interoperable CTR mobility tools
2010 – improved stack transport
2010 – space demonstration of technology to build macro structures in orbit
2015 – environmentally clean public transportation hydrogen-cell light train
2020 – nanotechnology for distributed manufacturing eliminates requirements for transporting certain goods
2020 – machine that moves in space, sea and on land
2020 – surrogate robots
2020 – high speed trains in Canada’s eastern corridor
2025 – pneumatic tunnels for transporting goods by container
2025 – capability to build and use direct tunnels for transcontinental transport

Symbol key: (+) = most innovative (!) = Canadian advantage

8.4 Enabling Technologies

- High-speed bandwidth so we can “move electrons not people”
- Open, accepted standards and open, scaleable systems
- Robotics
- Geo-location/identification/query of “vehicles” through the satellite infrastructure
- Solids pipeline
- Large conveyor system built from Toronto to Montreal,or to other major urban areas
- Tracking sensors
- Smart asphalt – embedded sensors
- Under-city tunnels and robotic drivers
- Expanded wireless, fibre optics, photonics and alternate communications technologies
- All goods are delivered direct to consumer
- Robot-butler
- Health monitors for transport, environment, human pathogens
- Updated variant of park and ride
- Virtual reality similar to the gaming technology
- Intelligent systems fusing data to determine most efficient routes, then transport goods and people

8.5 Key Drivers and Wild Cards

Drivers

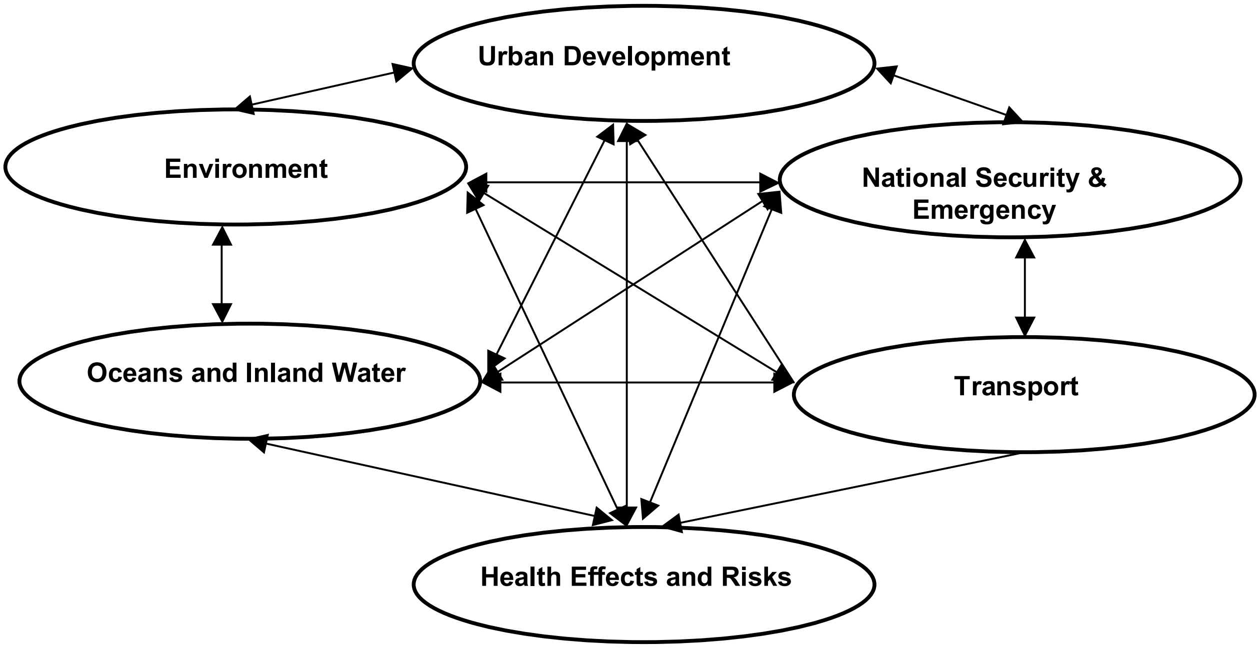
- Fully-costed transport
- National security
- High energy costs, fossil fuel emissions, fuel cells
- Cost effectiveness
- Information access
- Growth gridlock
- Cultural comfort
- Visual and communications space
- Widespread acceptance of tele-working
- Lower cost of communications, bandwidth
- Need to reduce traffic congestion and save time
- Just in time production and supply chain management
- New advanced coatings and materials for creating new types of vehicles
- Human mental health and muscle mass needs movement
- Cost of maintaining aging transportation system is too high
- Northern climate creates unique challenges
- Quality of life, environmental, human stress
- Size and distances of Canada
- Moving permafrost and shifting coastlines
- Human cocooning inclination
- Cap on public funding for the maintenance of transportation infrastructure

Wild Cards

- Disaster in the St. Lawrence River
- Holographic display and capture technologies
- Agri-manufacturing
- Earthquakes and other environmental disasters
- WW 2.9 - crisis in the Middle East
- Societal resistance to controls on freedom
- Sudden mass in-migration or exodus from Canada

9 Cross Topic Synergies

As mentioned in the introduction, many of the Geostrategics topics are interconnected. As an example, one cannot forecast weather or understand climate change without studying oceans. One cannot build a sustainable environment without focusing on urban development or transport. The following chart illustrates the many interconnections among the various Geostrategics topics. Given the magnitude of interconnections, we did not attempt to describe all of these relationships.



10 Horizontal Collaboration

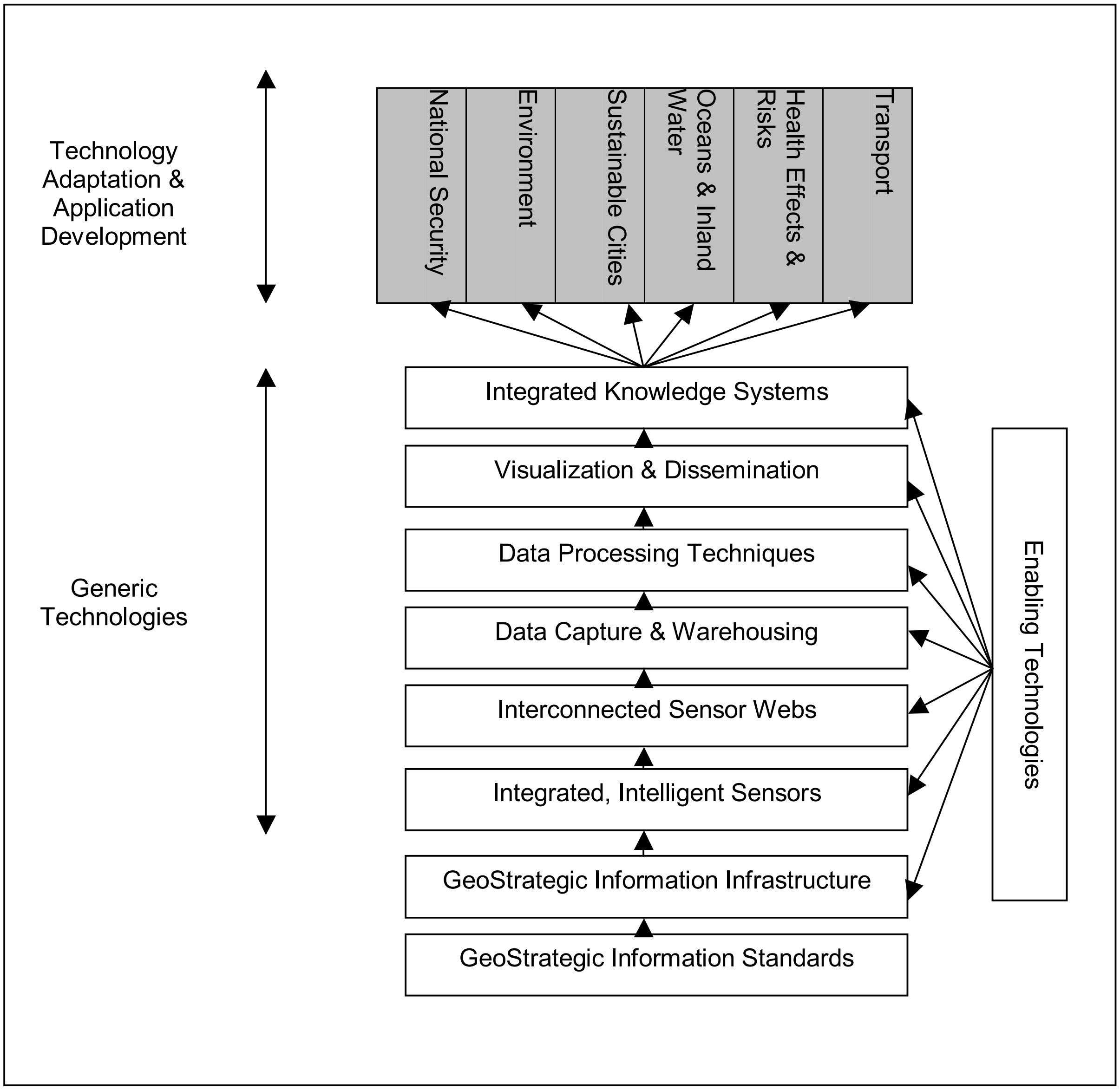
Horizontal collaboration is possible among the key stakeholders of all six geostratgic topics. As indicated by the following chart, when it comes to Geostrategic information management, some of the key building blocks of the technology applications are the same, which suggests that collaboration among the SBDAs would benefit them significantly.

Foresight participants indicated that horizontal collaboration among SBDAs may encompass sharing of resources, infrastructure and management of the development of inexpensive, integrated, intelligent sensors, ubiquitous peer-to-peer sensor webs, real-time wireless and wired data transmission, smart information synthesis, intelligent knowledge systems, data visualization, human-machine interface and a variety of enabling technologies. Once the basic building blocks of the technologies are built, SBDAs may follow through a collaborative implementation approach, if and when that is possible, or they may implement their own applications through a technology adaptation process. This is shown in the following graph on the following page.

Many of the applications of Geostrategic technologies are “common good” applications. These common good applications, in most cases, are implemented by various levels of governments. Therefore, technology development in the Geostrategics sector is largely dependent on governments’ interest and ability to act upon on these common needs, since many technologies would not have a captive market in the business-to-business or consumer sectors. Sometimes, however, once government has taken a leadership role in developing common good applications, private sector developers have found new applications and markets beyond the public sector (business-to-business or consumers). In such cases, the technology may become sustainable without further support from governments.

Collaboration among the various SBDAs will lead to many significant benefits. These include:

- Better understanding of the technology and its various uses and applications
- Ability to cost share and get more value for public funds
- Ability to leverage expertise among the SBDAs
- Reduced technical and project risks through joint pilot projects
- Improved management of technology issues and opportunities



The following table provides a few of the identified collaboration ideas for science knowledge and technology development within the technology areas indicated above. It must be noted here that the "√" marks indicate a potential interest (as perceived by the knowledge manager and the participants) in the technology and probably, to some extent, an opportunity for collaboration between the various SBDAs. Please note that only the participating SBDAs were listed in the following table, not all the SBDAs of the Government of Canada.

Interest in a technology or interest in collaboration may simply reflect an interest in knowing more about the technology with respect its performance reliability, risks etc., not necessarily a commitment to co-develop or apply such technologies within the SBDA.

SBDAs and Potential Geostrategic Collaboration Areas	National Defence	Natural Resources	Environment	Food Inspection Agency	Fisheries & Oceans	Health	Agriculture, Agri-food	Transport	Space Agency	Industry Canada, CRC	National Research Council	NSERC
Infrastructure, standards, data access												
Implementation of common standards		√	√	√	√	√	√	√	√			
Shared infrastructure for data collection	√	√	√	√	√	√	√	√	√			
Free access to government owned data		√	√	√	√	√	√	√	√		√	√
Calibration and data validation	√	√	√	√	√	√	√	√	√	√	√	√
Integrated data sets	√	√	√	√	√	√	√	√	√			√
Integrated data collection, transmission and processing systems	√	√	√	√	√	√	√	√	√	√	√	√
Inexpensive, integrated, intelligent sensors												
Continuous operating mode "in situ" nano sensors, with bio, chemical, physical measurement capabilities	√	√	√	√	√	√	√	√	√		√	√
Small, inexpensive integrated sensors for multi-use (e.g. air-water quality)	√	√	√		√	√	√		√		√	√
Intelligent sensors able to validate data with peers, process measurements, exception reporting	√	√	√	√	√	√		√	√	√	√	√
Biometric, genomic, health analysis capability for surveillance	√		√	√	√	√	√		√		√	√
Mobile, unmanned geo sensors with GPS for surface, ocean and aerial applications	√	√	√		√		√		√		√	√
Space sensors for environmental and security applications	√	√	√	√	√		√	√	√			√
Ubiquitous peer-to-peer sensor webs												
Ocean based sensor webs	√		√		√			√	√			√
Surface sensor webs	√	√	√	√	√	√	√	√	√	√	√	√
Integrated space and surface sensor webs	√	√	√	√	√	√	√	√	√	√	√	√
Intelligent, wireless, mobile sensor webs	√	√	√		√		√	√	√	√	√	√

Real-time wireless and wired data transmission												
Micro, nano satellite constellation	√	√	√		√		√		√	√	√	
Data compression algorithms	√	√	√						√	√	√	√
Inter-satellite communication	√								√	√	√	√
Inexpensive mobile software radios	√	√	√							√	√	√
Peer-to-peer wireless networks	√		√							√	√	√
Real-time, near real-time systems	√	√	√	√	√	√				√		
Continuous always on “geo utility”	√	√	√	√	√	√	√	√	√	√		√
Smart information synthesis												
Data fusion technologies	√	√	√	√	√	√	√	√			√	√
Semantic search and data integration	√	√	√		√	√	√				√	√
Feature extraction, classification algorithms	√	√	√	√	√		√	√	√			√
Dynamic, interactive complex models	√	√	√	√	√	√	√	√	√		√	√
Intelligent maps	√	√	√		√	√	√	√	√		√	√
Soft computing	√	√	√	√	√	√	√				√	√
Intelligent knowledge systems												
Learning systems, artificial intelligence	√		√		√						√	√
Proven predictive capability for decision support (e.g. hydrological cycle)	√	√	√	√	√	√	√	√	√		√	√
Interdisciplinary knowledge systems		√	√	√	√	√	√		√		√	√
Autonomous environmental control systems			√		√		√		√			√
Data visualization, dissemination												
Human-machine interface	√								√	√	√	√
Virtual reality environments	√	√	√	√	√	√	√	√			√	√
4D holographic map models		√	√		√		√		√			√
Telepresence	√	√	√	√	√	√	√	√	√	√	√	√
Open web access, information sharing	√	√	√	√	√	√	√	√			√	√
Web based community input, interaction and visioning tools and models	√	√	√	√	√	√	√	√	√	√	√	√

Interactive science and technology learning games for the public	√	√	√		√	√			√			
Intelligent maps	√	√	√	√	√	√	√	√	√		√	√
New environmental, ocean, public health indicators for TV, radio broadcasts			√	√	√	√						√
Direct info link to the brain	√										√	√
Enabling technologies												
Nanotechnology	√	√	√	√	√	√		√	√	√	√	√
Sentient robotics	√	√	√		√		√	√	√		√	√
New materials	√	√	√	√	√	√	√	√	√	√	√	√
Smart systems, agents	√	√	√	√	√	√	√	√	√	√	√	√
Bio, gene chips	√	√	√	√	√	√	√		√		√	√
Photonics, nanophotonics	√		√		√	√			√	√	√	√
Real-time computing, systems	√	√	√	√	√	√		√	√	√	√	√
Wireless communications	√	√	√	√	√	√	√	√	√	√	√	√
Data storage, compression	√	√	√	√	√	√	√	√	√	√	√	√
Data, information and network security	√	√	√	√	√	√	√	√	√	√	√	√
Semiconductors, information processing	√	√	√	√	√	√	√	√	√	√	√	√
Optical, quantum, DNA computing	√		√		√	√			√		√	√
Peer-to-peer networks, parallel computing	√		√	√				√	√	√	√	√
Dynamic data calibration and validation protocols	√	√	√	√	√	√	√	√	√		√	√
Data standards	√	√	√	√	√	√	√	√	√			
Simulation, complex modeling	√	√	√	√	√	√	√	√	√		√	√
Internet	√	√	√	√	√	√	√	√	√	√	√	√